

BAHRIA CLASSIFICATION SOCIETY



RULES FOR CLASSIFICATION OF STEEL SHIPS

Chapter 4 Machinery

July 2022

This latest edition incorporates all rule changes. The latest revisions are shown with a vertical line. The section title is framed if the section is revised completely. Changes after the publication of the rule are written in red color.

Unless otherwise specified, these rules apply to ships for which the date of contract for construction is on or after July 2022.

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Machinery

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AMENDMENTS

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A. General**1. Scope**

1.1 The Rules and instructions for machinery installations apply to the propulsion systems of the ships classed by (**BCS**), including all the auxiliary machinery and equipment necessary for the operation and safety of the ship.

They also apply to machinery which **BCS** is to confirm as being equivalent to classed machinery.

1.2 Apart from the machinery and equipment detailed below, the requirements are also individually applicable to other machinery and equipment where this is necessary to the safety of the ship or its cargo.

1.3 Designs which deviate from the Rules for Machinery may be approved provided that such designs have been examined by **BCS** for suitability and have been recognized as equivalent.

1.4 Machinery installations which have been developed on novel principles and/or which have not yet been sufficiently tested in shipboard service require the **BCS's** special approval

Such machinery may be marked by the notation **EXP** affixed to the character of classification and be subjected to an intensive survey, if sufficiently reliable proof cannot be provided of its suitability and equivalence in accordance with item. 1.3

1.5 In the instances mentioned in 1.3 and 1.4 **BCS** is entitled to require additional documentation to be submitted and special trials to be carried out.

1.6 In addition to the Rules, **BCS** reserves the right to impose further requirements in respect of all types of machinery where this is necessitated by new findings or operational experience, or **BCS** may permit deviations from the Rules where these are specially warranted.

1.7 National Rules or Regulations outside the **BCS's** Rules remain unaffected.

1.8 Passenger ships having a length of 120 m or

more or having three or more main vertical fire zones shall also comply with MSC.216 (82) and MSC.1/Circ.1369 with MSC.1/Circ.1369/Add.1 **(1)**.

1.9 All passenger ships shall comply with **BCS** additional rule "Qualitative Failure Analysis for Propulsion and Steering on Passenger Ships".

2. Definitions

Basic concept and definitions applied in this section are described in following items:

- **Rigid support**
In case of metal-to-metal contact where the engine mounts to the frame, rigidly. Main engines and auxiliaries are fixed onto their seatings (or their foundations) with utilizing bolts and nuts.
- **Yielding support**
A support that incorporates a sliding or flexible joint or stilt to accommodate early pressure and thus delays damage and distortion of the support. Friction or hydraulic devices may be used so that a support, when subjected to a load above its set load, yields mechanically rather than by distorting. This supports are also called as, resilient mount, shock absorber, vibration insulator, rubber insulator, damper etc.
- **Means of escape**
Means of escape in case of fire means the provision of a safe routes from the lowest part of the machinery room floor plates to a place of safety, enabling the person to escape from fire or smoke by his / her own unaided efforts.
- **Octave band**
It means the range of frequencies from a given frequency to double that frequency.
- **Machinery room (engine room)**
Engine room is a machinery space intended for the main engines and, in case of ships with electric propulsion plants, the main generator.

(1) *Applicable to passenger ship with keel laying on or after 1 July 2010.*

- Machinery spaces
Machinery spaces are all machinery spaces of Category A and all other spaces containing propelling machinery, boilers, fuel oil units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilising, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces.
- Machinery spaces of Category A
Machinery spaces of Category A are the spaces and trunks containing:
 - Internal combustion engines (ICE) used for main propulsion,
 - ICE used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW,
 - Any oil fired boiler or fuel oil unit,
 - Gas generators, incinerators, waste disposal units, etc., which use oil fired equipment.
- The "dead ship"– "blackout" condition
The "dead ship" condition and the blackout condition have same meaning such that the entire machinery installation including the electrical power supply is out of operation and that auxiliary sources of energy such as starting air, battery supplied starting current etc. are not available for restoring the ship's electrical system, restarting auxiliary operation and bringing the propulsion installation back into operation.
- Main machinery
Main machinery is the engine being part of the propulsion plant.
- Auxiliary machinery
Auxiliary machinery is the machinery necessary for the operation of main engines, supply of the ship with electric power and other kinds of energy, as well as functioning of the systems and arrangements subject to survey by **BCS**.
- Equipment
Equipment comprises all type of filters, heat exchangers, separators, purifiers, tanks and other arrangements ensuring normal operation of a machinery installation.
- Propulsion plant
Propulsion plant is the total machinery and arrangements which generate, convert and transmit the power for ensuring the cruising of ship in safe at all specified rates of speed and comprising propellers, shafting, main gearing and main machinery, including electric propulsion units.
- Main active means of the ship's steering It is a propulsion and steering unit being part of the propulsion plant.
- Auxiliary active means of the ship's steering It is a propulsion and steering unit ensuring propulsion and steering of a ship at low speed or steering of a ship at zero speed when the ship is equipped with main means of propulsion and steering, and is used either in combination with the latter or when the main means of propulsion and steering are inoperative.
- Remote control
Remote control is the changing of the speed and direction of rotation as well as starting and stopping the machinery from a remote position.
- Main machinery control room
It is the most essential place, as a heart of the vessel, which containing the remote controls of main and auxiliary machineries, Controllable Pitch Propellers (CPP), main and auxiliary Amplitude Modulation Signalling System (AMSS), indicating instruments, alarm devices and means of communication.

- Control station
Control station is a special place at where the simultaneous control of the main engine is intended and, the indicating instruments, the audial and visual alarm devices and the means of communications are fitted. It is also defined exclusively for purposes of Section 18 - Fire Protection and Fire Extinguishing Equipments, as intended by SOLAS.
- Technical condition monitoring system
It is a complex system of inspection facilities and actuators interacting with the control item on demand set forth by the appropriate documentation. The system provides for the identification of the type of the item technical condition and systematic observation (tracing) or its change on the basis the measurement of the controlled (diagnostic) parameters and comparison of these values with the set standards.
- Technical condition diagnosis
It is a process of establishing causes for the deviation of diagnostic parameters when performing condition monitoring and/or detecting malfunctions, as a requirement, by stripless methods in order to provide maintenance and repair on the actual condition basis.
- Technical condition prediction
It is the process of determining the causes for changes at the controlled item or parameter for the forthcoming time period, based on the trend of the diagnostic parameter values during the preceding time period.
- Hazardous area
Areas where flammable or explosive gases, vapour or dust are normally present or likely to be present are called as hazardous areas. These areas, however, more specifically defined for certain machinery installations, storage spaces and cargo spaces that present such hazard, e.g.:
 - Helicopter refuelling facilities,
 - Paint stores,

- Cargo oil tanks and other spaces of oil carriers,
- Ro-ro cargo spaces.

B. Documents for Approval

1. Drawings showing the general layout of the machinery installation together with all drawings of parts subject to mandatory testing, to the extent specified in the following sections of Chapter 4 - Machinery, the Rules for Machinery, are each to be submitted in triplicate to **BCS**.
2. The drawings must contain all the data necessary for approval. Where necessary, design calculations for components and descriptions of the plant are to be submitted.
3. Once the documents submitted have been approved by **BCS** they are binding on the execution of the work. And subsequent modifications require the **BCS's** approval before being put into effect.
4. The following plans and particulars are to be submitted for review:
 - Construction details of the machinery with materials and dimensions,
 - Engine layout diagram,
 - Machinery foundation details and material properties
 - Coordinates of the mass centre of machinery and the foundation,
 - Type of installation and arrangement details,
 - Corrosive effects and environmental operational conditions such as humidity, dust or rust
 - Mounting type such as resilient or shock mount,

- Static and dynamic loads arisen from engine.

shipboard machinery, equipment and appliances shall ensure faultless continuous operation under the ambient conditions specified in Tables 1.1-1.4.

C. Ambient Conditions

1. Operating conditions, general

1.2 Account is to be taken of the effects on the machinery installation of distortions of the ship's hull.

1.1 The selection, layout and arrangements of all

Table 1.1 Ambient conditions about inclinations

Installations, components	Angle of inclination [degrees] (2)			
	Athwartships		For-and-aft	
	Static	Dynamic (rolling)	Static	Dynamic (pitching)
Main and auxiliary machinery	15	22.5	5 (4)	7.5
Safety equipment, e.g. emergency power installations, emergency fire pumps and their devices	22.5 (3)	22.5 (3)	10	10
Switch gear, electrical and electronic appliances (1) and remote control systems				
Notes : (1) No undesired switching operations or operational changes are to occur. (2) Athwartships and fore-and-aft inclinations may occur simultaneously. (3) In ships for the carriage of liquefied gases and of chemicals the emergency power supply must also remain operable with the ship flooded to a final athwartships inclination up to maximum of 30°. (4) Where the length of the ship exceeds 100m, the fore-and-aft static angle of inclination may be taken as 500/L degrees where L = length of the ship, in metres.				

Table 1.2 Water temperatures

Coolant	Temperature (°C)
Seawater	+ 32 (1)
Charge air coolant inlet to charge air cooler	+ 32 (1)
(1) BCS may approve lower water temperatures for ships operating only in special geographical areas.	

Table 1.3 Air temperatures at an atmospheric pressure of 100 kPa and at a relative humidity of 60%

Installations, components	Location, arrangement	Temperature range [°C]
Machinery and electrical installations (1)	in enclosed spaces	0 to +45 (2)
	on machinery components, boilers in spaces, subject to higher or lower temperatures	According to specific local conditions
	on the open deck	-25 to +45
(1) Electronic appliances shall ensure satisfactory operation even at a constant air temperature of +55°C. (2) BCS may approve lower air temperatures for ships designed only for service in special geographical areas.		

Table 1.4 Other ambient conditions

Location	Conditions
in all spaces	Ability to withstand oil vapour and salt-laden air
	Trouble-Free operation within the temperature ranges stated in Table 1.3, and with a relative humidity up to 100% at a reference temperature of 45°C
	Tolerance to condensation is assumed
in specially protected control rooms	80% relative humidity at a reference temperature of 45°C
on the open deck	Ability to withstand temporary flooding with seawater and salt-laden spray

D. Design Principles

1. General

1.1 Propulsion plant shall provide the sufficient astern power to maintain manoeuvring of the ship in all normal service conditions.

1.2 Propulsion plant shall be capable of maintaining in free route astern at least 70% of rated ahead speed for a period of at least 30 minutes.

By the rated ahead speed is meant a speed corresponding to the maximum continuous power of the main machinery.

The astern power shall be sufficient to take way off a ship making a full ahead speed on an agreeable length, which must be confirmed during trials.

1.3 In propulsion plants with reversing gears or CPP propellers as well as in azimuthing thrusters, precautions are to be taken against any possible overload of main machinery in excess of permissible values.

1.4 Emergency diesel generators are to be capable of being readily started in cold condition at ambient temperature of 0°C. Where such starting is impracticable or at lower temperatures at the space, provision shall be made for heating devices to ensure safe starting and taking up the load by the diesel generators.

If necessary, provision is to be made for heating devices to ensure safe starting and taking up the load according to the requirements of Section 16 – Pipe, Valves, Fittings and Pumps and Chapter 5 - Electrical Installation.

Spaces for emergency diesel generators must comply with the same requirements mentioned above.

1.5 On ships where internal combustion engines are started by compressed air, the set of equipment for starting shall ensure the supply of air in quantity sufficient for the initial start without external aid.

Where the ships are not fitted with an emergency generator, or an emergency generator does not comply with the requirements of 1.4, the means for bringing main and auxiliary machinery into operation shall be such that the initial charge of starting air or initial electrical power and any power supplies for engine operation can be developed on board ship without external aid. For this purpose when an emergency air compressor or an electric generator is required, the machinery is to be powered by a hand-starting Internal Combustion Engine or a hand-operated compressor.

1.6 Emergency generator and other means needed to restore the propulsion shall have a capacity such that the necessary propulsion starting energy is available within at most 30 minutes of black out or dead ship condition. (See A.2).

Emergency generator stored starting energy is not to be

directly used to start the propulsion plant, the main source of electrical power and/or other essential auxiliaries (emergency generator excluded).

1.7 The power of main machinery in ships of river-sea navigation shall provide the ahead speed in loaded condition of at least 10 knots in calm water.

1.8 Supercharged high-speed diesel engines (over 750 rpm), which increased noise level makes direct local control difficult, may be admitted by **BCS** for usage as main engines in sea-going vessels, if provision is made for remote control and monitoring so that constant presence of the attending crew in the engine room shall not be necessary.

1.9 The machinery with horizontal arrangement of the shaft is to be installed parallel to the centre line of the ship. Installing such machinery in any other direction is permitted if the construction of machinery provides for operation under the conditions given in Table 1.1 ÷ 1.4.

1.10 The design of the main engines intended for installation aboard single-shaft ships shall provide, as a requirement, for a possibility of emergency operation at reduced power in case of a failure of parts, the replacement of which cannot be carried out aboard the ship or demands much time.

1.11 In case of ships with twin-hulls, the failure of the machinery installation of one hull shall not put the machinery installation of the other hull out of action.

1.12 Long run of the propulsion plant at all specified rates during its under the conditions corresponding to the assigned class shall not lead to overload. The substantiation of the required power is subject to special consideration by **BCS**.

1.13 Main and auxiliary machineries are to be so arranged as to provide passageways from the control stations and servicing flats to the means of escape from the machinery spaces and, of course to easy access for maintenance, servicing and repair.

1.14 The machinery parts that are in contact with a

corrosive medium are to be made of an anticorrosive material or shall have corrosion-resistant coatings. Sea water cooling spaces of engines and the coolers are to be provided with approved protectors by **BCS** surveyors. Parts which are exposed to corrosion in underwater or underground systems are to be safeguarded by being

manufactured of corrosion-resistant materials or provided with effective cathodic protection. Parts contacting with the moisturized or the acidic media are to be provided with effective anodic protection. Parts contacting upon air are to be protected by metallic or nonmetallic coating or mantling. However, the parts contacting with moisture and air should be protected with applying suitable galvanising methods.

1.15 The machinery for driving generators must be mounted on the same seatings as the generators.

1.16 The engine manufacturer shall not be expected to provide ambient reference conditions at test bed.

1.17 Vibration standards of machinery are specified in the relative chapters for rigid (seatings) and yielding supports (dampers) to which machinery can be attached under shipboard conditions.

1.17.1 Rigid supports are those supports where the first natural frequency of the "support + machinery" system exceeds the basic exciting frequency (working frequency of engine speed) in the vibration measurement direction by more than 25%.

1.17.2 Yielding supports are the supports where the first natural frequency is less than 25% of the engine running speed. Yielding of the support is ensured by resilient mounting of the machinery or support (vibration insulators – shock absorbers, springs, rubber insulators, etc.).

2. Engine Mounts, Rigid and Resilient

2.1 The machinery and equipment constituting the propulsion plant are to be installed on strong and rigid seatings and securely attached thereto. Construction of the seatings must comply with the requirements of Chapter 1 - Hull, Section 19, B.

2.2 Where the machinery is to be mounted on shock absorbers, the design shall confirm the requirements of Chapter 1 - Hull, Section 19, C.

3. Dimensioning

3.1 All parts must be capable of withstanding the stresses and loads peculiar to shipboard service, e.g. those due to motions of the ship, vibrations, intensified corrosive attack, temperature changes and wave impact, and must be dimensioned in accordance with the requirements set out in the relevant sections of Chapter 4 – Machinery.

In the absence of requirements governing the dimensions of parts, the recognized requirements of engineering practice are to be applied.

3.2 Where connections exist between systems or plant items which are designed for different forces, pressures and temperatures (stresses), safety devices are to be fitted which prevent the overstressing of the system or plant item designed for the lower design parameters. To preclude damage, such systems are to be fitted with devices affording protection against excessive pressures and temperatures and/or against overflow.

4. Vibration

4.1 Machinery, equipment and hull structures are normally subjected to vibration stresses. Design, construction and installation must in every case take account of these stresses.

The faultless long-term service of individual components shall not be endangered by vibration stresses.

BCS may consider deviations from the angles of inclination defined in Table 1 .1 taking into consideration the type, size and service conditions of the ship.

For reciprocating machinery, the following statements are only applicable for outputs over 100 kW and speeds below 3000 rpm.

The requirements in this section are related to the

vibrations in a frequency range from 2 to 300 Hz. The basic assumption is that the vibrations with oscillation frequencies below 2 Hz can be regarded as rigid-body vibrations while the local oscillation frequencies above 300 Hz are just occurred. Where, in special cases, these assumptions are not valid (e.g. where the vibration is generated by a gear pump with a tooth meshing frequency in the range above 300 Hz) the following provisions are to be applied in analogous manner.

4.2 Velocity amplitude is expressed in terms of its peak value, what is known as its root-mean-square (RMS) value. The RMS value of a vibration signal is an important measure of its amplitude. To calculate this value, the instantaneous amplitude values of the waveform must be squared and these squared values averaged over a certain length of time. This time interval must be at least one period of the wave in order to arrive at the correct value. The squared values are all positive, and thus so is their average. Then the square root of this average value is extracted to get the RMS value.

4.2.1 RMS value of vibration rate, measured in 1/3-octave band, is assumed as the basic vibration parameter. Measuring of vibration in octave band is allowed.

For most engineering applications, the greatest interest lies in the frequency range from 20 to 20,000 Hz. Although it is possible to analyse a source on a frequency by frequency basis, this is both impractical and time-consuming. For this reason, a scale of **octave bands** and **one-third octave bands** has been developed. Each band covers a specific range of frequencies and excludes all others. The ratio of the frequency of the highest note to the lowest note in an octave is 2:1.

If f_n is the lower cut-off frequency and f_{n+1} is the upper cut-off frequency, the ratio of band limits is given by:

$$\frac{f_{n+1}}{f_n} = 2^k \quad (2)$$

Where

$k = 1$ for full octave bands, [-]

= 1/3 for one-thirds octave bands

4.2.2 An octave has a centre frequency that is $\sqrt{2} = 1.4142$ times of the lower cut-off frequency and has an upper cut-off frequency that is twice the lower cut-off frequency (see 4.2.1). When vibration is measured in octave bands, the permissible values of the parameter measured may be increased by $\sqrt{2} = 1.4142$ times (3 dB) for bands with geometric mean frequency values of 2, 4, 8, 16, 31.5, 62.5, 125, 250, 500 Hz, 1 KHz, 2 KHz, 4 KHz and 8 KHz.

Centre frequency, f_0 is determined by the formula (3), as follows:

$$f_0 = \sqrt[3]{f_n} \quad (3)$$

4.2.3 The relationship between the centre frequency and band pressure level for one-third octave band is shown in Table 1.5.

4.2.4 Vibration parameters are measured in absolute units or in decibels relatively to standard limiting value of speed or acceleration being equal to $5.0 \cdot 10^{-5}$ mm/s, and $3.0 \cdot 10^{-4}$ m/s², respectively

4.3 Conversion of the measured values of vibration rate into relative units is to be made using the following formula (4):

$$L = 20 \cdot \log \left(\frac{V_e}{V_{eo}} \right) \quad (4)$$

Where;

V_e = the measured root-mean-square value of vibration rate, [mm/s]

V_{eo} = $5.0 \cdot 10^{-5}$ [mm/s]

4.4 For vibrations generated by main engine or auxiliaries the intensity shall not exceed the predefined limits by **BCS**. The purpose is to protect the vibration generators, the connected assemblies, peripheral equipment and hull components from additional, excessive vibration stresses liable to cause

failures or malfunctions.

Table 1.5 Vibration and octave band noise levels for 1/3 octave band

Lower cut-off frequency Hz	Centre frequency (Hz)	Upper cut-off frequency (Hz)	Pressure level (dB)
56.2	62.5	70.8	41
112	125	141	45
224	250	282	48
447	500	562	50
891	1,000	1,122	46
1,778	2,000	2,239	42
3,548	4,000	4,467	40
7,079	8,000	8,913	38

4.5 Attention has to be paid to vibration stresses over the whole relevant operating range of the vibration generator.

Where the vibration is generated by an engine, the considerations are to be extended to the whole available working speed range and, where appropriate, to the whole power range.

4.6 The procedure described below is largely standardized. Basically, a substitution quantity is formed for the vibration stresses or the intensity of the exciter spectrum (see 4.7). This quantity is then compared with permissible or guaranteed values to check that it is

premature

admissible. However, the mentioned procedure takes only incomplete account of the physical facts.

The general design purpose is to evaluate the true alternating stresses or alternating forces.

No simple relationship exists between the actual stresses and the substitution quantities: vibration amplitude, vibration velocity and vibration acceleration at external parts of the frame.

Nevertheless this procedure is adopted since it at present appears to be the only one which can be implemented in a reasonable way. For these reasons

it is expressly pointed out that the magnitude of the substitution quantities applied in relation to the relevant limits enables no conclusion to be drawn concerning the reliability or loading of components so long as these limits are not exceeded.

It is, in particular, inadmissible to compare the loading of components of different reciprocating machines by comparing the substitution quantities measured at the engine frame.

4.7 In assessing the vibration stresses imposed on machinery, equipment and hull structures, the vibration velocity, V is generally used as a criterion for the prevailing vibration stresses. The same criterion is used to evaluate the intensity of the vibration spectrum produced by a vibration exciter.

In the case of a purely sinusoidal oscillation, the effective value of the vibration velocity V_{eff} can be calculated by the formula (5):

$$V_{\text{eff}} = \frac{1}{\sqrt{2}} \hat{v} = \frac{1}{\sqrt{2}} \frac{\hat{a}}{\omega} = \frac{1}{\sqrt{2}} \hat{s} \omega \quad (5)$$

Where;

\hat{s} = vibration displacement amplitude,

\hat{v} = vibration velocity amplitude,

V_{eff} = effective value of vibration velocity,

\hat{a} = vibration acceleration amplitude,

ω = angular velocity of vibration.

For any periodic oscillation with individual harmonic components 1,2,...,n, the effective value of the vibration velocity can be calculated by the formula:

$$V_{\text{effi}} = \sqrt{V_{\text{eff1}}^2 + V_{\text{eff2}}^2 + \dots + V_{\text{effn}}^2} \quad (6)$$

in which V_{effi} is the effective value of the vibration velocity of the i-th harmonic component. Using formula (5), the individual values of V_{effi} are to be calculated for each harmonic.

Depending on the prevailing conditions, the effective value of the vibration velocity is given by formula (5) for purely sinusoidal oscillations or by formula (6) for any periodic oscillation.

4.8 The assessment of vibration stresses is generally based on areas A, B and C, which are enclosed by the boundary curves shown in Figure 1.1.

The vibration standards provide three categories of technical condition of ship machinery and equipment:

- **Area (A):** Condition of machinery and equipment after manufacturing (construction of the ship) or repair at the commissioning,
- **Area (B):** Condition of machinery and equipment during normal operation;
- **Area (C):** Condition of machinery and equipment when technical maintenance or repair is required.

The vibration standards A and B for several machineries installed on rigid supports are specified in the relevant tables and figures in this section.

However, when the machinery is attached to yielding supports, the values of permissible vibration standards are increased. In order to determine the values of permissible vibration rate, multiplication factor for the particular type of machinery is to be applied.

The permissible standards according to the boundary curves of areas A, B and C displayed on Figure 1.1 are presented in Table 1.6.

4.8.1 If the vibration to be assessed comprises several harmonic components, the effective value according to 4.7 must be applied. The assessment of this value is to take account of all important harmonic components in the range from 2 to 300 Hz.

4.8.2 Area A can be used for the assessment of all machines, equipment and appliances. Machines, equipment and appliances for use on board ship shall as a minimum requirement be designed to withstand a

vibration stress corresponding to the boundary curve of area A. Otherwise, with **BCS's** consent, steps must be taken (vibration damping etc.) to reduce the actual vibration stress to the permissible level.

4.8.3 Because they act as vibration exciters, reciprocating machines must be separately considered. Both the vibration generated by reciprocating machines and the stresses consequently imparted to directly connected peripheral equipment (e.g. governors, exhaust gas turbochargers and lubricating oil pumps) and adjacent machines or plant (e.g. generators, transmission systems and pipes) may, for the purpose of these requirements and with due regard to the limitations stated in 4.6, be assessed using the substitution quantities presented in 4.7.

4.8.4 In every case the manufacturer of reciprocating machines has to guarantee permissible vibration stresses for the important directly connected peripheral equipment.

The manufacturer of the reciprocating machine is responsible to **BCS** for proving that the vibration stresses are within the permissible limits in accordance with 5.

4.8.5 Where the vibration stresses of reciprocating machines lie within the A' area, separate consideration or proofs relating to the directly connected peripheral equipment (see 4.8.3) are not required. The same applies to machines and plant located in close proximity to the generator (see 4.8.3).

In these circumstances directly connected peripheral appliances shall in every case be designed for at least the limit stresses of area B', and machines located nearby for the limit stresses of area B.

If the permissible vibration stresses of individual directly connected peripheral appliances in accordance with 4.8.4 lie below the boundary curve of area B, admissibility must be proved by measurement of the vibration stress which actually occurs.

4.8.6 If the vibration stresses of reciprocating machines lie outside area A' but are still within area B', it

must be proved by measurement that directly connected peripheral appliances are not loaded above the limits for area C.

In these circumstances directly connected peripheral appliances shall in every case be designed for at least the limit stresses of area C, and machines located nearby for the limit loads of area B.

Proof is required that machines and appliances located in close proximity to the main exciter are not subjected to higher stresses than those defined by the boundary curve of area B.

If the permissible vibration stresses of individual directly connected peripheral appliances or machines in accordance with 4.8.4 lie below the stated values, admissibility must be proved by measurement of vibration stress which actually occurs

4.8.7 If the vibration stresses of reciprocating machines lie outside area B' but are still within area C, it is necessary to ensure that the vibration stresses on the directly connected peripheral appliances still remain within area C. If this condition cannot be met, the important peripheral appliances must in accordance with 5 be demonstrably designed for the higher stresses.

Suitable measures (vibration damping etc.) are to be taken to ensure reliable prevention of excessive vibration stresses on adjacent machines and appliances. The permissible stresses stated in 4.8.6 (the area B or a lower value specified by the manufacturer) continue to apply to these units.

4.8.8 For directly connected peripheral appliances, **BCS** may approve higher values than those specified in 4.8.5, 4.8.6 and 4.8.7 where these are guaranteed by the manufacturer of the reciprocating machine in accordance with 4.8.4 and are proved in accordance with 5.

Analogously, the same applies to adjacent machines and appliances where the relevant manufacturer guarantees higher values and provides proof of these in accordance with 5.

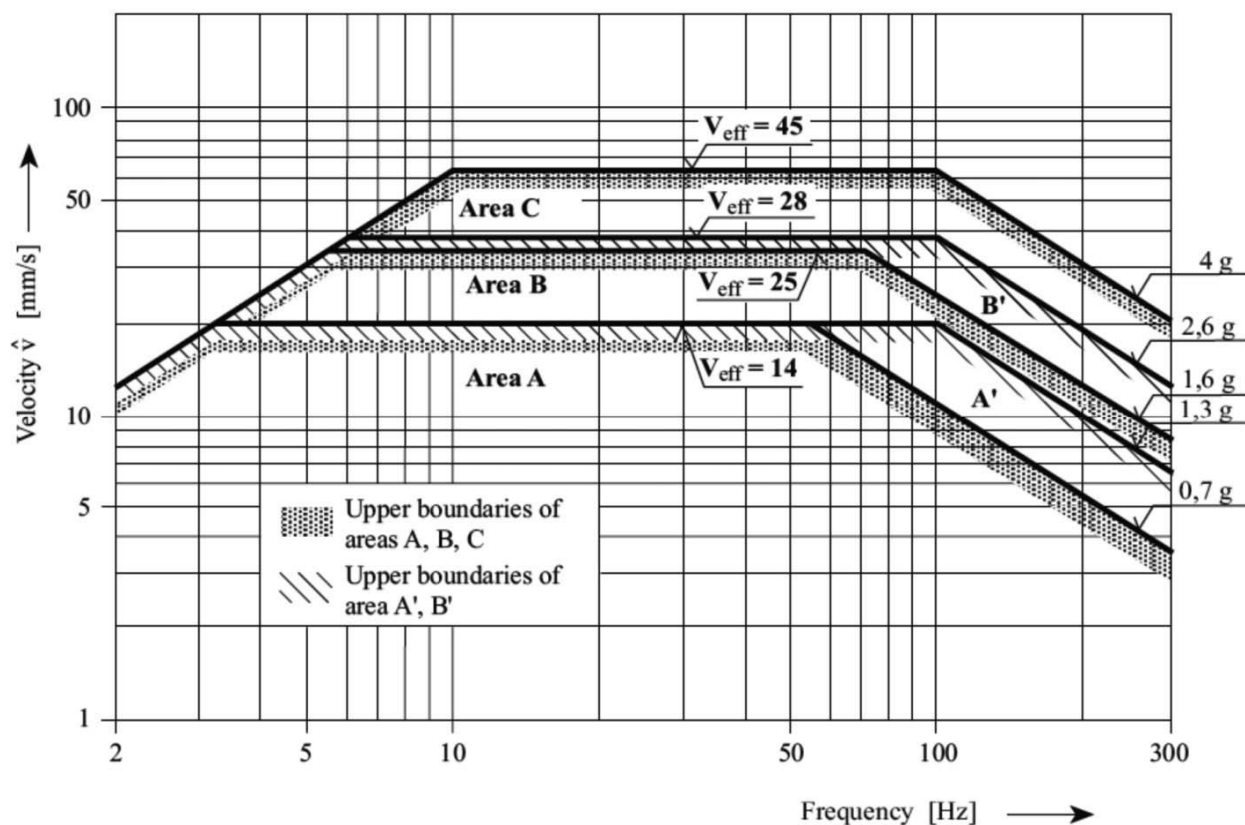


Figure 1.1 Regions for assesment of vibration loads

Table 1.6 Top limits for the areas indicating the assesment of vibration loads

Areas	\hat{s} mm	\hat{v} mm/s	V_{eff} mm/s	\hat{a} 9.80665 m/s ²
A	< 1	< 20	< 14	< 0.7
B	< 1	< 35	< 25	< 1.6
C	< 1	< 63	< 45	< 4.0
A'	< 1	< 20	< 14	< 1.3
B'	< 1	< 40	< 28	< 2.6

4.8.9 For appliances, equipment and components which, because of their installation in steering gear compartments or bow thruster compartments, are exposed to higher vibration stresses, the admissibility of the vibration stress may, notwithstanding 4.8.2, be assessed according to the limits of area B. The design of such equipment shall allow for the above mentioned increased stresses.

4.9 Vibration standards for (ICE) Internal Combustion Engines

4.9.1 Vibration standards are extended to cover ICE with 100 kW and above in power and engine speed of 3,000 rpm and more.

4.9.2 Vibration of low-speed internal combustion engines installed on rigid supports is considered permissible for categories A and B, provided the root-means-square value of vibration rate and vibration acceleration measured in the direction of X and Z (see E.1) do not exceeds the values specified in Figure 1.2 and Table 1.7.

4.9.3 When the vibration is measured along the axis Y (i.e., in transverse direction), the permissible vibration rate standards for Categories A and B are to be increased by 1.4 times.

4.9.4 When the internal combustion engines are installed on yielding supports (main medium-speed diesel engines and diesel gen-sets), the permissible vibration standards for Categories A and B in the direction of axes X, Y and Z specified in Figure 1.2 and Table 1.7 are to be increased by 1.4 times.

4.10 Vibration standards for Diesel Gen-Sets and Shaft Generators

4.10.1 Vibration of diesel gen-sets, shaft generators and turbo generators with the capacity of 1000 kW and more, measured on the bearing housing, is assumed to be permissible for Categories A and B, when the root-mean-square values of vibration rate and vibration acceleration do not exceed the value stated in Figure

1.3 and Table 1.8.

4.10.2 For the diesel-gen sets, shaft generators etc with a capacity lower than 1000 kW, the vibration standards for Categories A and B are by 4 dB lower than the values stated in Figure 1.3 and Table 1.8.

4.10.3 Vibration standards for diesel gen-sets, shafts generators etc when installed on yielding supports are to be increased 2 times.

4.11 Vibration standards for pumps

4.11.1 Vibration of pumps is assumed to be permissible for Categories A and B, when the root-mean-square values of vibration rate and vibration acceleration do not exceed the value stated in Figure 1.4 and Table 1.9.

4.11.2 In case when pumps are installed on yielding support, the permissible vibration standards are to be increased by 1.4 times for Categories A and B.

4.12 Vibration standards for centrifugal separators

4.12.1 Vibration of centrifugal separators is assumed to be permissible for Categories A and B, when the root-mean-square values of vibration rate and vibration acceleration do not exceed the value stated in Figure 1.5 and Table 1.9

4.12.2 The vibration standards are specified considering the installation of separators on shock absorbers.

4.13 Vibration standards for fans and gas blowers of inert gas system

4.13.1 Vibration of the fans and the gas blowers of the inert gas system is assumed to be permissible for Categories A and B, when the root-mean-square values of vibration rate and vibration acceleration do not exceed the value stated in Figure 1.6 and Table 1.9

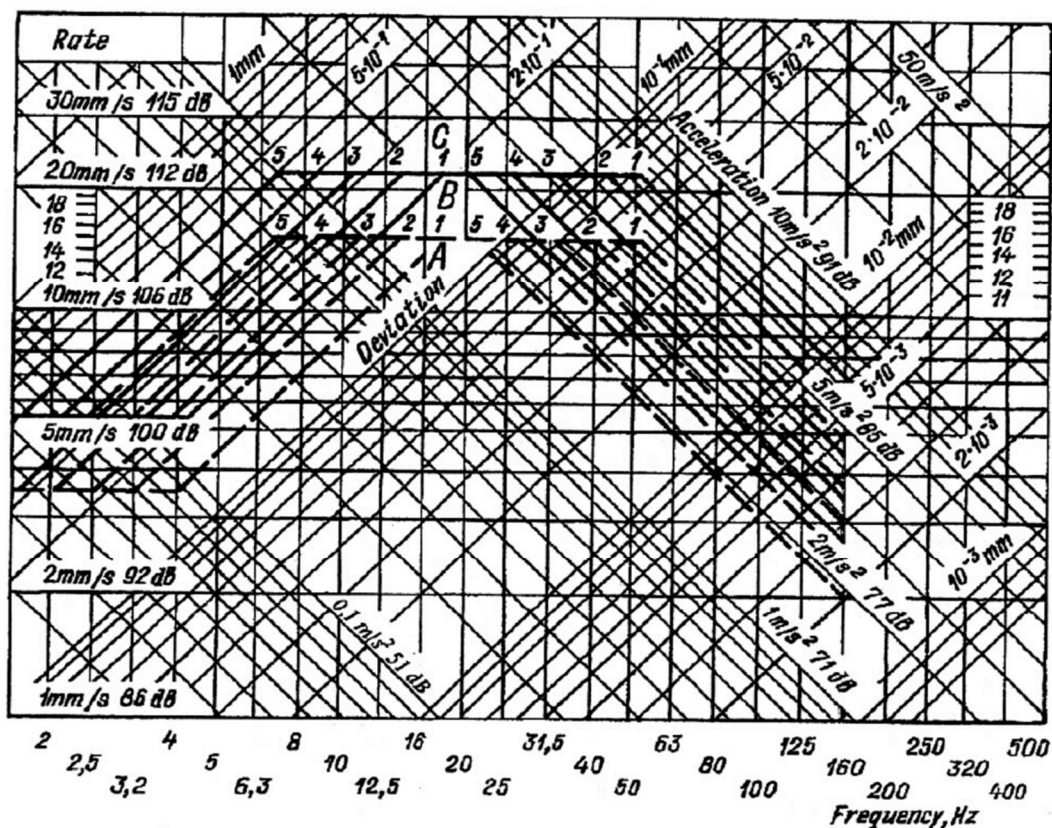


Figure 1.2 Vibration standards for Internal Combustion Engines (ICE) with a piston stroke (1- Under 30 cm, 2- 30 to 70 cm, 3- 71 to 140 cm, 4- 141 to 240 cm, 5- over 240 cm) - - - - Upper limit for Category A, ----- Upper limit for Category B

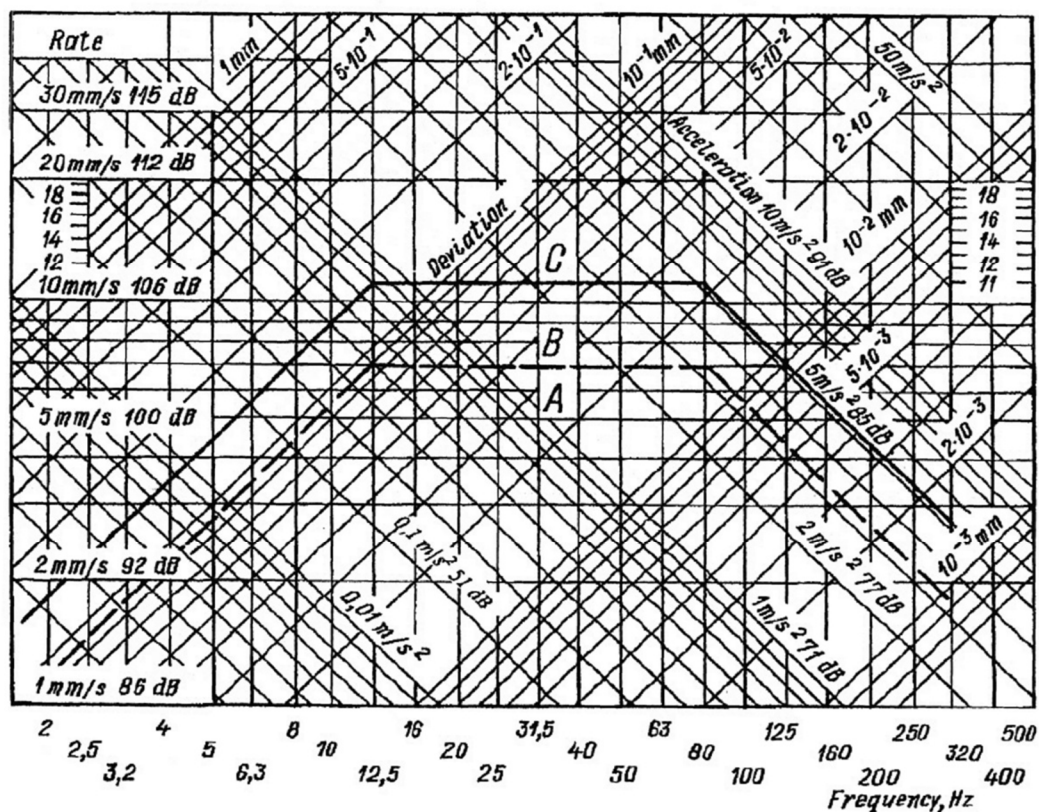


Figure 1.3 Vibration standards for diesel gen-sets and shaft generators of 1000 kW and more capacity
- - - - - Upper band for Category A, ----- Upper limit for Category B

Table 1.7 Vibration standards for Internal Combustion Engines (ICE)

Geometric mean frequencies 1/3 – octave bands Hz	Engines with piston stroke, cm																			
	Under 30				30 to 70				71 to 140				141 to 240				Over 240			
	Permissible values of vibration rate																			
	Category A		Category B		Category A		Category B		Category A		Category B		Category A		Category B		Category A		Category B	
	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB
1.6	4	98	5.6	101	4	98	5.6	101	4	98	5.6	101	4	98	5.6	101	4	98	5.6	101
2	4	98	5.6	101	4	98	5.6	101	4	98	5.6	101	4	98	5.6	101	4.5	99	6.3	102
2.5	4	98	5.6	101	4	98	5.6	101	4	98	5.6	101	4.6	99	6.3	102	5.6	101	8.0	104
3.2	4	98	5.6	101	4	98	5.6	101	4.5	99	6.3	102	5.6	101	8.0	104	7.1	103	10	106
4	4	98	5.6	101	4.5	99	6.3	102	5.6	101	8.0	104	7.1	103	10	106	8.9	105	12.5	108
5	4.5	99	6.3	102	5.6	101	8.0	104	7.1	103	10	106	8.9	105	12.5	108	11	107	16	110
6.3	5.6	101	8.0	104	7.1	103	10	106	8.9	105	12.5	108	11	107	16	110	14	109	20	112
8	7.1	103	10	106	8.9	105	12.5	108	11	107	16	110	14	109	20	112	16	110	22	113
10	8.9	105	12.5	108	11	107	16	110	14	109	20	112	16	110	22	113	16	110	22	113
12.5	11	107	16	110	14	109	20	112	16	110	22	113	16	110	22	113	16	110	22	113
16	14	109	20	112	16	110	22	113	16	110	22	113	16	110	22	113	16	110	22	113
20	16	110	22	113	16	110	22	113	16	110	22	113	16	110	22	113	16	110	22	113
25	16	110	22	113	16	110	22	113	16	110	22	113	16	110	22	113	12.5	108	18	111
31.5	16	110	22	113	16	110	22	113	16	110	22	113	12.5	108	18	111	10	106	14	109
40	16	110	22	13	16	110	22	113	12.5	108	18	111	10	106	14	109	8	104	11	107
50	16	110	22	113	12.5	108	18	111	10	106	14	109	8	104	11	107	6.3	102	8.9	105
63	12.5	108	18	111	10	106	14	109	8	104	11	107	6.3	102	8.9	105	5	100	7.1	103
80	10	106	14	109	8	104	11	107	6.3	102	8.9	105	5	100	7.1	103	4	98	5.6	101
100	8	104	11	107	6.3	102	8.9	105	5	100	7.1	103	4	98	5.6	101	3.2	96	4.5	99
125	6.3	102	8.9	105	5	100	7.1	103	4	98	5.6	101	3.2	96	4.5	99	2.5	94	3.6	97
160	5	100	7.1	103	4	98	5.6	101	3.2	96	4.5	99	2.5	94	3.6	97	2	92	2.8	95

Table 1.7 Vibration standards for diesel gen-sets, shaft generators and turbo generators of 1000 kW and more capacity

Geometric mean frequencies	Permissible value			
	Category A		Category B	
	mm/s	dB	mm/s	dB
1/3-octave bands				
HZ				
1.6	1	86	1.6	90
2	1.3	88	1.9	92
2.5	1.5	90	2.4	94
3.2	1.9	92	3	96
4	2.3	93	3.7	97
5	2.9	95	4.6	99
6.3	3.6	97	5.7	101
8	4.5	99	7.1	103
10	5.6	101	8.9	105
12.5	7	103	11	107
16	7	103	11	107
20	7	103	11	107
25	7	103	11	107
31.5	7	103	11	107
40	7	103	11	107
50	7	103	11	107
63	7	103	11	107
80	7	103	11	107
100	5.6	101	8.9	105
125	4.5	99	7.1	103
160	3.6	97	5.7	101
200	2.9	95	4.6	99
250	2.3	93	3.7	97
320	1.9	92	3	96

4.11.2 In case when pumps are installed on yielding support, the permissible vibration standards are to be increased by 1.4 times for Categories A and B.

4.12 Vibration standards for centrifugal separators

4.12.1 Vibration of centrifugal separators is assumed to be permissible for Categories A and B, when the root-mean-square values of vibration rate and vibration acceleration do not exceed the value stated in Figure 1.5 and Table 1.9

4.12.2 The vibration standards are specified

considering the installation of separators on shock absorbers.

4.13 Vibration standards for fans and gas blowers of inert gas system

4.13.1 Vibration of the fans and the gas blowers of the inert gas system is assumed to be permissible for Categories A and B, when the root-mean-square values of vibration rate and vibration acceleration do not exceed the value stated in Figure 1.6 and Table 1.9

4.13.2 The vibration standards are specified considering the installation of fans and gas blowers on shock absorbers. In case of rigid mounting, these standards are to be also applied.

4.14 Vibration standards for piston type air compressors

4.14.1 Vibration of piston type air compressors is assumed to be permissible for Categories A and B, when the root-mean-square values of vibration rate and vibration acceleration do not exceed the value stated in Figure 1.7 and Table 1.10.

4.14.2 In case when the compressors are installed on yielding support (shock absorbers), the permissible vibration standards are to be increased by 4 dB for Categories A and B.

5. Proofs

5.1 Where in accordance with 4.8.4, 4.8.7 and 4.8.8 **BCS** is asked to approve higher vibration stress values, all that is normally required for this is the binding guarantee of the admissible values by the manufacturer or the supplier.

5.2 **BCS** reserves the right to call for detailed proofs (calculations, design documents, measurements etc.) in cases where this is warranted.

5.3 Type testing in accordance with **BCS** is "Regulations for the Performance of the Type Tests Part 1- Test Requirements for Electrical / Electronic Equipment, Computers and Peripherals" regarded as proof of admissibility of the tested vibration stress.

5.4 BCS may recognize long-term trouble free operation as sufficient proof of the reliability and operational dependability.

5.5 The manufacturer of the reciprocating machine is in every case responsible to **BCS** for any proof which may be required concerning the level of the vibration spectrum generated by reciprocating machinery.

6. Materials and Welding

6.1 All components subject to the Rules for Machinery must comply with the Rules for Materials and welding contained in Chapter 2 - Material and Chapter 3 - Welding.

The fabrication of welded components, the approval of companies and the testing of welders are subject to Chapter 3 - Welding.

6.2 The forged, cast and welded steel parts, as well as cast iron parts of the machinery and its assembly are to be manufactured with utilizing the heat treatment method.

7. Means of Escape from Machinery Spaces

7.1 Means of escape from machinery spaces, including ladders, corridors, doors and hatches, shall, if not expressly provided otherwise, provide safe escape to the lifeboat and liferaft embarking decks (see Chapter 1 - Hull, Section 21).

8. Measurements, Testing and Certification

8.1 Proof based on measurements is normally required only for reciprocating machines with an output of more than 100 kW, where the other conditions set out from 2.8.5 to 2.8.7 are met. Where circumstances warrant this, **BCS** may also require proofs based on measurements for smaller outputs.

8.2 Measurements are to be performed in every case under realistic service conditions at the point of installation. During verification, the output supplied by the reciprocating machine shall be not less than 80% of the rated value. The measurement shall cover the entire

available speed range in order to facilitate the detection of any resonance phenomena.

Table 1.8 Vibration standards for piston type air compressors

Geometric mean frequencies	Permissible value			
	Category A		Category B	
	mm/s	dB	mm/s	dB
1/3-octave bands				
HZ				
1.6	2	92	3.2	96
2	2.5	94	4	98
2.5	3.1	96	5.1	100
3.2	4	98	6.4	102
4	5	100	38	104
5	6.2	102	10	106
6.3	7.9	104	12.5	108
8	10	106	16	110
10	10	106	16	110
12.5	10	106	16	110
16	10	106	16	110
20	10	106	16	110
25	10	106	16	110
31.5	10	106	16	110
40	10	106	16	110
50	10	106	16	110
63	7.9	104	12.5	108
80	6.2	102	10	106
100	5	100	8	104
125	4	98	6.4	102
160	3.1	96	5.1	100
200	2.5	94	4	98
250	2	92	3.2	96
320	1.6	90	2.5	94
400	1.3	88	2.1	92
500	1	86	1.6	90

8.3 BCS may accept proofs based on measurements which have not been performed at the point of installation (e.g. test bed runs) or at the point of installation but under different mounting conditions provided that the transferability of the results can be proved.

The results are normally regarded as transferable in the case of flexibly mounted reciprocating machines of customary design.

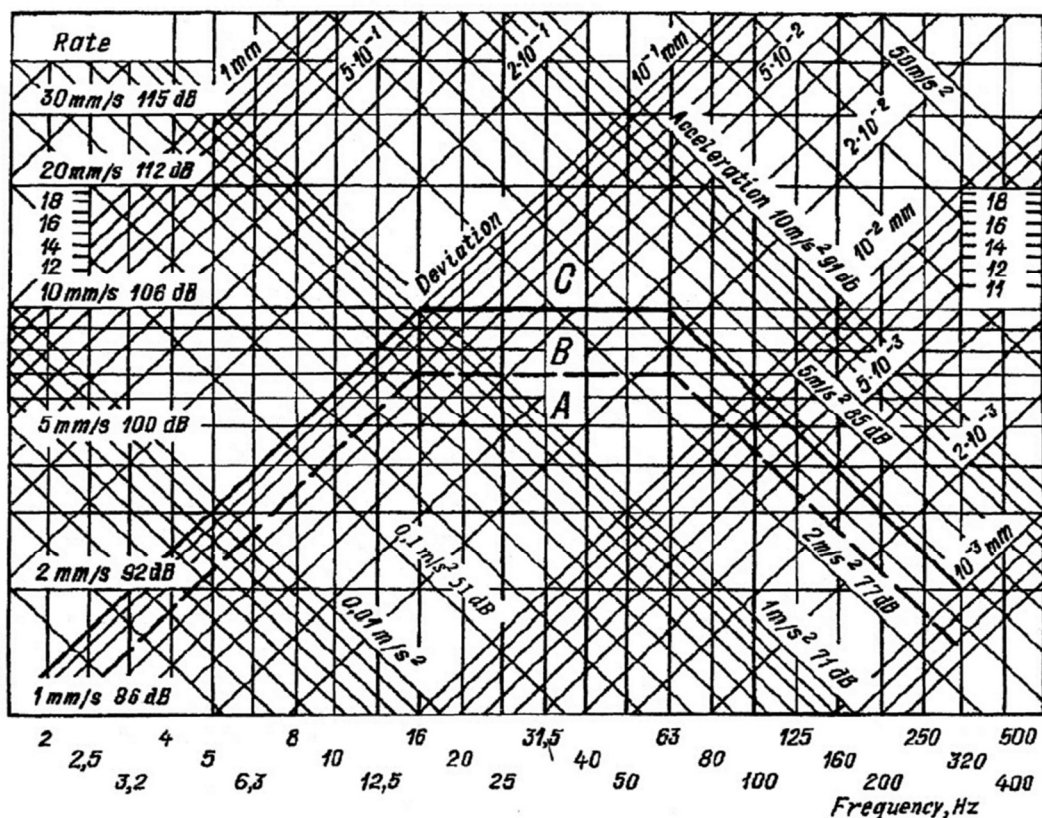


Figure 1.4 Vibration standards for pumps, - - - Upper limit for Category A ----- Upper limit for Category B

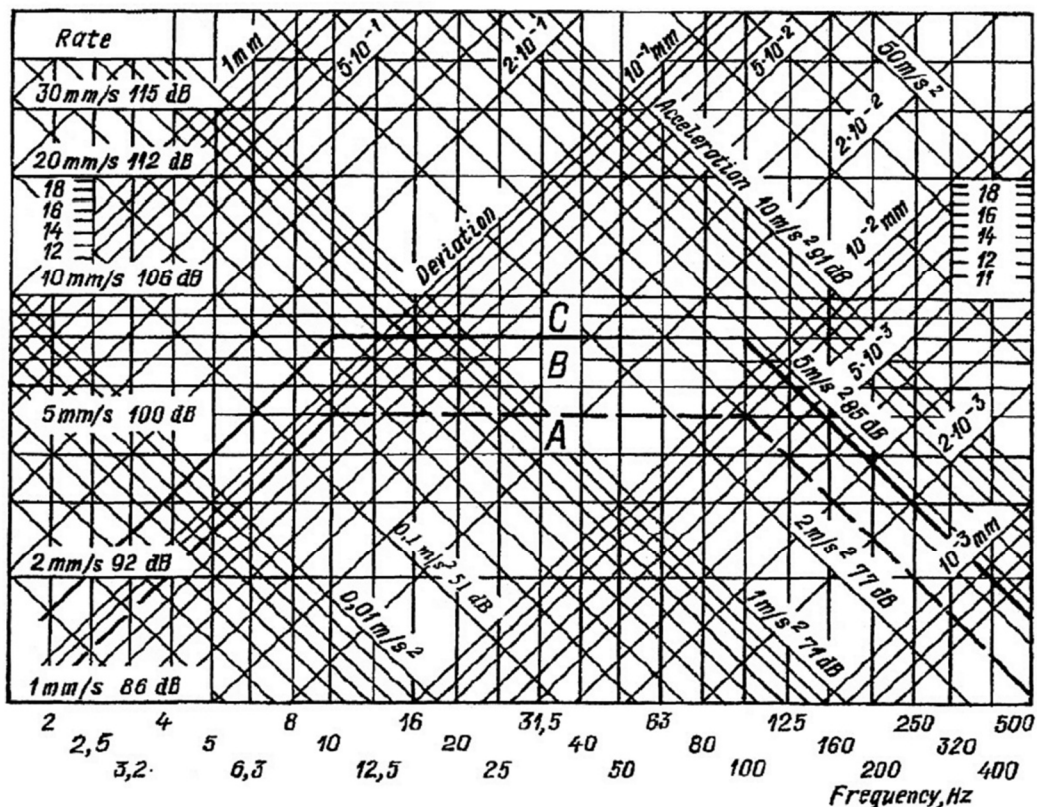


Figure 1.5 Vibration standards for centrifugal separators - - - Upper limit for Category A ----- Upper limit for Category B

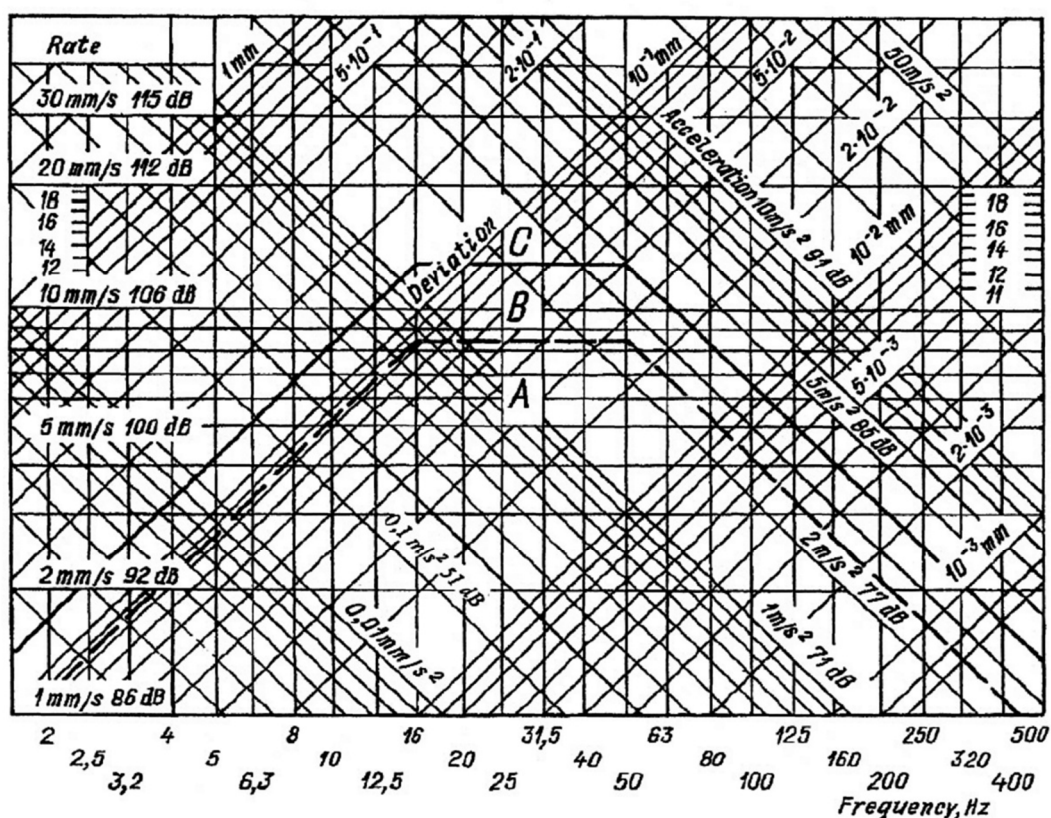


Figure 1.6 Vibration standards for fans - - - Upper limit for Category A ----- Upper limit for Category B

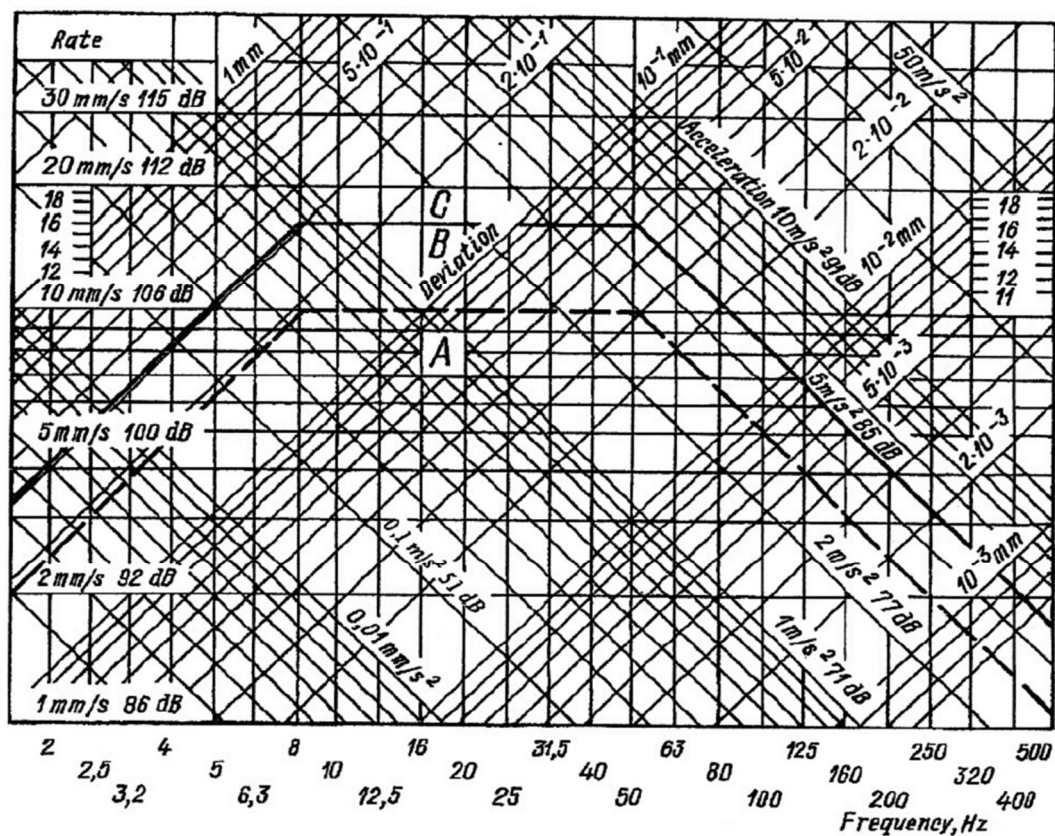


Figure 1.7 Vibration standards for piston compressors, - - - Upper limit for Category A ----- Upper limit for Category B

Table 1.9 Vibration standards for pumps, centrifugal compressors and fans

Geometric mean frequencies 1/3 – octave bands Hz	Pumps				Certrifugal separators				Fans			
	Permissible values of vibration rate											
	Category A		Category B		Category A		Category B		Category A		Category B	
	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB
1.6	1	86	1	86	1	86	1.3	88	1	86	1.3	88
2	1	86	1.2	88	1	86	1.6	90	1	86	1.6	90
2.5	1.1	87	1.4	89	1.3	88	2	92	1.3	88	2	92
3.2	1.4	89	2	92	1.6	90	2.5	94	1.6	90	2.5	94
4	1.7	91	2.5	94	2	92	3.2	96	2	92	3.2	96
5	2.2	93	3.3	96	2.5	94	4	98	2.6	94	4	98
6.3	2.7	95	4	98	3.2	96	5	100	3.3	96	5	100
8	3.5	97	5	100	4	98	6.4	102	4.1	98	6.4	102
10	4.3	99	6.3	102	5	100	8	104	5.2	100	8	104
12.5	5.5	101	8	104	5	100	8	104	6.7	103	10.3	106
16	7	103	10	106	5	100	8	104	8.5	105	13	108
20	7	103	10	106	5	100	8	104	8.5	105	13	108
25	7	103	10	106	5	100	8	104	8.5	105	13	108
31.5	7	103	10	106	5	100	8	104	8.5	105	13	108
40	7	103	10	106	5	100	8	104	8.5	105	13	108
50	7	103	10	106	5	100	8	104	8.5	105	13	108
63	7	103	10	106	5	100	8	104	6.7	103	10.3	106
80	5.5	101	8	104	5	100	8	104	5.2	100	8	104
100	4.3	99	6.3	102	5	100	8	104	4.1	98	6.4	102
125	3.5	97	5	100	4	98	6.4	102	3.3	96	5	100
160	2.7	95	4	98	3.2	96	5	100	2.6	94	4	98

If the reciprocating machine is not flexibly mounted, the transferability of the results may still be acknowledged if the essential conditions for this (similar bed construction, similar installation and pipe routing etc.) are satisfied.

8.4 The assessment of the vibration stresses affecting or generated by reciprocating machines normally related to the location in which the vibration stresses are greatest. Figure 1.8 indicates the points of measurement which are normally required for an in-line piston engine. The measurement has to be performed in all three directions. In justified cases exceptions can be made to the inclusion of all the measuring points.

8.5 The measurements may be performed with mechanical manually-operated instruments provided that the instrument setting is appropriate to the measured values bearing in mind the measuring accuracy.

Directionally selective, linear sensors with a frequency range of at least 2 to 300 Hz should normally be used. Non-linear sensors can also be used provided that the measurements take account of the response characteristic.

With extremely slow-running reciprocating machines, measurements in the 0.5 to 2 Hz range may also be required. The results of such measurements within the stated range cannot be evaluated in accordance with 2.8.

8.6 The records of the measurements for the points at which the maximum stresses occur are to be submitted to **BCS** together with a tabular evaluation.

The stresses are to be determined proceeding from the greatest vibration or stress amplitudes measured in the respective section of the torsigram or oscillogram.

When estimating the total stresses due to the vibration of several orders, the registered parameters.

8.7 The free resonance vibration frequencies

obtained as a result of measurement shall not differ from the design values by more than 5%. Otherwise, the calculation needs to be corrected accordingly.

8.8 For new building ships or repaired ships, the vibration level of the machinery and the equipment shall not exceed the upper limit of Category A, determined as to ensure sufficient margin for changing of vibration strength and reliability of ship machinery and equipment.

Under conditions of long-term service of the ship, the vibration level of the machinery and equipment shall not exceed the upper limit of Category B, determined as to ensure vibration strength and reliability of ship machinery and equipment.

8.9 The measurement results shall be compared with the permissible vibration levels. Vibration levels of machinery and equipment shall not exceed the standards both when the ships is lying and at specified ahead speeds under different conditions.

Where vibration exceeds the standards, the suitable solutions and analyses which are approved by **BCS** surveyor shall be taken to reduce it to permissible levels.

8.10 At non-specified rates of speed vibration exceeding established standards may be permitted after confirming of approval from **BCS**, when these rates are not continuous.

Withdrawal from the present standards is in each case subject to special consideration by **BCS**.

8.11 Machinery and its component parts are subject to constructional and material tests, pressure and leakage tests, and trials. All the tests prescribed in the following Sections are to be conducted under the supervision of **BCS**.

8.12 In the case of parts produced in series, other methods of testing may be agreed with **BCS** instead of the tests prescribed, provided that the former are recognized as equivalent by **BCS**.

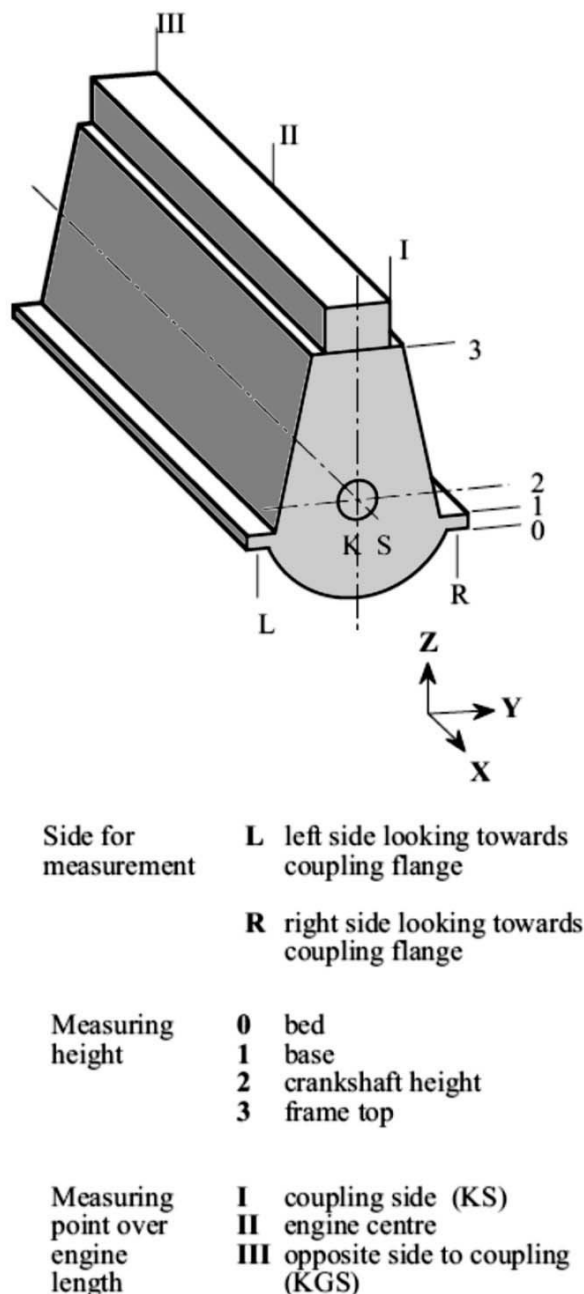


Figure 1.8 Schematic representation of in-line piston engine

8.13 BCS reserves the right, where necessary, to increase the scope of the tests and also to subject to testing those parts which are not expressly required to be tested according to the Rules.

8.14 Components subject to mandatory testing are to be replaced with tested parts.

8.15 After installation on board of the main and auxiliary machinery, the operational functioning of the

machinery including the associated ancillary equipment is to be verified. All safety equipment is to be tested, unless adequate testing has already been performed at the manufacturer's works in the presence of the **BCS's** Representative.

In addition, the entire machinery installation is to be tested during sea trials, as far as possible under the intended service conditions.

9. Corrosion Protection

Parts which are exposed to corrosion are to be safeguarded by being manufactured of corrosion-resistant materials or provided with effective corrosion protection (see Chapter 1 - Hull, Section 22).

10. Availability of Machinery

10.1 Ship's machinery is to be so arranged and equipped that it can be brought into operation from the "dead ship" condition with the means available on board.

To overcome the "dead ship" condition use may be made of an emergency generator set provided that it is ensured that the electrical power for emergency services is available at all times. It is assumed that means are available to start the emergency generator at all times.

10.2 In case of "dead-ship" condition it must be ensured that it will be possible for the propulsion system and all necessary auxiliary machinery to be restarted within a period of 30 minutes (see Chapter 5 - Electrical Installation, Section 3, C.).

11. Control and Regulating Equipments

11.1 Machinery must be so equipped that it can be controlled in accordance with operating requirements in such a way that the service conditions prescribed by the manufacturer can be met.

11.1.1 For the control equipment of main engine and system essential for operation see Chapter 5 - Electrical Installation, Section 9, B.3.

11.2 In the event of failure or fluctuations of the supply of electrical, pneumatic or hydraulic power to regulating and control systems, or in case of a break in a regulating or control circuit, steps must be taken to ensure that:

- The appliances remain at their present operational setting or, if necessary, are changed to a setting which will have the minimum adverse effect on operation (fail-safe conditions),
- The power output or engine speed of the machinery being controlled or regulated is not increased, and

No unintentional start-up sequences are initiated.

11.3 Manual operation

Every functionally important, automatically or remote controlled system must also be capable of manual and local operation respectively.

12. Propulsion Plant

12.1 Manoeuvring equipment

Every engine control platform is to be equipped in such a way that:

- The propulsion plant can be adjusted to any setting,
- The direction of propulsion can be reserved, and,
- The propulsion unit or the propeller shaft can be stopped.

12.2 Remote controls

The remote control of the propulsion plant from the bridge is subject to the provisions of Chapter 4-1, Automation, Section 5, A.2.

12.3 Multiple-shaft and multi-engine systems

Steps are to be taken to ensure that, in the event of the

failure of a propulsion engine, operation can be maintained with the other engines, where appropriate by a simple change-over system.

For multiple-shaft systems each shaft is to be provided with a locking device by means of which dragging of the shaft can be prevented.

13. Turning Appliances

13.1 Machinery is to be equipped with the necessary turning appliances.

13.2 The turning appliances are to be of the self-locking type. Electric motors are to be fitted with suitable retaining brakes.

13.3 An automatic interlocking device is to be provided to ensure that the propulsion and auxiliary prime movers cannot start up while the turning gear is engaged. In case of manual turning installation warning devices may be provided alternatively.

14. Operating and Maintenance Instructions

14.1 Manufacturers of machinery, boilers and auxiliary equipment must supply a sufficient number of operating and maintenance notices and manuals together with the equipment.

In addition, an easily legible board is to be mounted on boiler operating platforms giving the most important operating instructions for boilers and oil-firing equipment.

15. Marking, Identification of Machinery Parts

In order to avoid unnecessary operating and switching errors, all parts of the machinery whose function is not immediately apparent are to be adequately marked and labeled.

16. Fuels

16.1 Liquid fuel oils employed for engines and boilers are, in general, to have a flash point **(2)** of not less than 60°C.

However, for engines driving emergency generators, fuel oils having a flash point of less than 60°C but not less than 43°C are acceptable.

16.2 For ships assigned with a restricted navigation notation in limited geographical areas or, or whenever special precautions are taken to **BCS** 's approval, fuel oils having a flash point of less than 60°C but not less than 43 °C may be used for engines and boilers, provided that, from previously effected checks, it is evident that the temperature of spaces where fuel oil is stored or employed will be at least 10°C below the fuel oil flash point at all times.

16.3 Fuel oil having flash points of less than 43°C may be employed on board provided that it is stored outside machinery spaces and the arrangements adopted are specially approved by **BCS**.

16.4 The use of gaseous fuels taken from the cargo is subject to Chapter 10 – Liquefied Gas Tankers.

17. Refrigerating Installations

Refrigerating installations for which no Refrigerating Installation Certificate is to be issued are subject to the requirements in this section.

17.1 The provisions assume that the refrigerating installations are permanently installed and belong to the ship.

17.2 For refrigerating installations which are built under the supervision and in accordance with **BCS**.

17.3 Refrigerants of Group 1 are approved to be used in ships since they are incombustible refrigerants without significant hazard to human health, such as R22 (3), R134a, R404A, R407A, R407B, R407C, R410A and R507.

(2) Based, up to 60°C, on determination of the flash point in a closed crucible (cup test).

17.4 Refrigerants of Group 2 are also approved although they are classified as toxic or caustic refrigerants and those which, when mixed with air, have a lower explosion limit of at least 3.5 % by volume, such as R717, Ammonia and NH₃.

Ammonia is to be not used in refrigerating plants operating with direct evaporation. In addition, the regulations imposed by the competent authorities of the country of registration are to be observed.

17.5 Refrigerants of Group 3 which, when mixed with air, have a lower explosion limit of less than 3.5 % by volume are not approved by **BCS** and permitted to be used in ships, e.g. ethane, ethylene.

17.6 On board ship, reserve supplies of refrigerants may be stored only in steel bottles approved for this purpose by the competent authorities of the country of registration.

17.7 Bottles containing refrigerant are to be securely anchored in an upright position and protected against overheating. The bottles may be stored only in well ventilated spaces specially prepared for this purpose or in refrigerating machinery spaces.

17.8 Refrigerating machinery spaces are to be separated by bulkheads from other service spaces and housing refrigerating machinery and the associated equipment.

17.9 Even if not installed in specially designated spaces, refrigerating machinery is approved by **BCS** to be installed in such a way that sufficient space is left for operation, servicing and repair.

17.10 The rating of forced ventilation systems is subject to the following rules:

(3) National regulations and Flag State regulations are to be complied with and MARPOL Annex VI Chapter III Reg.12; Installations which contain hydro-chlorofluorocarbons shall be prohibited on ships constructed on or after 1 July 2020.

- For refrigerating machinery spaces with Group 1 refrigerants, forced ventilation is required which ensures at least 30 changes of air per hour.
- For refrigerating machinery spaces in which ammonia is used as refrigerant, the minimum capacity of the fan is to be determined by the following formula:

$$\dot{V} = 60 \cdot \sqrt[3]{m^2} \quad (7)$$

However, the number of air changes per hour shall not be less than 40.

Where:

\dot{V} = Capacity of fan, [m³/h]

m = Charge of refrigerant in system[kg].

In the case of refrigeration systems using ammonia installed in rooms with an effective sprinkler system, the minimum required capacity of the fans indicated above may be reduced by 20 %.

17.11 Provision must be made for the safe blow-off of refrigerants directly into the open air. Safety valves are to be set to the maximum allowable working pressure and secured to prevent the setting from being altered inadvertently.

17.12 Access doors or hinged hatch covers from companionways leading to cold rooms which are used for operational purposes, such as refrigerated spaces or air cooler spaces, refrigerated provision stores and also brine spaces must be capable of being opened from inside, irrespective of their closed condition.

These spaces are to be fitted with an alarm which must be connected to a station which is constantly monitored.

17.13 Insulating materials must be odourless and must not, as far as possible, absorb any moisture. Insulating materials, along with their cladding, must have highly flame-resistant properties to recognized standards. Polyurethane foams and insulating materials which have comparable flame-resistant properties may

only be used with a metal or equivalent cladding

The insulating materials used in refrigerated spaces must be approved by **BCS**. Where in-situ cellular plastic is used, the respective processing methods and also the processing recommendations issued by the manufacturer are to be submitted for examination. The behaviour of insulating material in fire is to be proven, on demand, by means of independent tests.

18. Machinery Space Ventilation

18.1 Machinery spaces are to be sufficiently ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather conditions, including heavy weather, a sufficient supply of air is maintained to the spaces for the operation of the machinery.

18.2 This sufficient amount of air is to be supplied through suitably protected openings arranged in such a way that they can be used in all weather conditions, taking into account Regulation 19 of the 1966 Load Line Convention.

18.3 Special attention is to be paid both to air delivery and extraction and to air distribution in the various spaces. The quantity and distribution of air are to be such as to satisfy machinery requirements for developing maximum continuous power.

18.4 The ventilation is to be so arranged as to prevent any accumulation of flammable gases or vapours.

19. Hot Surfaces and Fire Protection

19.1 Surfaces, having temperature exceeding 60°C, with which the crew are likely to come into contact during operation are to be suitably protected or insulated.

19.2 Surfaces of machinery with temperatures above 220°C, e.g. steam, thermal oil and exhaust gas lines, silencers, exhaust gas boilers and turbochargers, are to be effectively insulated with non-combustible material or equivalently protected to prevent the ignition

of combustible materials coming into contact with them.

Where the insulation used for this purpose is oil absorbent or may permit the penetration of oil, the insulation is to be encased in steel sheathing or equivalent material.

19.3 Fire protection, detection and extinction is to comply with the requirements of Section 18.

E. Engine and Boiler Room Equipment

1. Operating and Monitoring Equipment

1.1 Instruments, warning and indicating systems and operating appliances are to be clearly displayed and conveniently sited. Absence of dazzle, particularly on the bridge, is to be ensured.

Operating and monitoring equipment is to be grouped in such a way as to facilitate easy supervision and control of all important parts of the installation.

The following requirements are to be observed when installing equipment and appliances:

- Protection against humidity and the accumulation of dirt,
- Avoidance of excessive temperature variations,
- Adequate ventilation.

In consoles and cabinets containing electrical or hydraulic equipment or lines carrying steam or water the electrical equipment is to be protected from damage due to leakage. Redundant ventilation systems are to be provided for air-conditioned machinery and control rooms.

1.2 Pressure gauges

The scales of pressure gauges must extend up to the specified test pressure. The maximum permitted operating pressures are to be marked on the pressure gauges for boilers, pressure vessels and in systems

protected by safety valves. Pressure gauges must be installed in such a way that they can be isolated.

Lines leading to pressure gauges must be installed in such a way that the readings cannot be affected by liquid heads and hydraulic hammer.

2. Accessibility of Machinery and Boilers

2.1 Machinery and boiler installations and apparatus must be accessible for operation and maintenance.

2.2 In the layout of machinery spaces (design of foundation structures, laying of pipelines and cable conduits etc.) and the design of machinery and equipment (mountings for filters, coolers etc.), 2.1 is to be complied with.

3. Engine Control Rooms

Engine control rooms are to be provided with at least two exits, one of which can also be used as an escape route.

4. Lighting

All operating spaces must be adequately lit to ensure that control and monitoring instruments can be easily read. In this connection see the Rules for the Electrical Installations Chapter 5 – Electrical Installation, Section 11.

5. Bilge Wells / Bilges

5.1 Bilge wells and bilges must be readily accessible, easy to clean and either visible or adequately lit.

5.2 Bilges beneath electrical machines must be so designed as to prevent bilge water from penetrating into the machinery at all angles of inclination and movements of the ship in service.

5.3 For the following spaces bilge level monitoring is to be provided and limit values being exceeded are to be indicated at a permanently manned alarm point:

- Unmanned machinery rooms of category “A” and other machinery rooms (class notation AUT) are to be equipped with at least 2 indicators for bilge level monitoring. (For division of machinery rooms of category “A” and other “machinery rooms” see A.2).
- Other unmanned machinery rooms, such as bow thruster and steering gear compartments arranged below the load waterline are irrespective of class notation AUT to be equipped at least one indicator for bilge level monitoring.

6. Ventilation

The machinery ventilation is to be designed under consideration of ambient conditions as mentioned in Table 1.3. See, Chapter 1 - Hull, Section 16, E.2.4.

7. Noise Abatement

“The Code on noise levels on board ships” (adopted by resolution MSC.337(91)) is to be applied.

F. Safety Equipment and Protective Measures

1. General

Machinery is to be installed and safeguarded in such a way that the risk of accidents is largely ruled out. Besides national regulations particular attention is to be paid to following:

1.1 Moving parts, flywheels, chain and belt drives, linkages and other components which could constitute an accident hazard for the operating personnel are to be fitted with guards to prevent contact. The same applies to hot machine parts, pipes and walls for which are not protected by insulation, e.g. the pressure lines of air compressors.

1.2 When using hand cranks for starting internal combustion engines, step are to be taken to ensure that the crank disengages automatically when the engines start.

Dead Man's circuits are to be provided for rotating equipment.

1.3 Blowdown and drainage facilities are to be designed in such a way that the discharged medium is safely drained off.

1.4 In operating spaces, anti-skid floor-plates and floor-coverings must be used.

1.5 Service gangways, operating platforms, stairways and other areas open to access during operation must be safeguarded by guard rails. The outside edges platforms and floor areas are to be fitted with coamings unless some other means is adopted to prevent persons and objects from sliding off.

1.6 Devices for blowing through water level gauges must be capable of safe operation and observation.

1.7 Safety valves and shutoffs must be capable of safe operation. Fixed steps, stairs or platforms are to be fitted where necessary.

1.8 Safety valves are to be installed to prevent the occurrence of excessive operating pressures.

1.9 Steam and feedwater lines, exhaust gas ducts, boilers and other equipment and pipelines carrying steam or hot water are to be effectively insulated. Insulating materials must be incombustible. Points at which combustible liquids or moisture can penetrate into the insulation are to be suitably protected, e.g. by means of shielding.

G. Communication and Signalling Equipment

1. Oral Communication

Means of oral communication are to be provided between the ship's manoeuvring station, the engine room and the steering gear compartment, and these means shall allow fully satisfactory intercommunication

independent of the shipboard power supply under all operating conditions (see also Rules for Electrical Installations, Section 9, C.5).

2. Engineer Alarm

From the engine room or the engine control room it must be possible to activate an alarm in the engineers' living quarters (see also Rules for Electrical Installations, Section 9, C.5).

3. Engine Telegraph

Machinery operated from the engine room must be equipped with a telegraph.

In the case of multiple-shaft installations, a telegraph must be provided for each unit.

Local control stations are to be equipped with an emergency telegraph.

4. Shaft Revolution Indicator

The speed and direction of rotation of the propeller shafts are to be indicated on the bridge and in the engine room. In the case of small propulsion units, the indicator may be dispensed with.

Barred speed ranges are to be marked on the shaft revolution indicators (see Section 6 - Torsional Vibration).

5. Design of Communication and Signaling Equipment

Reversing, command transmission and operating controls etc. are to be grouped together at a convenient point on the control platform.

The current status, "Ahead" or "Astern", of the reversing control must be clearly indicated at the main engine control platform.

Signaling devices must be clearly perceptible from all parts of the engine room when the machinery is in full operation.

For details of the design of electrically operated command transmission, signaling and alarm systems, see Section 18-Fire Protection and Fire Extinguishing Equipments and Chapter 5 - Electrical Installations, Section 9.

H. Essential Equipments

1. Essential for ship operation are all main propulsion plants.

2. Essential (operationally important) are the following auxiliary machinery and plants, which:

- Are necessary for propulsion and manoeuvrability of the ship,
- Are required for maintaining ship safety,
- Serve the safety of human life,

as well as

- Equipment according to special Characters of Classification and Class Notations.

3. Essential auxiliary machinery and plants are comprising e.g.:

- Generator units,
- Steering gear plant,
- Fuel oil supply units,
- Lubricating oil pumps,
- Cooling water/cooling media pumps,
- Starting and control air compressor,
- Starting installations for auxiliary and main engines,
- Charging air blowers,

- Exhaust gas turbochargers,
- Controllable pitch propeller installation,
- Azimuth drives,
- Engine room ventilation fans,
- Steam, hot and warm water generation plants,
- Thermal oil systems,
- Oil firing equipment,
- Pressure vessels and heat exchangers in essential systems,
- Hydraulic pumps,
- Fuel oil treatment units,
- Fuel oil transfer pumps,
- Lubrication oil treatment units,
- Bilge and ballast pumps,
- Heeling compensation systems,
- Fire pumps and fire fighting equipment,
- Anchor windlass,
- Transverse thrusters,
- Ventilation fans for hazardous areas,
- Turning gears for main engines,
- Bow and stern ramps as well as shell openings,
- Bulkhead door closing equipment.
- Boiler feed water pump

4. For ships with equipment according to special Characters of Classification and Notations certain type-specific plants may be classed as essential equipment.

I. Tests and Trials

1. Machinery and its component parts shall be subject to constructional and material tests, pressure and leakage tests, and trials.

In the case of parts produced in series, other methods of testing can be agreed instead of the tests prescribed, provided that the former are recognized as equivalent by **BCS**.

2. **BCS** reserves the right, where necessary, to increase the scope of the tests and also to test those parts which are not expressly required to be tested according to the rules.

3. After installation on board of the main and auxiliary machinery, the installation as well as the operational functioning of the machinery, including the associated ancillary equipment, shall be verified according to rule requirements in the following sections. Safety functions and safety equipment shall be tested as far as practically feasible. Tests for safety equipment that has formerly been performed and witnessed by **BCS** need not to be repeated.

In addition, the entire machinery installation shall be tested during sea trials, as far as possible under the intended service conditions.

The tests shall be carried out according to approved test programmes, see Classification and Surveys, Section 2 item B.2.3.4.

4. Main propulsion systems shall undergo tests to demonstrate the astern response characteristics. The tests shall be carried out at least over the manoeuvring range of the propulsion system and from all control positions. A test plan shall be provided by the yard and accepted by the surveyor. If specific operational characteristics have been defined by the manufacturer these shall be included in the test plan. See also item D.1.2 and Section 3 item C.10.1.1.

5. The reversing characteristics of the propulsion plant, including the blade pitch control system of controllable pitch propellers, shall be demonstrated and recorded during trials.

SECTION 2

INTERNAL COMBUSTION ENGINES AND AIR COMPRESSORS

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Appendix III - Guidance For Calculation of Stress Concentration Factors in The Web Fillet Radio of Crankshafts
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Appendix V - Guidance For Calculation of Surface Treated Fillets and Oil Bore Outlets

Appendix VI - Guidance for Calculation of Stress Concentration Factors in the Oil Bore Outlets of Crankshafts Through
Utilisation of the Finite Element Method

A. General

1. Application

The requirements in this Section apply to internal combustion engines used as main propulsion units and auxiliary units (including emergency units) as well as to air compressors.

For the purpose of these requirements, internal combustion engines are:

- Diesel engines, fuelled with liquid fuel oil,
- Dual-fuel engines, fuelled with liquid fuel oil and/or gaseous fuel,
- Gas engines, fuelled with gaseous fuel.

Requirements for dual-fuel engines and gas engines are specified in N.

2. Definitions

2.1 Diesel engine type

- Low-Speed Engines; means diesel engines having a rated speed of less than 300 rpm.
- Medium-Speed Engines; means diesel engines having a rated speed of 300 rpm and above, but less than 1400 rpm.
- High-Speed Engines means; diesel engines having a rated speed of 1400 rpm or above.

2.2 Rated power

2.2.1 The rated power is the maximum power output at which the engine is designed to run continuously at its rated speed between the normal maintenance intervals stated by the manufacturer.

2.2.2 The rated power is to be specified in a way that an overload power of 110% of the rated power can be demonstrated at the corresponding speed for an uninterrupted period of 1 hour. Deviations from the overload power value require the agreement of **BCS**.

2.2.3 After running on the test bed, the fuel delivery system of main engines is to be so adjusted that after installation on board, overload power cannot be delivered. The limitation of the fuel delivery system has to be secured permanently.

2.2.4 Subject to the prescribed conditions, diesel engines driving electrical generators are to be capable of overload operation even after installation on board.

2.2.5 Subject to the approval of **BCS**, diesel engines for special vessels and special applications may be designed for a continuous power (fuel stop power) which cannot be exceeded.

2.2.6 For main engines, a power diagram (Fig. 2.15) is to be prepared showing the power ranges within which the engine is able to operate continuously and for short periods under service conditions.

2.3 Ambient reference conditions

In determining the rated power of diesel engines used on board ships with unrestricted service, the following ambient conditions are to be applied by the engine manufacturer:

Atmospheric pressure.....	1 [bar]
Suction air temperature	45°C
Relative humidity of air.....	60%
Seawater temperature (Charging air coolant inlet).....	32°C

3. Engine Certificate

Each diesel engine manufactured for a shipboard application is to have an engine certificate. The certification process details for obtaining the engine certificate are in BCS -R M 44 (Section 5). This process consists of the engine builder /licensee obtaining design approval of the engine application specific documents, submitting a comparison list of the production drawings to the previously approved engine design drawings (see B.), forwarding the relevant production drawings and comparison list for the use of the Surveyors at the manufacturing plant and shipyard if necessary, engine testing (see E.) and upon satisfactorily meeting the Rule requirements , the issuance of an engine certificate.

B. Documents for Approval**1. General**

For each engine type the drawings and documents listed in Table 2.1, Table 2.2 and Table 2.3 shall, wherever applicable, be submitted by the engine manufacturer to **BCS** for information or approval or inspection of components and systems.

Where considered necessary, **BCS** may request further documents to be submitted. This also applies to the documentation of design changes according to 3.

2. Engines Manufactured Under License

For each engine type manufactured under license, the licensee shall submit to **BCS**, as a minimum requirement, the following documents:

- Comparison of all the drawings and documents as per Table 2.1, Table 2.2 and Table 2.3 - where applicable-indicating the relevant drawings used by the licensee and the licensor.
- All drawings of modified components, if available, as per Table 2.1, Table 2.2 and Table 2.3 together with the licensor's declaration of consent to the modifications,
- A complete set of drawings shall be put at the disposal of the local inspection office of **BCS** as a basis for the performance of tests and inspections.

3. Design Modifications

Following initial approval of an engine type by **BCS**, only those documents listed in Table 2.1, Table 2.2 and

Table 2.3 are to be resubmitted for examination which embody important design modification.

4. Approval of Engine Components

The approval of exhaust gas turbochargers, heat exchangers, engine-driven pumps, etc. is to be requested from **BCS** by the respective manufacturer.

5. Mass/Serial Produced Engines

Trunk engines manufactured in mass or in series, can be produced according to agreed survey arrangement in accordance with Classification and Survey Rules, Section 2, F. Alternative Certification Scheme. The scope and extent of the application of Alternative Certification Scheme are to be agreed on a case by case basis.

C. Materials**1. Approved Materials**

1.1 The mechanical characteristics of materials used for the components of diesel engines shall conform to the **BCS** Material Rules. The materials approved for the various components are shown in Table 2.4 together with their minimum required characteristics and material certificates

1.2 Materials with properties deviating from the Rules specified may be used only with **BCS**'s special approval. **BCS** requires proof of the suitability of such materials.

D. Crankshaft Design**1. General**

1.1 These Rules for the scantlings of crankshafts are to be applied to diesel engines for main propulsion and auxiliary purposes, where the engines are so designed as to be capable of continuous operation at their rated power when running at rated speed.

Crankshafts which cannot satisfy these Rules will be subject to special consideration as far as detailed calculations or measurements can be submitted.

In case of:

- Surface treated fillets,
- Tested parameters influencing the fatigue behaviour,
- Measured working stresses,

these data can be considered on special request.

Table 2.1 Documentation to be submitted for information, as applicable

No.	Item	Quantity
1	Engine particulars (e.g. Data sheet with general engine information (7) , Project Guide, Marine Installation Manual)	3
2	Engine cross section	3
3	Engine longitudinal section	3
4	Bedplate and crankcase of cast design	1
5	Thrust bearing assembly (1)	3
6	Frame/framebox/gearbox of cast design (2)	1
7	Tie rod	1
8	Connecting rod	3
9	Connecting rod, assembly (3)	3
10	Crosshead, assembly (3)	3
11	Piston rod, assembly (3)	3
12	Piston, assembly (3)	3
13	Cylinder jacket/ block of cast design(2)	1
14	Cylinder cover, assembly (3)	1
15	Cylinder liner	1
16	Counterweights (if not integral with crankshaft), including fastening	3
17	Camshaft drive, assembly (3)	1
18	Flywheel	1
19	Fuel oil injection pump	1
20	Shielding and insulation of exhaust pipes and other parts of high temperature which may be impinged as a result of a fuel system failure, assembly	3
	For electronically controlled engines, construction and arrangement of:	
21	Control valves	3
22	High-pressure pumps	3
23	Drive for high pressure pumps	3
24	Operation and service manuals (4)	1
25	FMEA (for engine control system) (5)	3
26	Production specifications for castings and welding (sequence)	1
27	Evidence of quality control system for engine design and in service maintenance	1
28	Quality requirements for engine production	1
29	Type approval certification for environmental tests, control components (6)	1

Footnotes:

- (1)** If integral with engine and not integrated in the bedplate.
- (2)** Only for one cylinder or one cylinder configuration.
- (3)** Including identification (e.g. drawing number) of components. Only necessary if sufficient details are not shown on the transverse cross section and longitudinal section.
- (4)** Operation and service manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance. The installation of mechanical joints is to be in accordance with the manufacturer's assembly instructions. Where special tools and gauges are required for installation of the joints, these are to be supplied by the manufacturer.
- (5)** And the system, where this is supplied by the engine manufacturer. Where engines rely on hydraulic, pneumatic or electronic control of fuel injection and/or valves, a failure mode and effects analysis (FMEA) is to be submitted to demonstrate that failure of the control system will not result in the operation of the engine being degraded beyond acceptable performance criteria for the engine. The FMEA reports required will not be explicitly approved by **BCS**. For FMEA process of diesel engine control systems see **BCS- G 138**.
- (6)** Tests are to demonstrate the ability of the control, protection and safety equipment to function as intended under the specified testing conditions per **BCS Additional Rules, Regulations for the Performance of the Type Tests**

Part

- (7)** According to **BCS- R 114 Rev.9, Approval of Internal Combustion Engine Approval Application Form and Data Sheet** should be filled and submitted to **BCS**

Table 2.2 Documentation to be submitted for approval, as applicable

No.	Item	Quantity
1	Bedplate and crankcase of welded design, with welding details and welding Instructions (1) (2)	3
2	Thrust bearing bedplate of welded design, with welding details and welding instructions (1)	3
3	Bedplate/oil sump welding drawings (1)	3
4	Frame/framebox/gearbox of welded design, with welding details and instructions (1) (2)	3
5	Engine frames, welding drawings (1) (2)	3
6	Crankshaft, details, each cylinder No.	3
7	Crankshaft, assembly, each cylinder No.	3
8	Crankshaft calculations (for each cylinder configuration) according to the BCS-R M44 Rev.9 Appendix 3 and BCS- R M53.	3
9	Thrust shaft or intermediate shaft (if integral with engine)	3
10	Shaft coupling bolts	3
11	Material specifications of main parts with information on non-destructive material tests and pressure tests (3)	3
	Schematic layout or other equivalent documents on the engine of:	
12	Starting air system	3
13	Fuel oil system	3
14	Lubricating oil system	3
15	Cooling water system	3
16	Hydraulic system	3
17	Hydraulic system (for valve lift)	3
18	Engine control and safety system	3
19	Shielding of high pressure fuel pipes, assembly (4)	3
20	Construction of accumulators (for electronically controlled engine)	3
21	Construction of common accumulators (for electronically controlled engine)	3
22	Arrangement and details of the crankcase explosion relief valve (see item F.4) (5)	3
23	Calculation results for crankcase explosion relief valves (see item F.4)	3
24	Details of the type test program and the type test report) (7)	1
25	High pressure parts for fuel oil injection system (6)	3
26	Oil mist detection and/or alternative alarm arrangements (see Table 2.7)	3
27	Details of mechanical joints of piping systems (see Section 16)	3
28	Documentation verifying compliance with inclination limits (see Section 1, Table 1.1)	3
29	Documents as required in BCS Chapter 5, Section 10 as applicable	3

Footnotes:

- (1)** For approval of materials and weld procedure specifications. The weld procedure specification is to include details of pre and post weld heat treatment, weld consumables and fit-up conditions.
- (2)** For each cylinder for which dimensions and details differ.
- (3)** For comparison with **BCS** requirements for material, NDT and pressure testing as applicable.
- (4)** All engines.
- (5)** Only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0.6 m³ or more.
- (6)** The documentation to contain specifications for pressures, pipe dimensions and materials.
- (7)** The type test report may be submitted shortly after the conclusion of the type test.

Table 2.3 Documentation for the inspection of components and systems

- Special consideration will be given to engines of identical design and application.
- For engine applications refer to BCS- R M72.

No.	Item	Quantity
1	Engine particulars (11)	3
2	Material specifications of main parts with information on non-destructive material tests and pressure tests (1)	3
3	Bedplate and crankcase of welded design, with welding details and welding instructions (2)	3
4	Thrust bearing bedplate of welded design, with welding details and welding instructions (2)	3
5	Frame/framebox/gearbox of welded design, with welding details and instructions (2)	3
6	Crankshaft, assembly and details	3
7	Thrust shaft or intermediate shaft (if integral with engine)	3
8	Shaft coupling bolts	3
9	Bolts and studs for main bearings	3
10	Bolts and studs for cylinder heads and exhaust valve (two stroke design)	3
11	Bolts and studs for connecting rods	3
12	Tie rods	1
	Schematic layout or other equivalent documents on the engine of (3)	
13	Starting air system	3
14	Fuel oil system	3
15	Lubricating oil system	3
16	Cooling water system	3
17	Hydraulic system	3
18	Hydraulic system (for valve lift)	3
19	Engine control and safety system	3
20	Shielding of high pressure fuel pipes, assembly (4)	3
21	Construction of accumulators for hydraulic oil and fuel oil	3
22	High pressure parts for fuel oil injection system (5)	3
23	Arrangement and details of the crankcase explosion relief valve (see item F.4) (6)	3
24	Oil mist detection and/or alternative alarm arrangements (see Table 2.7)	3
25	Cylinder head	1
26	Cylinder block, engine block	1
27	Cylinder liner	1
28	Counterweights (if not integral with crankshaft), including fastening	3
29	Connecting rod with cap	3
30	Crosshead	3
31	Piston rod	3
32	Piston, assembly (7)	3
33	Piston head	3
34	Camshaft drive, assembly (7)	1
35	Flywheel	1
36	Arrangement of foundation (for main engines only)	3
37	Fuel oil injection pump	1
38	Shielding and insulation of exhaust pipes and other parts of high temperature which may be impinged as a result of a fuel system failure, assembly	3

No.	Item	Quantity
39	Construction and arrangement of dampers	3
	For electronically controlled engines, assembly drawings or arrangements of:	3
40	Control valves	3
41	High-pressure pumps	3
42	Drive for high pressure pumps	3
43	Valve bodies, if applicable	3
44	Operation and service manuals (8)	1
45	Test program resulting from FMEA (for engine control system) (9)	1
46	Production specifications for castings and welding (sequence)	1
47	Type approval certification for environmental tests, control components (10)	1
48	Quality requirements for engine production	1

Footnotes:

- (1)** For comparison with **BCS** requirements for material, NDT and pressure testing as applicable.
- (2)** For approval of materials and weld procedure specifications. The weld procedure specification is to include details of pre and post weld heat treatment, weld consumables and fit-up conditions.
- (3)** Details of the system so far as supplied by the engine manufacturer such as: main dimensions, operating media and maximum working pressures.
- (4)** All engines.
- (5)** The documentation to contain specifications for pressures, pipe dimensions and materials.
- (6)** Only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0.6 m³ or more.
- (7)** Including identification (e.g. drawing number) of components.
- (8)** Operation and service manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance. The installation of mechanical joints is to be in accordance with the manufacturer's assembly instructions. Where special tools and gauges are required for installation of the joints, these are to be supplied by the manufacturer.
- (9)** Required for engines that rely on hydraulic, pneumatic or electronic control of fuel injection and/or valves. For FMEA process of diesel engine control systems see BCS- G 138.
- (10)** Documents modified for a specific application are to be submitted to **BCS** for information or approval, as applicable. See BCS- R M44 Rev.9 Item 3.2.2.2, Appendix 4 and Appendix 5.
- (11)** According to BCS- R M44 Rev.9, Appendix 3 - "Internal Combustion Engine Approval Application Form and Data Sheet" should be filled and submitted to **BCS**.

Table 2.4 Approved materials and type of test certificate

Approved materials	BCS's Rules (*)	Components	Test certificate (**)		
			A	B	C
Forged steel $R_m \geq 360 \text{ N/mm}^2$	Section 5,	Crankshafts	X	-	-
		Connecting rods	X	-	-
		Piston rods	X (3)	X (4)	-
		Crossheads	X (3)	X (4)	-
		Pistons and piston crowns	X (3)	X (4)	-
		Cylinder covers/heads	X	-	-
		Camshaft drive wheels	X (3)	X (4)	-
Rolled or forged steel rounds $R_m \geq 360 \text{ N/mm}^2$	Section 5,	Tie rods	X	-	-
		Bolts and studs	X (1)	X (2)	-
Special grade cast steel $R_m \geq 440 \text{ N/mm}^2$ and Special grade forged steel $R_m \geq 440 \text{ N/mm}^2$	Section 6, Section 5,	Throws and webs of built-up crankshafts	X	-	-
Cast steel	Section 6,	Bearing transverse girders (weldable)	X	-	-
		Pistons and piston crowns	X (3)	X (4)	-
		Cylinder covers/heads	X (1)	X (2)	-
		Camshaft drive wheels	X (3)	X (4)	-
Nodular cast iron, preferably ferritic grades $R_m \geq 370 \text{ N/mm}^2$	Section 7,	Engine blocks	-	X (1)	-
		Bed plates	-	X (1)	-
		Cylinder blocks	-	X (1)	-
		Pistons and piston crowns	X (3)	X (4)	-
		Cylinder covers/heads	-	X (1)	-
		Flywheels	-	X (1)	-
		Valve bodies	-	X (1)	-
Lamellar cast iron $R_m \geq 200 \text{ N/mm}^2$	Section 7,	Engine blocks	-	-	X
		Bedplates	-	-	X
		Cylinder blocks	-	-	X
		Cylinder liners	-	-	X
		Cylinder covers/heads	-	-	X
		Flywheels	-	-	X
Shipbuilding steel, all BCS grades for plate thickness ≤ 35	Section 3,	Welded cylinder blocks	X	-	-
		Welded bedplates	X	-	-
Shipbuilding steel, BCS grade B for plate thickness $>35 \text{ mm}$		Welded frames	X	-	-
		Welded housings	X	-	-
Structural steel, unalloyed, for welded assemblies	Section 3,				
(*) All details refer to the BCS Material Rules (**) Test certificates are to be issued in accordance with BCS Material Rules, Test Procedures, with the following abbreviations: A : BCS Material Certificate, B: Manufacturer Inspection Certificate, C: Manufacturer Test Report (1) Only for cylinder bores $>300 \text{ mm}$. (2) For cylinder bores $\leq 300 \text{ mm}$. (3) Only for cylinder bores $>400 \text{ mm}$. (4) For cylinder bores $\leq 400 \text{ mm}$.					

1.2 Outside the end bearings, crankshafts designed according to the requirements specified in this section may be adapted to the diameter of the adjoining shaft by a generous fillet ($r \geq 0,06 \cdot d$) or a taper.

1.3 These Rules apply only to solid-forged and semi-built crankshafts of forged or cast steel, with one crank throw between main bearings

1.4 The scantlings of crankshafts are based on an evaluation of safety against fatigue in the highly stressed areas.

The calculation is also based on the assumption that the fillet transitions between the crankpin and web as well as between the journal and web are the areas exposed to the highest stresses.

The outlets of oil bores into crankpins and journals are to be formed in such a way that the safety margin against fatigue at the oil bores is not less than that acceptable in the fillets. The engine manufacturer, if requested by **BCS** should submit a documentation supporting his oil bore design.

Calculation of crankshaft strength consists initially in determining the nominal alternating bending and nominal alternating torsional stresses which, multiplied by the appropriate stress concentration factors using the theory of constant energy of distortion (v. Mises' Criterion), result in an equivalent alternating stress (uni-axial stress). This equivalent alternating stress is then compared with the

fatigue strength of the selected crankshaft material. This comparison will then show whether or not the crankshaft concerned is dimensioned adequately.

1.5 For the calculation of crankshafts, the documents and particulars listed in the following are to be submitted:

- Crankshaft drawing which must contain all data in respect of the geometrical configuration of the crankshaft
- Type designation and kind of engine (in-line engine or V-type engine with adjacent connecting rods, forked connecting rod or articulated type connecting rod)
- Operating and combustion method (2-stroke or 4-stroke cycle, direct injection, precombustion chamber, etc.)
- Number of cylinders
- Rated power [kW]
- Rated engine speed [min^{-1}]
- Sense of rotation (see Fig. 2.1)
- Ignition sequence with the respective ignition intervals and, where necessary, V-angle α_v (see Fig. 2.1)

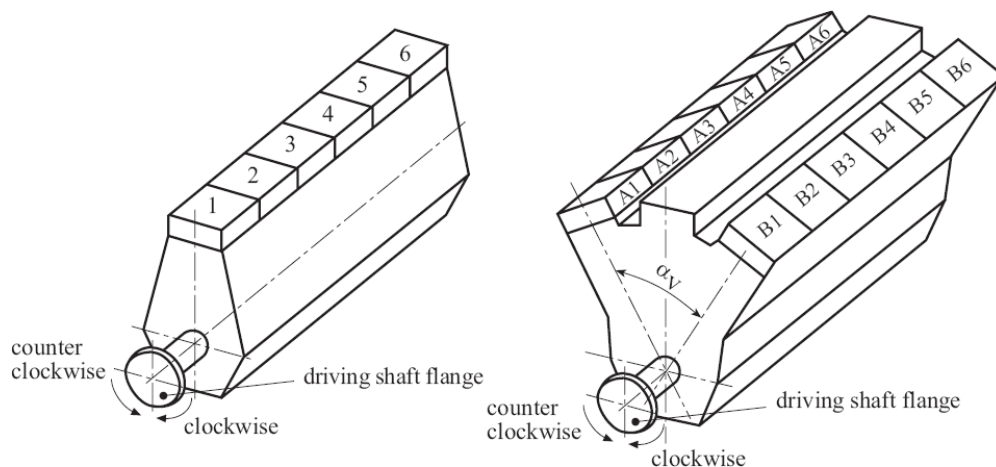


Fig. 2.1 Designation of the cylinders

- Cylinder diameter [mm]
- Stroke [mm]
- Maximum cylinder pressure P_{\max} [bar]
- Charge air pressure [bar] (before inlet valves or scavenge ports, whichever applies)
- Connecting rod length L_H [mm]
- Oscillating weight of one crank gear [kg] (in case of V-type engines, where necessary, also for the cylinder unit with master and articulated type connecting rod or forked and inner connecting rod)
- Digitalized gas pressure curve presented at equidistant intervals (bar versus crank angle, but not more than 5° CA)
- For engines with articulated-type connecting rod (see Fig. 2.2)
 - Distance to link point L_A [mm]
 - Link angle α_N [°]
 - Connecting rod length L_N [mm]
- Details of crankshaft material
 - Material designation (according to DIN, AISI, etc.)
 - Mechanical properties of material (minimum values obtained from longitudinal test specimens)
 - Tensile strength [N/mm²]
 - Yield strength [N/mm²]
 - Reduction in area at fracture [%]
 - Elongation A5 [%]

- Impact energy – KV [J]

- Type of forging (free form forged, continuous grain flow forged, drop-forged, etc., with description of the forging process)

Every surface treatment affecting fillets or oil holes shall be specified so as to enable calculation according to Appendix V

- Particulars for alternating torsional stresses, see 2.2.

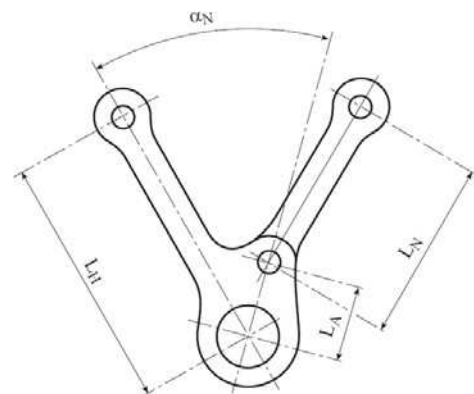


Fig. 2.2 Articulated-type connecting rod

2. Calculation of Stresses

2.1 Calculation of alternating stresses due to bending moments and shearing forces

2.1.1 Assumptions

The calculation is based on a statically determinate system, so that only one single crank throw is considered of which the journals are supported in the centre of adjacent bearings and which is subject to gas and inertia forces. The bending length is taken as the length between the two main bearings (distance L_3) see Figs. 2.3 and 2.4.

The bending moments, M_{BR} and M_{BT} , are calculated in the relevant section based on triangular bending moment diagrams due to the radial component, F_R and tangential component, F_T of the connecting-rod force, respectively (see Fig. 2.3).

For crankthrows with two connecting-rods acting upon one crankpin the relevant bending moments are obtained by superposition of the two triangular bending moment diagrams according to phase (see Fig. 2.4)

2.1.1.1 Bending moments and radial forces acting in web

The bending moment M_{BRF} and the radial force Q_{RF} are taken as acting in the centre of the solid web (distance L_1) and are derived from the radial component of the connecting-rod force.

The alternating bending and compressive stresses due to bending moments and radial forces are to be related to the cross-section of the crank web. This reference section results from the web thickness W and the web width B (see fig. 2.6).

Mean stresses are neglected.

2.1.1.2 Bending acting in outlet of crankpin oil bore

The two relevant bending moments are taken in the crankpin cross-section through the oil bore

M_{BRO} is the bending moment of the radial component of the connecting-rod force

M_{BTO} is the bending moment of the tangential component of the connecting-rod force

The alternating stresses due to these bending moments are to be related to the cross-sectional area of the axially bored crankpin.

Mean bending stresses are neglected.

2.1.2 Calculation of nominal alternating bending and compressive stresses in web

The radial and tangential forces due to gas and inertia loads acting upon the crankpin at each connecting-rod position will be calculated over one working cycle.

Using the forces calculated over one working cycle and taking into account of the distance from the main bearing midpoint, the time curve of the bending moments M_{BRF} , M_{BRO} , M_{BTO} and radial forces Q_{RF} - as defined in 2.1.1.1 and 2.1.1.2 - will then be calculated.

In case of V-type engines, the bending moments progressively calculated from the gas and inertia forces of the two cylinders acting on one crankthrow are superposed according to phase. Different designs (forked connecting-rod, articulated-type connecting-rod or adjacent connecting-rods) shall be taken into account.

Where there are cranks of different geometrical configurations in one crankshaft, the calculation is to cover all crank variants.

The decisive alternating values will then be calculated according to:

$$X_N = \pm \frac{1}{2} (X_{\max} - X_{\min})$$

where:

X_N = Alternating force, moment or stress

X_{\max} = Maximum value within one working cycle

X_{\min} = Minimum value within one working cycle

2.1.2.1 Nominal alternating bending and compressive stresses in web cross section

The calculation of the nominal alternating bending and compressive stresses is as follows:

$$\sigma_{BFN} = \pm \frac{M_{BRFN}}{W_{eqw}} \cdot 10^3 \cdot K_e$$

$$\sigma_{QFN} = \pm \frac{Q_{RFN}}{F} \cdot K_e$$

σ_{BFN} = Nominal alternating bending stress related to the web, [N/mm²]

M_{BRFN} = Alternating bending moment related to the centre of the web [Nm] (see fig. 2.3 and 2.4)

$$M_{BRFN} = \pm \frac{1}{2} (M_{BRF,max} - M_{BRF,min})$$

W_{eqw} = Section modulus related to cross-section of web [mm³]

$$W_{eqw} = \frac{B \cdot W^2}{6}$$

K_e = Empirical factor considering to some extent the influence of adjacent crank and bearing restraint

with:

$K_e = 0.8$ for 2-stroke engines

$K_e = 1.0$ for 4-stroke engines

$$Q_{RFN} = \pm \frac{1}{2} (Q_{RF,max} - Q_{RF,min})$$

σ_{QFN} = Nominal alternating compressive stress due to radial force related to the web [N/mm²]

Q_{RFN} = Alternating radial force related to the web (see fig. 2.3 and 2.4) [N]

$$F = B \cdot W$$

F = Area related to cross-section of web [mm²]

2.1.2.2 Nominal alternating bending stress in outlet of crankpin oil bore

The calculation of nominal alternating bending stress is as follows:

$$\sigma_{BON} = \pm \frac{M_{BON}}{W_e} \cdot 10^3$$

σ_{BON} = Nominal alternating bending stress related to the crank pin diameter, [N/mm²]

M_{BON} = Alternating bending moment calculated at the outlet of crankpin oil bore, [Nm]

$$M_{BON} = \pm \frac{1}{2} (M_{BO,max} - M_{BO,min})$$

With

$$M_{BO} = (M_{BTO} \cos \psi + M_{BRO} \sin \psi)$$

and ψ [°] angular position (see fig. 2.5)

W_e = Section modulus related to cross-section of axially bored crankpin, [mm³]:

$$W_e = \frac{\pi D^4 - D_{BH}^4}{32 D}$$

2.1.3 Calculation of alternating bending stresses in fillets

The calculation of stresses is to be carried out for the crankpin fillet as well as for the journal fillet.

For the crankpin fillet:

$$\sigma_{BH} = \pm (\alpha_B \cdot \sigma_{BN})$$

σ_{BH} = Alternating bending stress in crankpin fillet [N/mm²],

α_B = Stress concentration factor for bending in crankpin fillet [–] (determination, see 3.).

For the journal fillet (not applicable to semi-built crankshafts):

$$\sigma_{BG} = \pm (\beta_B \cdot \sigma_{BN} + \beta_Q \cdot \sigma_{QN})$$

σ_{BG} = Alternating stresses in journal fillet [N/mm²],

β_B = Stress concentration factor for bending in journal fillet [–] (determination, see 3.),

β_Q = Stress concentration factor for shearing [–] (determination, see 3.).

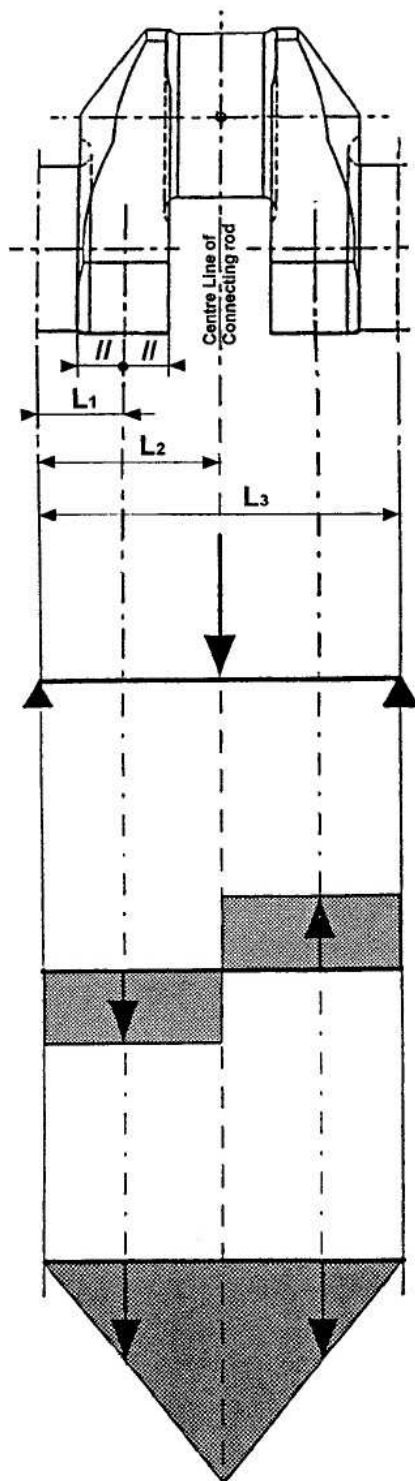


Fig. 2.3 Crankthrow for in line engine

L_1 = Distance between main journal centre line and crankweb centre
 (see also Fig 2.5 for crankshaft without overlap)
 L_2 = Distance between main journal centre line and connecting-rod centre
 L_3 = Distance between two adjacent main journal centre lines

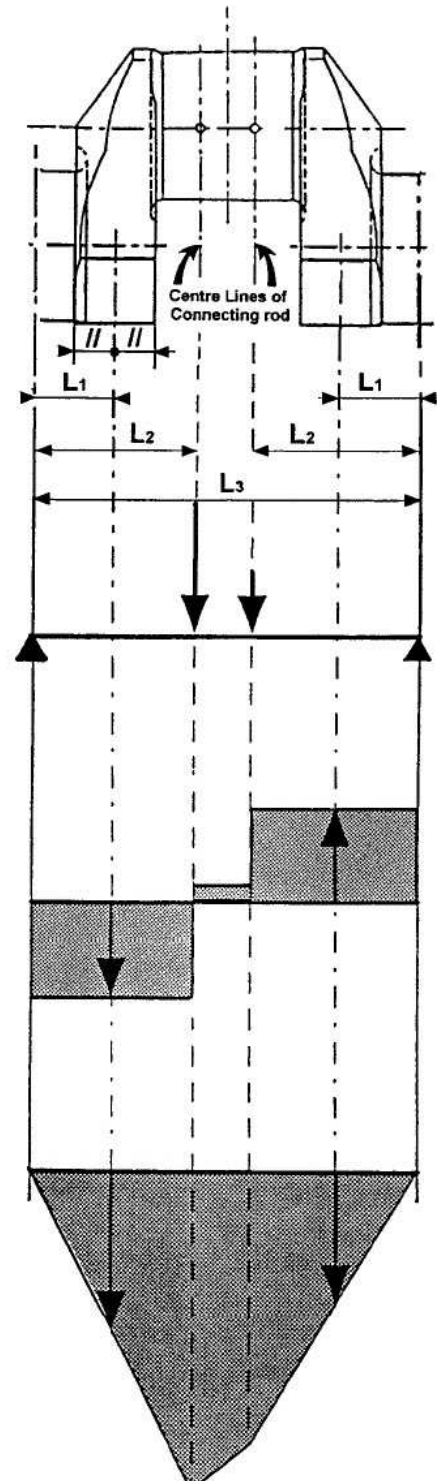


Fig. 2.4 Crankthrow for Vee engine with 2 adjacent connecting-rods

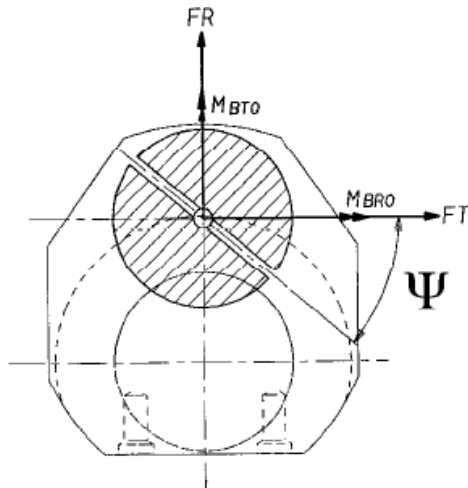


Fig. 2.5 Crankpin section through the oil bore

2.1.4 Calculation of alternating bending stresses in outlet of crankpin oil bore

$$\sigma_{BO} = \pm (\gamma_B \cdot \sigma_{BON})$$

σ_{BO} = Alternating bending stress in outlet of crankpin oil bore, [N/mm²]

γ_B = Stress concentration factor for bending in crankpin oil bore, [-] (determination -see item 3)

2.2 Calculation of alternating torsional stresses

2.2.1 General

The calculation for nominal alternating torsional stresses is to be undertaken by the engine manufacturer according to the information contained in 2.1.2. The manufacturer shall specify the maximum nominal alternating torsional stress.

The maximum value obtained from such calculations will be used by **BCS** when determining the equivalent alternating stress, according to 5. In the absence of such a maximum value it will be necessary for **BCS** to incorporate a fixed value in the calculation for the crankshaft dimensions on the basis of an estimation.

In case **BCS** is entrusted with carrying out a forced vibration calculation on behalf of the engine

manufacturer to determine the torsional vibration stresses to be expected in the engine and possibly in its shafting, the following data are to be submitted to **BCS** additionally to 1.5:

- Equivalent dynamic system of the engine comprising
 - Mass moment of inertia of every mass point [kgm²]
 - Inertialess torsional stiffnesses [Nm/rad]
- Vibration dampers
 - Type designation
 - Mass moments of inertia [kgm²]
 - Inertialess torsional stiffnesses [Nm/rad]
 - Damping coefficients [Nms]
- Flywheels
 - Mass moment of inertia [kgm²]

If the whole installation is to be considered, the above information is to be extended by the following:

- Coupling
 - Dynamic characteristics and damping data
- Gearing data
 - Shaft diameter of gear shafts, thrust shafts, intermediate shafts and propeller shafts
- Shafting
 - Diameter of thrust shafts, intermediate shafts and propeller shafts

- Propellers

$$W_p = \frac{\pi}{16} \left(\frac{D - D_{BH}^4}{D} \right)$$

- Propeller diameter

or

- Number of blades

or

- Pitch and area ratio

$$W_p = \frac{\pi D D_{GG}^4 - D_{BG}^4}{16 D_G}$$

- Natural frequencies with their relevant modes of vibration and the vector sums for the harmonics of the engine excitation.

τ_N = Nominal alternating torsional stress referred to crankpin or journal [N/mm²],

- Estimated torsional vibration stresses in all important elements of the system with particular reference to clearly defined resonance speeds of rotation and continuous operating ranges.

M_{TN} = Maximum alternating torque [Nm],

W_p = Polar section modulus related to cross section of axially bored crankpin or bored journal [mm³],

2.2.2 Calculation of nominal alternating torsional stresses

The maximum and minimum alternating torques are to be ascertained for every mass point of the system and for the entire speed range by means of a harmonic synthesis of the forced vibrations from the 1st order up to and including the 15th order for 2-stroke cycle engines and from the 0.5th order up to and including the 12th order for 4-stroke cycle engines. Whilst doing so, allowance must be made for the damping that exist in the system and for unfavourable conditions (misfiring in one of the cylinders). The speed step calculation shall be selected in such a way that any resonance found in the operational speed range of the engine shall be detected and the transient response can be recorded with sufficient accuracy. Misfiring is defined as cylinder condition when no combustion occurs but only compression cycle.

The values received from such calculation are to be submitted.

The nominal alternating torsional stress in every mass point, which is essential to the assessment, results from the following equation:

$$\tau_N = \pm \frac{M_T}{W_p} \cdot 10^3$$

$$M_{TN} = \pm \frac{1}{2} (M_{Tmax} - M_{Tmin})$$

M_{Tmax} = Maximum value of the torque [Nm].

M_{Tmin} = Minimum value of the torque [Nm].

The assessment of the crankshaft is based on the torsional stress which in conjunction with the associated bending stress, results in the lowest acceptability factor. Where barred speed ranges are necessary, the torsional stresses within these ranges are to be neglected in the calculation of the acceptability factor.

Barred speed ranges are to be so arranged that satisfactory operation is possible despite of their existence. There are to be no barred speed ranges above a speed ratio of $\lambda \geq 0,8$ of the rated speed.

The approval of crankshafts is to be based on the installation having the lowest acceptability factor.

Thus, for each installation, it is to be ensured by suitable calculation that the approved nominal alternating torsional stress is not exceeded. This calculation is to be submitted for assessment.

2.2.3 Calculation of alternating torsional stresses in fillets and outlet of crankpin oil bore

The calculation of stresses is to be carried out for both the crankpin and the journal fillet

For the crankpin fillet:

$$\tau_H = \pm(\alpha_T \cdot \tau_N)$$

τ_H = Alternating torsional stress in crankpin fillet [N/mm²],

α_T = Stress concentration factor for torsion in crankpin fillet [-] (determination, see C.).

τ_N = Nominal alternating torsional stress related to crankpin diameter [N/mm²]

For the journal fillet (not applicable to semi-built crankshafts):

$$\tau_G = \pm(\beta_T \cdot \tau_N)$$

τ_G = Alternating torsional stress in journal fillet [N/mm²],

β_T = Stress concentration factor for torsion in journal fillet [-] (determination, see C.).

τ_N = Nominal alternating torsional stress related to journal diameter [N/mm²],

For the outlet of crankpin oil bore:

$$\sigma_{TO} = \pm(\gamma_T \cdot \tau_N)$$

σ_{TO} = Alternating stress in outlet of crankpin oil bore due to torsion [N/mm²]

γ_T = Stress concentration factor for torsion in outlet of crankpin oil bore [-] (determination-see item C)

τ_N = Nominal alternating torsional stress related to crankpin diameter [N/mm²]

3. Evaluation of Stress Concentration Factors

3.1 General

The stress concentration factors are evaluated by

means of the formulae according to items 3.2, 3.3 and 3.4 applicable to the fillets and crankpin oil bore of solid forged web-type crankshafts and to the crankpin fillets of semi-built crankshafts only. It must be noticed that stress concentration factor formulae concerning the oil bore are only applicable to a radially drilled oil hole. All formulae are based on investigations of FVV (ForschungsvereinigungVerbrennungskraftmaschinen) for fillets and on investigations of ESDU (Engineering Science Data Unit) for oil holes.

Where the geometry of the crankshaft is outside the boundaries of the analytical stress concentration factors (SCF) the calculation method detailed in item D.3.5 may be undertaken.

The stress concentration factors for bending (α_B , β_B) are defined as the ratio of the maximum bending stress – occurring in the fillets under bending load acting in the central cross-section of a crank – to the nominal stress related to the web cross-section.

The stress concentration factor for compression (β_Q) in the journal fillet is defined as the ratio of the maximum equivalent stress (VON MISES) – occurring in the fillet due to the radial force – to the nominal compressive stress related to the web cross-section.

The stress concentration factors for torsion (α_T , β_T) are defined as the ratio of the maximum torsional stress occurring under torsional load in the fillets to the nominal stress related to the bored crankpin or journal cross-section.

The stress concentration factors for bending (γ_B) and torsion (γ_T) are defined as the ratio of the maximum principal stress – occurring at the outlet of the crankpin oil-hole under bending and torsional loads – to the corresponding nominal stress related to the axially bored crankpin cross section.

When reliable measurements and/or calculations are available, which can allow direct assessment of stress concentration factors, the relevant documents and their analysis method have to be submitted to **BCS** in order to demonstrate their equivalence to present rules evaluation. This is always to be performed when dimensions are outside of any of the validity ranges for the empirical formulae presented in 3.2 to 3.4.

Appendix III and VI describes how FE analyses can be used for the calculation of the stress concentration factors. Care should be taken to avoid mixing equivalent (von Mises) stresses and principal stresses.

All crank dimensions necessary for the calculation of stress concentration factors are shown in Fig. 2.6.

Actual dimensions:

D = Crankpin diameter [mm],

D_{BH} = Diameter of axial bore in crankpin [mm],

D_O = Diameter of oil bore in crankpin [mm],

R_H = Fillet radius of crankpin [mm],

T_H = Recess of crankpin [mm],

D_G = Journal diameter [mm].

D_{BG} = Diameter of axial bore in journal [mm],

R_G = Fillet radius of journal [mm],

T_G = Recess of journal fillet [mm],

E = Pin eccentricity [mm],

S = Pin overlap [mm],

$$S = \frac{D + D_G}{2} - E$$

$W^{(*)}$ = Web thickness [mm],

$B^{(*)}$ = Web width [mm].

(*)In the case of 2 stroke semi-built crankshafts::

- When $T_H > R_H$, the web thickness must be considered as equal to:

$$W_{red} = W - (T_H - R_H) \text{ (refer to fig. 2.6)}$$

- Web width B must be taken in way of crankpin fillet radius centre according to fig. 2.6

The following related dimensions will be applied for the calculation of stress concentration factors in:

Table 2.5 Stress concentration factors

Crankpin Fillets	Journal Fillets
$r = R_H / D$	$r = R_G / D$
$s = S/D$ $w = W/D$ crankshafts with overlap $w = W_{red}/D$ crankshafts without overlap $b = B/D$ $d_O = D_O/D$ $d_G = D_{BG}/D$ $d_H = D_{BH}/D$ $t_H = T_H/D$ $t_G = T_G/D$	

Stress concentration factors are valid for the ranges of related dimensions for which the investigations have been carried out. Ranges are as follows:

$$s \leq 0.5$$

$$0.2 \leq w \leq 0.8$$

$$1.1 \leq b \leq 2.2$$

$$0.03 \leq r \leq 0.13$$

$$0 \leq d_G \leq 0.8$$

$$0 \leq d_H \leq 0.8$$

$$0 \leq d_O \leq 0.2$$

Low range of s can be extended down to large negative values provided that:

If calculated f (recess) < 1 then the factor f (recess) is not to be considered (f (recess) = 1)

If $s < -0.5$ then $f(s, w)$ and $f(r, s)$ are to be evaluated replacing actual value of s by -0.5 .

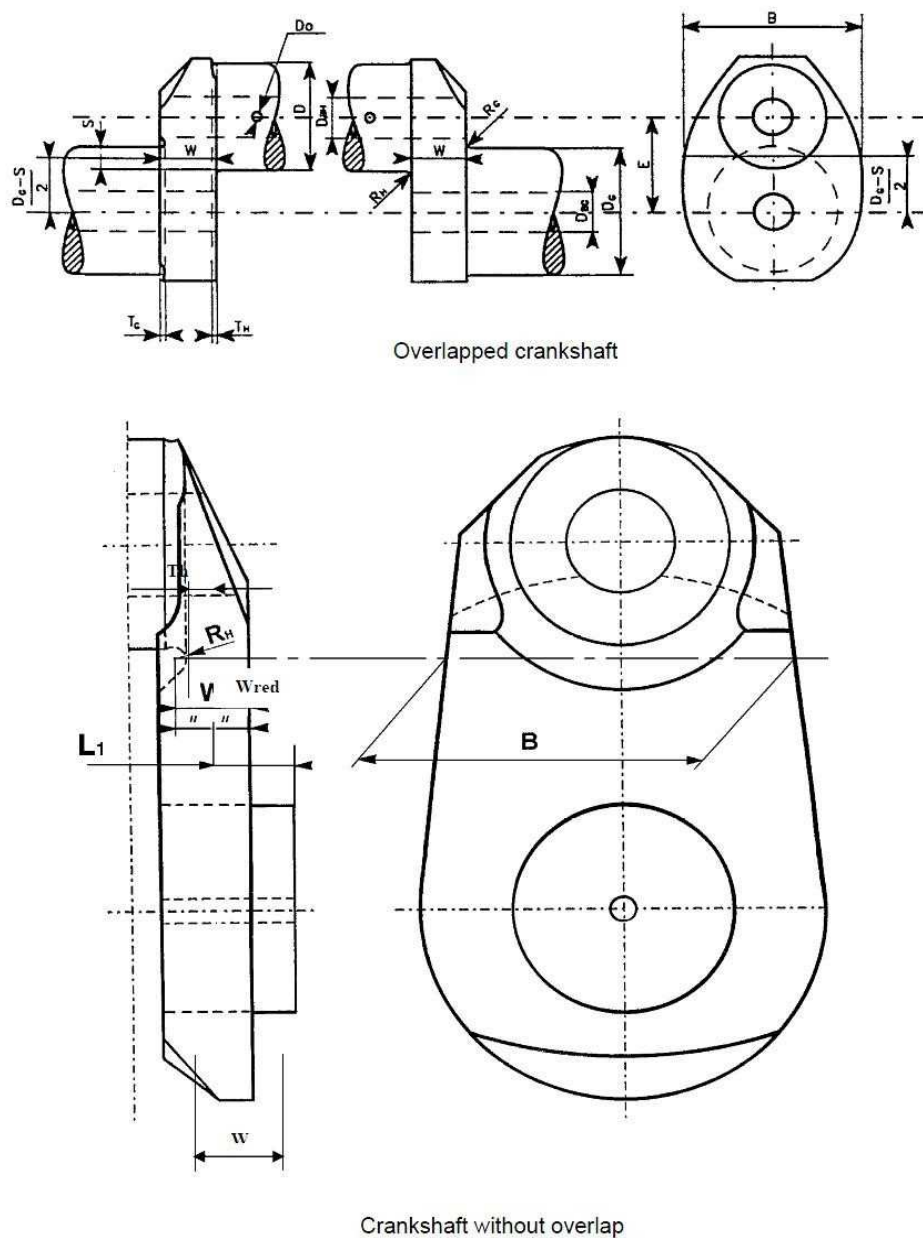


Fig. 2.6 Crank dimensions necessary for the calculation of stress concentration factors

3.2 Crankpin fillet

The stress concentration factor for bending α_B is:

$$\alpha_B = 2.6914 \cdot f(s, w) \cdot f(w) \cdot f(b) \cdot f(r) \cdot f(d_G) \cdot f(d_H) \cdot f(\text{recess})$$

$$f(s, w) = -4.1883 + 29.2004 \cdot w - 77.5925 \cdot w^2 + 91.9454 \cdot w^3 - 40.0416 \cdot w^4 + (1 - s) \cdot (9.5440 - 58.3480 \cdot w + 159.3415 \cdot w^2 - 192.5846 \cdot w^3 + 85.2916 \cdot w^4) + (1 - s)^2 \cdot (-3.8399 + 25.0444 \cdot w - 70.5571 \cdot w^2 + 87.0328 \cdot w^3 - 39.1832 \cdot w^4)$$

$$f(w) = 2.1790 \cdot w^{0.7171}$$

$$f(b) = 0.6840 - 0.0077 \cdot b + 0.1473 \cdot b^2$$

$$f(r) = 0.2081 \cdot r^{-0.5231}$$

$$f(d_G) = 0.9993 + 0.27 \cdot d_G - 1.0211 \cdot d_G^2 + 0.5306 \cdot d_G^3$$

$$f(d_H) = 0.9978 + 0.3145 \cdot d_H - 1.5241 \cdot d_H^2 + 2.4147 \cdot d_H^3$$

$$f(\text{recess}) = 1 + (t_H + t_G) \cdot (1.8 + 3.2 \cdot s)$$

The stress concentration factor for torsion (α_T) is:

$$\alpha_T = 0.8 \cdot f(r, s) \cdot f(b) \cdot f(w)$$

$$f(r, s) = r^{-0.322 + 0.1015 \cdot (1 - s)}$$

$$f(b) = 7.8955 - 10.654 \cdot b + 5.3482 \cdot b^2 - 0.857 \cdot b^3$$

$$f(w) = w^{-0.145}$$

3.3 Journal fillet (not applicable to semi-built crankshaft)

The stress concentration factor for bending β_B is:

$$\beta_B = 2.7146 \cdot f_B(s, w) \cdot f_B(w) \cdot f_B(b) \cdot f_B(r) \cdot f_B(d_G) \cdot f_B(d_H) \cdot f(\text{recess})$$

$$f_B(s, w) = -1.7625 + 2.9821 \cdot w - 1.5276 \cdot w^2 + (1 - s) \cdot (5.1169 - 5.8089 \cdot w + 3.1391 \cdot w^2) + (1 - s)^2 \cdot (-2.1567 + 2.3297 \cdot w - 1.2952 \cdot w^2)$$

$$f_B(w) = 2.2242 \cdot w^{0.7548}$$

$$f_B(b) = 0.5616 + 0.1197 \cdot b + 0.1176 \cdot b^2$$

$$f_B(r) = 0.1908 \cdot r^{-0.5568}$$

$$f_B(d_G) = 1.0012 - 0.6441 \cdot d_G + 1.2265 \cdot d_G^2$$

$$f_B(d_H) = 1.0022 - 0.1903 \cdot d_H + 0.0073 \cdot d_H^2$$

$$f(\text{recess}) = 1 + (t_H + t_G) \cdot (1.8 + 3.2 \cdot s)$$

The stress concentration factor for shearing β_Q is:

$$\beta_Q = 3.0128 \cdot f_Q(s) \cdot f_Q(w) \cdot f_Q(b) \cdot f_Q(r) \cdot f_Q(d_H) \cdot f(\text{recess})$$

$$f_Q(s) = 0.4368 + 2.6130 \cdot (1 - s) - 1.5212 \cdot (1 - s)^2$$

$$f_Q(w) = w / (0.0637 + 0.9369 \cdot w)$$

$$f_Q(b) = -0.5 + b$$

$$f_Q(r) = 0.5331 \cdot r^{-0.2038}$$

$$f_Q(d_H) = 0.9937 - 1.1949 \cdot d_H + 1.7373 \cdot d_H^2$$

$$f(\text{recess}) = 1 + (t_H + t_G) \cdot (1.8 + 3.2 \cdot s)$$

The stress concentration factor for torsion β_T is:

if the diameters and fillet radii of crankpin and journal are the same,

$$\beta_T = \alpha_T$$

if crankpin and journal diameters and/or radii are of different sizes

$\beta_T = 0.8 \cdot f(r, s) \cdot f(b) \cdot f(w) f(r, s), f(b)$ and $f(w)$ are to be determined in accordance with 3.2. (see calculation of α_T), however, the radius of the journal fillet is to be related to the journal diameter:

$$r = \frac{R_G}{D_G}$$

3.4 Outlet of crankpin oil bore

The stress concentration factor for bending (γ_B) is:

$$\gamma_B = 3 - 5,88 d_o + 34,6 d_o^2$$

The stress concentration factor for torsion (γ_T) is:

$$\gamma_T = 4 - 6 d_o + 30 d_o^2$$

4. Additional Bending Stresses

In addition to the alternating bending stresses in fillets (see 2.1.3) further bending stresses due to misalignment and bedplate deformation as well as due to axial and bending vibrations are to be considered by applying σ_{add} as given by the following table:

Table 2.6 Additional stress

Type of engine	σ_{add} [N/mm ²]
Crosshead engines	± 30 (*)
Trunk piston engines	± 10
<p>(*) The additional stress of ± 30 N/mm² is composed of two components:</p> <p>(1) An additional stress of ± 20 N/mm² resulting from axial vibration</p> <p>(2) An additional stress of ± 10 N/mm² resulting from misalignment / bedplate deformation</p> <p>It is recommended that a value of ± 20 N/mm² be used for the axial vibration component for assessment purposes where axial vibration calculation results of the complete dynamic system (engine / shafting / gearing / propeller) are not available. Where axial vibration calculation results of the complete dynamic system are available, the calculated figures may be used instead.</p>	

5. Calculation of Equivalent Alternating Stress

5.1 General

In the fillets, bending and torsion lead to two different

biaxial stress fields which can be represented by a Von Mises equivalent stress with the additional assumptions that bending and torsion stresses are time phased and the corresponding peak values occur at the same location. (See Appendix I).

As a result the equivalent alternating stress is to be calculated for the crankpin fillet as well as for the journal fillet by using the Von Mises criterion.

At the oil hole outlet, bending and torsion lead to two different stress fields which can be represented by an equivalent principal stress equal to the maximum of principal stress resulting from combination of these two stress fields with the assumption that bending and torsion are time phased. (See Appendix II).

The above two different ways of equivalent stress evaluation both lead to stresses which may be compared to the same fatigue strength value of crankshaft assessed according to Von Mises criterion.

5.2 Equivalent alternating stress

The equivalent alternating stress is calculated in accordance with the formulae given.

For the crankpin fillet:

$$\sigma_v = \pm \sqrt{(\sigma_{BH} + \sigma_{add})^2 + 3 \cdot \tau_H^2}$$

For the journal fillet:

$$\sigma_v = \pm \sqrt{(\sigma_{BG} + \sigma_{add})^2 + 3 \cdot \tau_G^2}$$

For the outlet of crankpin oil bore:

$$\sigma_v = \pm \sqrt{\frac{1}{3} \sigma_{BO}^2 + 1 + \frac{9}{4} \frac{\sigma_{TO}^2}{\sigma_{BO}^2}}$$

σ_v = Equivalent alternating stress [N/mm²]

For other parameters, see D.2.1.3, D.2.2.3 and D.4.

6. Calculation of Fatigue Strength

The fatigue strength is to be understood as that value of alternating bending stress which a crankshaft can permanently withstand at the most highly stressed points of the fillets: Where the fatigue strength for a crankshaft cannot be furnished by reliable measurements, the fatigue strength may be evaluated by means of the following formulae:

Related to the crankpin diameter:

$$\sigma_{DW} = \pm K \cdot (0,42 \cdot \sigma_B + 39,3) \cdot \left(0,264 + 1,073 \cdot D^{-0,2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{R_X}} \right)$$

$R_X = R_H$ in the fillet area

$R_X = D_o/2$ in the oil bore area

Related to the journal diameter:

$$\sigma_{DW} = \pm K \cdot (0,42 \cdot \sigma_B + 39,3) \cdot \left(0,264 + 1,073 \cdot D^{-0,2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{R_G}} \right)$$

σ_{DW} = Allowable fatigue strength of crankshaft [N/mm²],

K = Factor for different types of forged and cast crankshafts without surface treatment.

Values greater than 1 are only applicable to fatigue strength in fillet area. [–],

= 1.05 for continuous grain flow forged or drop-forged crankshafts,

= 1.0 for free form forged crankshafts (without continuous grain flow),

Factor for cast steel crankshafts with cold rolling treatment in fillet area.

= 0.93 for cast steel crankshafts manufactured by companies using a **BCS** approved cold rolling process.

σ_B = Minimum tensile strength of crankshaft material [N/mm²].

For other parameters see D.3.1.

When a surface treatment process is applied, it must be approved by **BCS**. Guidance for calculation of surface treated fillets and oil bore outlets is presented in Appendix V.

However, it is to be considered that, the surfaces of the fillet, the outlet of the oil bore and inside the oil bore (down to a minimum depth equal to 1.5 times the oil bore diameter) shall be smoothly finished and for calculation purposes R_H , R_G and R_X are not to be taken less than 2 mm.

As an alternative the fatigue strength of the crankshaft can be determined by experiment based either on full size crankthrow (or crankshaft) or on specimens taken from a full size crankthrow. For evaluation of test results, see Appendix IV.

7. Acceptability Criteria

The sufficient dimensioning of crankshaft is confirmed by a comparison of the equivalent alternating stress and the fatigue strength. This comparison has to be carried out for the crankpin fillet, the journal fillet, the outlet of crankpin oil bore and is based on the formula:

$$QQ = \frac{\sigma_{\sigma_{DDD}}}{\sigma_{\sigma_{VV}}}$$

Q = Acceptability factor [–]

Adequate dimensioning of the crankshaft is ensured if the smallest of all acceptability factors satisfies the criteria: $Q \geq 1.15$

8. Calculation of Shrink-fits of Semi-Built Crankshafts

8.1 General

All crank dimensions necessary for the calculation of the shrink-fit are shown in Fig. 2.7.

D_S = Shrink diameter [mm],

L_S = Length of shrink-fit [mm],

D_A = Outside diameter of web [mm],
or
twice the minimum distance x between
centreline of journals and outer contour of
web, whichever is less.

y = Distance between the adjacent generating
lines of journal and pin [mm].

$y \geq 0,05 D_S$

Where y is less than $0,1 \cdot D_S$, special consideration is to be given to the effect of the stress due to the shrink on the fatigue strength at the crankpin fillet.

For other parameter, see D.3.1 (Fig. 2.6).

Regarding the radius of the transition from the journal to the shrink diameter, the following must be observed:

$$R_G \geq 0.015 \cdot D_G \text{ and } R_G \geq 0.5 \cdot (D_S - D_G)$$

where the greater value is to be considered.

The actual oversize Z of the shrink-fit must be within the limits Z_{\min} and Z_{\max} calculated in accordance with items 8.2. and 8.3.

In the case where 8.2 condition cannot be fulfilled then 8.3 and 8.4 calculation methods of Z_{\min} and Z_{\max} are not applicable due to multizone-plasticity problems.

In such case Z_{\min} and Z_{\max} have to be established based on FEM calculations.

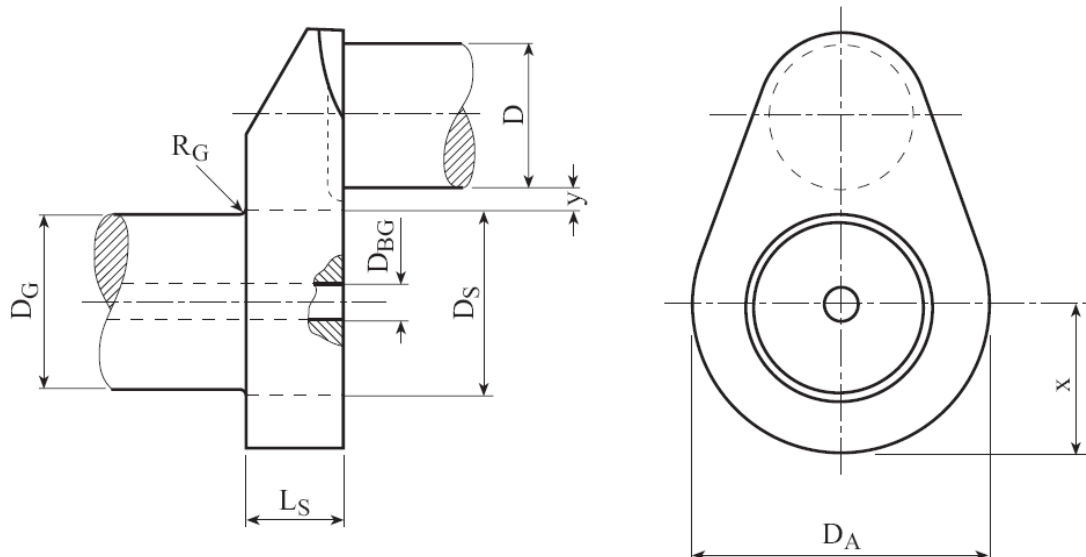


Fig. 2.7 Crank throw of semi-built crankshaft

8.2 Maximum permissible hole in the journal pin

The maximum permissible hole diameter in the journal pin is calculated in accordance with the following formula:

$$D_{BG} = D_S \left[1 - \frac{4000 \cdot S_R \cdot M_{\max}}{\mu \cdot \pi \cdot D_S^2 \cdot L_S \cdot \sigma_{SP}} \right]$$

S_R = Safety factor against slipping, [-], however a value not less than 2 is to be taken unless documented by experiments.

M_{\max} = Absolute maximum value of the torque $M_{T\max}$ [Nm] in accordance with 2.2.2

μ = Coefficient for static friction [-], however a value not greater than 0.2 is to be taken unless documented by experiments.

σ_{SP} = Minimum yield strength of material for journal pin [N/mm²]

This condition serves to avoid plasticity in the hole of the journal pin.

8.3 Necessary minimum oversize of shrink-fit

The necessary minimum oversize is determined by the greater value calculated in accordance with 8.3.1 and 8.3.2.

8.3.1 The calculation of the minimum oversize is to be carried out for the crank throw with the absolute maximum torque M_{\max} . The torque M_{\max} corresponds to the maximum value of the torque $M_{T\max}$, ascertained as per D.2.2 for the various mass points of the crankshaft.

$$Z_{\min} \geq \frac{4 \cdot 10^3}{\pi \cdot \mu} \cdot \frac{S_R \cdot M_{\max}}{E_m \cdot D_S \cdot L_S} \cdot \frac{1 - Q_A^2 \cdot Q_S^2}{(1 - Q_A^2) \cdot (1 - Q_S^2)}$$

$$Q = \frac{D_S}{D_A}$$

$$Q_S = \frac{D_{BG}}{D_S}$$

Z_{\min} = Minimum oversize [mm],

S_R = Safety factor against slipping, however a value not less than 2 is to be taken [-],

Q_A, Q_S = Ratio of different diameters [-],

μ = Coefficient for static friction, see 8.2 [-],

E_m = Young's modulus [N/mm²].

8.3.2 In addition to 8.3.1 the minimum oversize is also to be calculated according to the following formula:

$$Z_{\min} \geq \frac{\sigma_{SW} \cdot D_S}{E_m}$$

σ_{SW} = Minimum yield strength of material for crank web [N/mm²].

8.4 Maximum permissible oversize of shrink-fit

The maximum permissible oversize is calculated in accordance with the following formula:

$$Z_{\max} \leq \frac{\sigma_{SW} \cdot D_S}{E_m} + \frac{0.8 \cdot D_S}{1000}$$

Z_{\max} = Maximum oversize [mm].

The condition serves to restrict the shrinkage induced mean stress in the fillet.

E. Tests and Trials

1. Engine Manufacturer's Workshop and Manufacturing Inspections

1.1 The manufacture of all engines with **BCS** classification is subject to supervision by **BCS** and the manufacturer's works are to be audited by **BCS**. The scope should be agreed between manufacturer and **BCS**.

1.2 Where engine manufacturers have been approved by the **BCS** as "Suppliers of Mass Produced Internal Combustion Engines", these engines are to be tested in accordance with 4.

1.3 Every workshop where engines are assembled and tested are to be approved by **BCS** if the workshop is newly set up or a new production line is set up or a new engine type is introduced or a new production process is implemented.

1.4 Manufacturer's works have to have suitable production and testing facilities, competent staff and a quality management system, which ensures a uniform production quality of the products according to the specification.

- Manufacturing plants shall be equipped in such a way that all materials and components can be machined and manufactured to a specified standard. Production facilities and assembly lines, including machining units, welding processes, special tools, special devices, assembly and testing rigs as well as lifting and transportation devices shall be suitable for the type and size of engine, its components, and the purpose intended. Materials and components shall be manufactured in compliance with all production and quality instructions specified by the manufacturer and recognised by **BCS**.
- Suitable test bed facilities for load tests have to be provided, if required also for dynamic response testing. All liquids used for testing purposes such as fuel oil, lubrication oil and cooling water shall be suitable for the purpose intended, e.g. they shall be clean, preheated if necessary and cause no harm to engine parts.

- Trained personnel shall be available for production of parts, assembly, testing and partly dismantling for shipping, if applicable.

- Storage, reassembly and testing processes for diesel engines at shipyards shall be such that the risk of damage to the engine or its parts is minimized.

Engine manufacturer's workshops shall have in place a Quality Management System recognized by **BCS**.

2. Certification of Engine Components

2.1. General

2.1.1 The engine manufacturer is to have a quality control system that is suitable for the actual engine types to be certified by **BCS**. The quality control system is also to apply to any sub-suppliers. **BCS** reserves the right to review the system or parts thereof. Materials and components are to be produced in compliance with all the applicable production and quality instructions specified by the engine manufacturer. **BCS** requires that certain parts are verified and documented by means of **BCS** Certificate (SC), Work Certificate (W) or Test Report (TR).

2.1.2 BCS Certificate (SC)

This is a document issued by **BCS** stating:

- Conformity with Rule requirements.
- That the tests and inspections have been carried out on:
 - the finished certified component itself, or
 - on samples taken from earlier stages in the production of the component, when applicable.
- That the inspection and tests were performed in the presence of the Surveyor or in accordance with special agreements, i.e. Alternative Certification Scheme (ACS).

2.1.3 Work's Certificate (W)

This is a document signed by the manufacturer stating:

- Conformity with requirements.

- That the tests and inspections have been carried out on:
 - the finished certified component itself,
 - or on samples taken from earlier stages in the production of the component, when applicable
- That the tests were witnessed and signed by a qualified representative of the applicable department of the manufacturer.

A Work's Certificate may be considered equivalent to a **BCS** Certificate and endorsed by **TLif**:

- The test was witnessed by **BCS** Surveyor; or
- An Alternative Certification Scheme (ACS) agreement is in place between **BCS** and the manufacturer or material supplier; or
- The Work's certificate is supported by tests carried out by an accredited third party that is accepted by the Society and independent from the manufacturer and/or material supplier.

2.1.4 Test Report (TR)

This is a document signed by the manufacturer stating:

- Conformity with requirements.
- That the tests and inspections have been carried out on samples from the current production batch.

2.1.5 The documents above are used for product documentation as well as for documentation of single inspections such as crack detection, dimensional check, etc. If agreed to by **BCS**, the documentation of single tests and inspections may also be arranged by filling in results on a control sheet following the component through the production.

2.1.6 The Surveyor is to review the TR and W for compliance with the agreed or approved specifications. SC means that the Surveyor also witnesses the testing, batch or individual, unless an ACS provides other arrangements.

2.1.7 The manufacturer is not exempted from responsibility for any relevant tests and inspections of those parts for which documentation is not explicitly requested by **BCS**.

The manufacturing process and equipment is to be set up and maintained in such a way that all materials and components can be consistently produced to the required standard. This includes production and assembly lines, machining units, special tools and devices, assembly and testing rigs as well as all lifting and transportation devices.

2.2 Parts to be documented

2.2.1 The extent of parts to be documented depends on the type of engine, engine size and criticality of the part.

2.2.2 Symbols used are listed in Table 2.6.A. A summary of the required documentation for the engine components is listed in Table 2.6.B.

2.2.3 For components and materials not specified in Table 2.6.B, consideration will be given by **BCS** upon full details being submitted and reviewed.

3. Type Tests of Diesel Engines

3.1 General

3.1.1 Type approval of I.C. engine types consists of drawing approval, specification approval, conformity of production, approval of type testing programme, type testing of engines, review of the obtained results, and the issuance of the Type Approval Certificate. The maximum period of validity of a Type Approval Certificate is 5 years.

3.2 Objectives

3.2.1 The type testing is to be arranged to represent typical foreseen service load profiles, as specified by the engine builder, as well as to cover for required margins due to fatigue scatter and reasonably foreseen in-service deterioration.

Table 2.6.A Symbols used in Table 2.6.B

Symbol	Description
C	Chemical composition
CD	Crack detection by MPI or DP
CH	Crosshead engines
D	Cylinder bore diameter [mm]
GJL	Gray cast iron
GJS	Spheroidal graphite cast iron
GS	Cast steel
M	Mechanical properties
SC	BCS certificate
TR	Test report
UT	Ultrasonic testing
W	Work certificate
X	Visual examination of accessible surfaces by the Surveyor

Table 2.6.B Summary of required documentation for engine components

Part (4), (5), (6), (7), (8)	Material properties (1)	Non- destructive Examination (2)	Hydraulic testing (3)	Dimensional inspection, including surface condition	Visual inspection (Surveyor)	Applicable to engines	Component certificate
Welded bedplate	W (C+M)	W (UT+CD)			Fit-up+ post welding	All	SC
Bearing transverse girders GS	W (C+M)	W (UT+CD)			X	All	SC
Welded frame box	W (C+M)	W (UT+CD)			Fit-up+ post welding	All	SC
Cylinder block GJL			W (10)			> 400 kW/cyl	
Cylinder block GJS			W (10)			> 400 kW/cyl	
Welded cylinder frames	W (C+M)	W (UT+CD)			Fit-up+ post welding	CH	SC
Engine block GJL			W (10)			> 400 kW/cyl	
Engine block GJS	W (M)		W (10)			> 400 kW/cyl	
Cylinder liner	W (C+M)		W (10)			D> 300 mm	
Cylinder head GJL			W			D> 300 mm	
Cylinder head GJS			W			D> 300 mm	
Cylinder head GS	W (C+M)	W (UT+CD)	W		X	D> 300 mm	SC
Forged cylinder head	W (C+M)	W (UT+CD)	W		X	D> 300 mm	SC
Piston crown GS	W (C+M)	W (UT+CD)			X	D> 400 mm	SC
Forged piston crown	W (C+M)	W (UT+CD)			X	D> 400 mm	SC
Crankshaft: made in one piece	SC (C+M)	W (UT+CD)		W	Random, of fillets and oil bores	All	SC
Semi-built crankshaft(Crankthrow, forged main journal and journals with flange)	SC(C+M)	W(UT+CD)		W	Random, of fillets and shrink fittings	All	SC

Table 2.6.B Summary of required documentation for engine components (continued)

Part (4), (5), (6), (7), (8)	Material properties (1)	Non- destructive Examination (2)	Hydraulic testing (3)	Dimension al inspection, including surface condition	Visual inspection (Surveyor)	Applicable to engines	Component certificate
Exhaust gas valve cage			W			CH	
Piston rod	SC (C+M)	W (UT+CD)			Random	D > 400 mm CH	SC
Cross head	SC (C+M)	W (UT+CD)			Random	CH	SC
Connecting rod with cap	SC (C+M)	W (UT+CD)		W	Random, of all surfaces, in particular those shot peened	All	SC
Coupling bolts for crankshaft	SC (C+M)	W (UT+CD)		W	Random, of interference fit	All	SC
Bolts and studs for main bearings	W (C+M)	W (UT+CD)				D > 300 mm	
Bolts and studs for cylinder heads	W (C+M)	W (UT+CD)				D > 300 mm	
Bolts and studs for connecting rods	W (C+M)	W (UT+CD)		TR of thread making		D > 300 mm	
Tie rod	W (C+M)	W (UT+CD)		TR of thread making	Random	CH	SC
High pressure fuel injection pump body	W (C+M)		W			D > 300 mm	
	W (C+M)		TR			D ≤ 300 mm	
High pressure fuel injection valves (only for those not autofretted)			W			D > 300 mm	
			TR			D ≤ 300 mm	
High pressure fuel injection pipes including common fuel rail	W (C+M)		W for those that are not autofretted			D > 300 mm	
	W (C+M)		TR for those that are not autofretted			D ≤ 300 mm	
High pressure common servo oil system	W (C+M)		W			D > 300 mm	
	W (C+M)		TR			D ≤ 300 mm	

Table 2.6.B Summary of required documentation for engine components (continued)

Part (4), (5), (6), (7), (8)	Material properties (1)	Non- destructive Examination (2)	Hydraulic testing (3)	Dimensional inspection, including surface condition	Visual inspection (Surveyor)	Applicable to engines	Component certificate
Cooler, both sides (9)	W (C+M)		W			D> 300 mm	
Accumulator	W (C+M)		W			All engines with accumulators with a capacity of > 0,5 l	
Piping, pumps, actuators, etc. for hydraulic drive of valves, if applicable	W (C+M)		W			> 800 kW/cyl	
Engine driven pumps (oil, water, fuel, bilge) other than pumps referred to in item 27 and 33			W			> 800 kW/cyl	
Bearing for main, crosshead and crankpin	TR (C)	TR (UT for full contact between base material and bearing metal		W		> 800 kW/cyl	

Notes :

(1) Material properties include chemical composition and mechanical properties, and also surface treatment such as surface hardening (hardness, depth and extent), peening and rolling (extent and applied force).

(2) Non-destructive examination means e.g. ultrasonic testing, crack detection by MPI or DP.

(3) Hydraulic testing is applied on the water/oil side of the component. Items are to be tested by hydraulic pressure at the pressure equal to 1.5 times the maximum working pressure. High pressure parts of the fuel injection system are to be tested by hydraulic pressure at the pressure equal to 1.5 maximum working pressure or maximum working pressure plus 300 bar, whichever is the less. Where design or testing features may require modification of these test requirements, special consideration may be given.

(4) Material certification requirements for pumps and piping components are dependent on the operating pressure and temperature. Requirements given in this Table apply except where alternative requirements are explicitly given in Sections 14 and 16.

(5) For turbochargers, see Section 3.

(6) Crankcase explosion relief valves are to be type tested..

(7) Oil mist detection systems are to be type tested.

(8) For speed governor and overspeed protective devices, see F.

(9) Charge air coolers need only be tested on the water side.

(10) Hydraulic testing is also required for those parts filled with cooling water and having the function of containing the water which is in contact with the cylinder or cylinder liner.

3.2.2 The type testing applies to:

- Parts subjected to high cycle fatigue (HCF) such as connecting rods, cams, rollers and spring tuned dampers where higher stresses may be provided by means of elevated injection pressure, cylinder maximum pressure, etc.
- Parts subjected to low cycle fatigue (LCF) such as “hot” parts when load profiles such as idle - full load - idle (with steep ramps) are frequently used.
- Operation of the engine at limits as defined by its specified alarm system, such as running at maximum permissible power with the lowest permissible oil pressure and/or highest permissible oil inlet temperature.

3.3. Validity

3.3.1 Type testing is required for every new engine type intended for installation onboard ships subject to classification.

3.3.2 A type test carried out for a particular type of engine at any place of manufacture will be accepted for all engines of the same type built by licensees or the licensor, subject to each place of manufacture being found to be acceptable to **BCS**.

3.3.3 A type of engine is defined by:

- Bore and stroke
- Injection method (direct or indirect)
- Valve and injection operation (by cams or electronically controlled)
- Kind of fuel (liquid, dual-fuel, gaseous)
- Working cycle (4-stroke, 2-stroke)
- Turbo-charging system (pulsating or constant pressure)
- The charging air cooling system (e.g. with or without intercooler)
- Cylinder arrangement (in-line or V) **(1)**

- Cylinder power, speed and cylinder pressures **(2)**

De-rated engine

If an engine has been design approved, and internal testing per Stage A is documented to a rating higher than the one type tested, the Type Approval may be extended to the increased power/mep/rpm upon submission of an Extended Delivery Test Report at:

- Test at over speed (only if nominal speed has increased)

***(1)** One type test will be considered adequate to cover a range of different numbers of cylinders. However, a type test of an in-line engine may not always cover the V-version. According to **BCS**, separate type tests may be required for the V-version. On the other hand, a type test of a V-engine covers the in-line engines, unless the bmep is higher.*

Items such as axial crankshaft vibration, torsional vibration in camshaft drives, and crankshafts, etc. may vary considerably with the number of cylinders and may influence the choice of engine to be selected for type testing.

***(2)** The engine is type approved up to the tested ratings and pressures (100% corresponding to MCR).*

Provided documentary evidence of successful service experience with the classified rating of 100% is submitted, an increase (if design approved) may be permitted without a new type test if the increase from the type tested engine is within:*

- 5% of the maximum combustion pressure, or
- 5% of the mean effective pressure, or
- 5% of the rpm

Providing maximum power is not increased by more than 10%, an increase of maximum approved power may be permitted without a new type test provided engineering analysis and evidence of successful service experience in similar field applications (even if the application is not classified) or documentation of internal testing are submitted if the increase from the type tested engine is within:

- 10% of the maximum combustion pressure, or
- 10% of the mean effective pressure, or
- 10% of the rpm

** Only crankshaft calculation and crankshaft drawings, if modified.*

- Rated power, i.e. 100% output at 100% torque and 100% speed corresponding to load point 1., 2 measurements with one running hour in between
- Maximum permissible torque (normally 110%) at 100% speed corresponding to load point 3 or maximum permissible power (normally 110%) and speed according to nominal propeller curve corresponding to load point 3a., ½ hour
- 100% power at maximum permissible speed corresponding to load point 2, ½ hour

Integration Test

An integration test demonstrating that the response of the complete mechanical, hydraulic and electronic system is as predicted maybe carried out for acceptance of sub-systems (Turbo Charger, Engine Control System, Dual Fuel, Exhaust Gas treatment...) separately approved. The scope of these tests shall be proposed by the designer/licensor taking into account of impact on engine.

3.4. Safety precautions

3.4.1 Before any test run is carried out, all relevant equipment for the safety of attending personnel is to be made available by the manufacturer/shipyard and is to be operational, and its correct functioning is to be verified.

3.4.2 This applies especially to crankcase explosive conditions protection, but also over-speed protection and any other shut down function.

3.4.3 The inspection for jacketing of high-pressure fuel oil lines and proper screening of pipe connections (as required in 3.8.9 fire measures) is also to be carried out before the test runs.

3.4.4 Interlock test of turning gear is to be performed when installed.

3.5 Test programme

3.5.1 The type testing is divided into 3 stages:

3.5.1.1. Stage A - internal tests

This includes some of the testing made during the engine development, function testing, and collection of measured parameters and records of testing hours. The results of testing required by **BCS** or stipulated by the designer are to be presented to **BCS** before starting stage B.

3.5.1.2. Stage B - witnessed tests

This is the testing made in the presence of **BCS** Surveyor.

3.5.1.3. Stage C - component inspection

This is the inspection of engine parts to the extent as required by **BCS**.

3.5.2 The complete type testing program is subject to approval by **BCS**. The extent the Surveyor's attendance is to be agreed in each case, but at least during stage B and C.

3.5.3 Testing prior to the witnessed type testing (stage B and C), is also considered as a part of the complete type testing program.

3.5.4 Upon completion of complete type testing (stage A through C), a type test report is to be submitted to **BCS** for review. The type test report is to contain:

- Overall description of tests performed during stage A. Records are to be kept by the builders quality assurance management for presentation to **BCS**.
- Detailed description of the load and functional tests conducted during stage B.
- Inspection results from stage C.

3.5.5 As required in 3.2 the type testing is to substantiate the capability of the design and its suitability for the intended operation. Special testing such as LCF and endurance testing will normally be conducted during stage A.

3.5.6 High speed engines for marine use are normally to be subjected to an endurance test of 100 hours at full

load. Omission or simplification of the type test may be considered for the type approval of engines with long service experience from non-marine fields or for the extension of type approval of engines of a well-known type, in excess of the limits given in 3.3.

Propulsion engines for high speed vessels that may be used for frequent load changes from idle to full are normally to be tested with at least 500 cycles (idle - full load - idle) using the steepest load ramp that the control system (or operation manual if not automatically controlled) permits. The duration at each end is to be sufficient for reaching stable temperatures of the hot parts.

3.6 Measurements and recordings

3.6.1 During all testing the ambient conditions (air temperature, air pressure and humidity) are to be recorded.

3.6.2 As a minimum, the following engine data are to be measured and recorded:

- Engine r.p.m.
- Torque
- Maximum combustion pressure for each cylinder **(3)**
- Mean indicated pressure for each cylinder **(3)**
- Charging air pressure and temperature
- Exhaust gas temperature
- Fuel rack position or similar parameter related to engine load
- Turbocharger speed
- All engine parameters that are required for control and monitoring for the intended use (propulsion, auxiliary, emergency).

3.7 Stage A - internal tests

3.7.1 During the internal tests, the engine is to be operated at the load points important for the engine designer and the pertaining operating values are to be

recorded. The load conditions to be tested are also to include the testing specified in the applicable type approval programme.

3.7.2 At least the following conditions are to be tested:

- Normal case:

The load points 25%, 50%, 75%, 100% and 110% of the maximum rated power for continuous operation, to be made along the normal (theoretical) propeller curve and at constant speed for propulsion engines (if applicable mode of operation i.e. driving controllable pitch propellers), and at constant speed for engines intended for generator sets including a test at no load and rated speed.

- The limit points of the permissible operating range. These limit points are to be defined by the engine manufacturer.
- For high speed engines, the 100 hr full load test and the low cycle fatigue test apply as required in connection with the design assessment.
- Specific tests of parts of the engine, required by **BCS** or stipulated by the designer.

(3) For engines where the standard production cylinder heads are not designed for such measurements, a special cylinder head made for this purpose may be used. In such a case, the measurements may be carried out as part of Stage A and are to be properly documented. Where deemed necessary e.g. for dual fuel engines, the measurement of maximum combustion pressure and mean indicated pressure may be carried out by indirect means, provided the reliability of the method is documented.

Calibration records for the instrumentation used to collect data as listed above are to be presented to - and reviewed by the attending Surveyor.

Additional measurements may be required in connection with the design assessment.

3.8 Stage B - witnessed tests

3.8.1 The tests listed below are to be carried out in the presence of a Surveyor. The achieved results are to be recorded and signed by the attending Surveyor after the type test is completed.

3.8.2 The over-speed test is to be carried out and is to demonstrate that the engine is not damaged by an actual engine overspeed within the overspeed shutdown system set-point. This test may be carried out at the manufacturer's choice either with or without load during the speed overshoot.

3.8.3 Load points

The engine is to be operated according to the power and speed diagram (see Fig. 2.8). The data to be measured and recorded when testing the engine at the various load points have to include all engine parameters listed in 3.6. The operating time per load point depends on the engine size (achievement of steady state condition) and on the time for collection of the operating values. Normally, an operating time of 0.5 hour can be assumed per load point, however sufficient time should be allowed for visual inspection by the Surveyor.

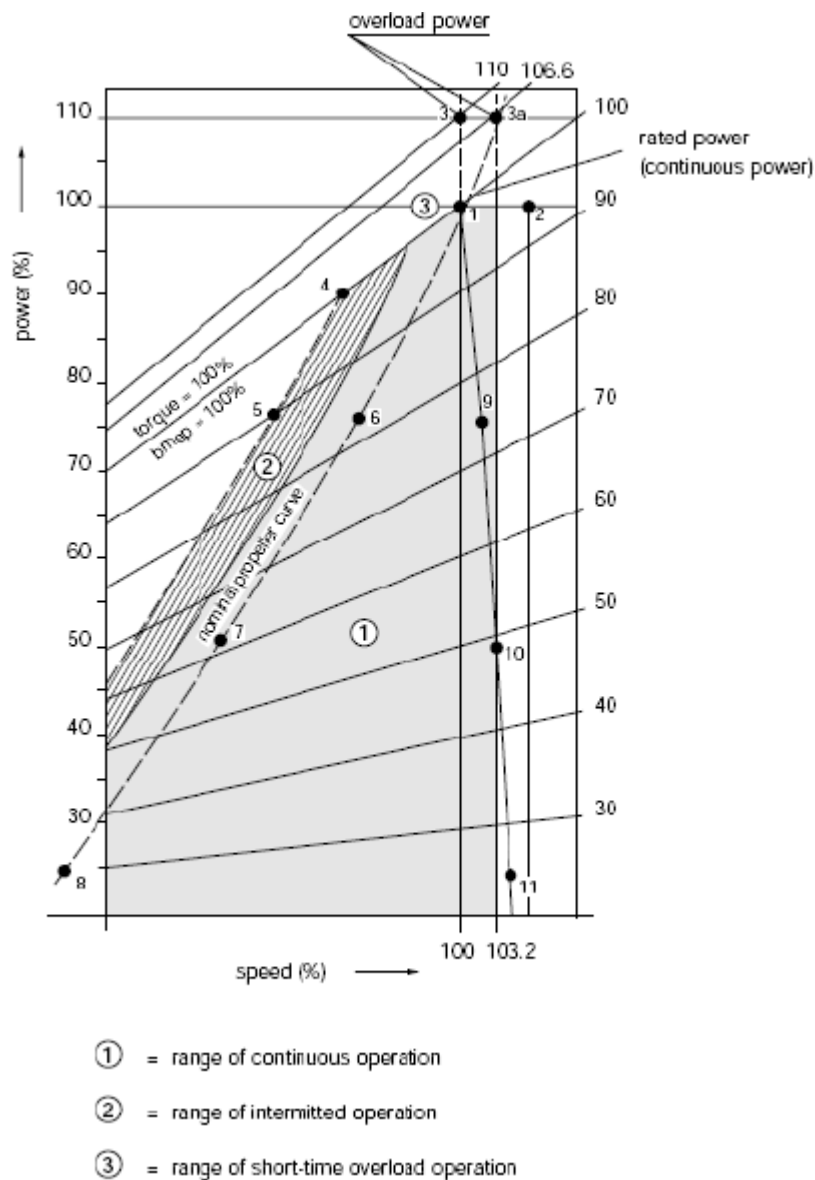


Fig. 2.8 – Load points

3.8.4 The load points are:

- Rated power (MCR), i.e. 100% output at 100% torque and 100% speed corresponding to load point 1, normally for 2 hours with data collection with an interval of 1 hour. If operation of the engine at limits as defined by its specified alarm system (e.g. at alarm levels of lub oil pressure and inlet temperature) is required, the test should be made here.
- 100% power at maximum permissible speed corresponding to load point 2.
- Maximum permissible torque (at least and normally 110%) at 100% speed corresponding to load at point 3, or maximum permissible power (at least and normally 110%) and 103.2% speed according to the nominal propeller curve corresponding to load point 3a. Load point 3a applies to engines only driving fixed pitch propellers or water jets. Load point 3 applies to all other purposes.

Load point 3 (or 3a as applicable) is to be replaced with a load that corresponds to the specified overload and duration approved for intermittent use. This applies where such overload rating exceeds 110% of MCR. Where the approved intermittent overload rating is less than 110% of MCR, subject overload rating has to replace the load point at 100% of MCR. In such case the load point at 110% of MCR remains.

- Minimum permissible speed at 100% torque, corresponding to load point 4.- Minimum permissible speed at 90% torque corresponding to load point 5. (Applicable to propulsion engines only).
- Part loads e.g. 75%, 50% and 25% of rated power and speed according to nominal propeller curve (i.e. 90.8%, 79.3% and 62.9% speed) corresponding to points 6, 7 and 8 or at constant rated speed setting corresponding to points 9, 10 and 11, depending on the intended application of the engine.

- Crosshead engines not restricted for use with C.P. propellers are to be tested with no load at the associated maximum permissible engine speed.

3.8.5 During all these load points, engine parameters are to be within the specified and approved values.

3.8.6 Operation with damaged turbocharger

For 2-stroke propulsion engines, the achievable continuous output is to be determined in the case of turbocharger damage.

Engines intended for single propulsion with a fixed pitch propeller are to be able to run continuously at a speed (r.p.m) of 40% of full speed along the theoretical propeller curve when one turbocharger is out of operation. (The test can be performed by either by-passing the turbocharger, fixing the turbocharger rotor shaft or removing the rotor.)

Note:

The engine manufacturer is to state whether the achievable output is continuous. If there is a time limit, the permissible operating time is to be indicated.

3.8.7 Functional tests

- Verification of the lowest specified propulsion engine speed according to the nominal propeller curve as specified by the engine designer (even though it works on a water- brake). During this operation, no alarm shall occur.
- Starting tests, for non-reversible engines and/or starting and reversing tests, for reversible engines, for the purpose of determining the minimum air pressure and the consumption for a start.
- Governor tests: tests for compliance with item F. are to be carried out.

3.8.8 Integration test

For electronically controlled diesel engines, integration tests are to verify that the response of the complete mechanical, hydraulic and electronic system is as

predicted for all intended operational modes. The scope of these tests is to be agreed with **BCS** for selected cases based on the FMEA required in Table 2.1.

3.8.9 Fire protection measures

Verification of compliance with requirements for jacketing of high-pressure fuel oil lines, screening of pipe connections in piping containing flammable liquids and insulation of hot surfaces:

- The engine is to be inspected for jacketing of high-pressure fuel oil lines, including the system for the detection of leakage, and proper screening of pipe connections in piping containing flammable liquids.
- Proper insulation of hot surfaces is to be verified while running the engine at 100% load, alternatively at the overload approved for intermittent use. Readings of surface temperatures are to be done by use of Infrared Thermoscanning Equipment. Equivalent measurement equipment may be used when so approved by **BCS**. Readings obtained are to be randomly verified by use of contact thermometers.

3.9 Stage C - Opening up for Inspections

3.9.1 The crankshaft deflections are to be measured in the specified (by designer) condition (except for engines where no specification exists).

3.9.2 High speed engines for marine use are normally to be stripped down for a complete inspection after the type test.

3.9.3 For all the other engines, after the test run the components of one cylinder for in-line engines and two cylinders for V-engines are to be presented for inspection as follows (engines with long service experience from non-marine fields can have a reduced extent of opening):

- Piston removed and dismantled
- Crosshead bearing dismantled
- Guide planes

- Connecting rod bearings (big and small end) dismantled (special attention to serrations and fretting on contact surfaces with the bearing backsides)
- Main bearing dismantled
- Cylinder liner in the installed condition
- Cylinder head, valves disassembled
- Cam drive gear or chain, camshaft and crankcase with opened covers. (The engine must be turnable by turning gear for this inspection.)

3.9.4 For V-engines, the cylinder units are to be selected from both cylinder banks and different crank throws.

3.9.5 If deemed necessary by the surveyor, further dismantling of the engine may be required.

4. Factory Acceptance Test and Shipboard Trials of I.C. Engines

4.1 Safety precautions

4.1.1 Before any test run is carried out, all relevant equipment for the safety of attending personnel is to be made available by the manufacturer / shipyard and is to be operational.

4.1.2 This applies especially to crankcase explosive conditions protection, but also to over-speed protection and any other shut down function.

4.1.3 The overspeed protective device is to be set to a value, which is not higher than the overspeed value that was demonstrated during the type test for that engine. This set point shall be verified by the surveyor.

4.2 General

4.2.1 Before any official testing, the engines shall be run-in as prescribed by the engine manufacturer.

4.2.2 Adequate test bed facilities for loads as required in Item 4.3.3 shall be provided. All fluids used for testing purposes such as fuel, lubrication oil and cooling water are to be suitable for the purpose intended, e.g. they are to be clean, preheated if necessary and cause no harm to engine parts. This applies to all fluids used temporarily or repeatedly for testing purposes only.

4.2.3 The testing consists of workshop and shipboard (quay and sea trial) testing.

4.2.4 Engines are to be inspected for:

- Jacketing of high-pressure fuel oil lines including the system used for the detection of leakage.
- Screening of pipe connections in piping containing flammable liquids.
- Insulation of hot surfaces by taking random temperature readings that are to be compared with corresponding readings obtained during the type test. This shall be done while running at the rated power of engine. Use of contact thermometers may be accepted at the discretion of the attending Surveyor. If the insulation is modified subsequently to the Type Approval Test, BCS may request temperature measurements as required by 3.8.9.

4.2.5 These inspections are normally to be made during the works trials by the manufacturer and the attending surveyor, but at the discretion of the **BCS** parts of these inspections may be postponed to the shipboard testing.

4.3 Works trials (Factory Acceptance Test)

4.3.1 Objectives

The purpose of the works trials is to verify design premises such as power, safety against fire, adherence to approved limits (e.g. maximum pressure), and

functionality and to establish reference values or base lines for later reference in the operational phase.

4.3.2 Records

4.3.2.1 The following environmental test conditions are to be recorded:

- Ambient air temperature
- Ambient air pressure
- Atmospheric humidity

4.3.2.2 For each required load point, the following parameters are normally to be recorded:

- Power and speed
- Fuel index (or equivalent reading)
- Maximum combustion pressures (only when the cylinder heads installed are designed for such measurement).
- Exhaust gas temperature before turbine and from each cylinder (to the extent that monitoring is required in Section 2 - Table 2.7, Section 4 - Item B.7, Section 8 - Table 8.1 and Table 8.2)
- Charge air temperature
- Charge air pressure
- Turbocharger speed (to the extent that monitoring is required in Section 4, Item B.7)

4.3.2.3 Calibration records for the instrumentation are, upon request, to be presented to the attending Surveyor.

4.3.2.4 For all stages at which the engine is to be tested, the pertaining operational values are to be measured and recorded by the engine manufacturer. All results are to be compiled in an acceptance protocol to be issued by the engine manufacturer. This also

includes crankshaft deflections if considered necessary by the engine designer.

4.3.2.5 In each case, all measurements conducted at the various load points are to be carried out at steady state operating conditions. However, for all load points provision should be made for time needed by the Surveyor to carry out visual inspections. The readings for MCR, i.e. 100% power (rated maximum continuous power at corresponding rpm) are to be taken at least twice at an interval of normally 30 minutes.

4.3.3 Test loads

4.3.3.1 Test loads for various engine applications are given below. In addition, the scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

Note:

Alternatives to the detailed tests may be agreed between the manufacturer and BCS when the overall scope of tests is found to be equivalent.

4.3.3.2 Propulsion engines driving propeller or impeller only

4.3.3.2.1 100% power (MCR) at corresponding speed n_0 :
at least 60 min.

4.3.3.2.2 110% power at engine speed $1.032n_0$:

Records to be taken after 15 minutes or after steady conditions have been reached, whichever is shorter.

Note:

Only required once for each different engine/turbocharger configuration.

4.3.3.2.3 Approved intermittent overload (if applicable):

testing for duration as agreed with the manufacturer.

4.3.3.2.4 90% (or normal continuous cruise power), 75%, 50% and 25% power in accordance with the nominal propeller curve, the sequence to be selected by the engine manufacturer.

4.3.3.2.5 Reversing manoeuvres (if applicable).

Note:

After running on the test bed, the fuel delivery system is to be so adjusted that overload power cannot be given in service, unless intermittent overload power is approved by the BCS. In that case, the fuel delivery system is to be blocked to that power.

4.3.3.3 Engines driving generators for electric propulsion

4.3.3.3.1 100% power (MCR) at corresponding speed n_0 :
at least 60 min.

4.3.3.3.2 110% power at engine speed n_0 :
15 min. - after having reached steady conditions.

4.3.3.3.3 Governor tests for compliance with Item F are to be carried out.

4.3.3.3.4 75%, 50% and 25% power and idle, the sequence to be selected by the engine manufacturer.

Note:

After running on the test bed, the fuel delivery system is to be adjusted so that full power plus a 10% margin for transient regulation can be given in service after installation onboard. The transient overload capability is required so that the required transient governing characteristics are achieved also at 100% loading of the engine, and also so that the protection system utilised in the electric distribution system can be activated before the engine stalls.

4.3.3.4 Engines driving generators for auxiliary purposes

Tests to be performed as in Item 4.3.3.3.

4.3.3.5 Propulsion engines also driving power take off (PTO) generator

4.3.3.5.1 100% power (MCR) at corresponding speed

n_0 :

at least 60 min.

4.3.3.5.2 110% power at engine speed n_0 :

15 min. - after having reached steady conditions.

4.3.3.5.3 Approved intermittent overload (if applicable):

testing for duration as agreed with the manufacturer.

4.3.3.5.4 90% (or normal continuous cruise power), 75%, 50% and 25% power in accordance with the nominal propeller curve or at constant speed n_0 , the sequence to be selected by the engine manufacturer.

Note:

After running on the test bed, the fuel delivery system is to be adjusted so that full power plus a margin for transient regulation can be given in service after installation onboard. The transient overload capability is required so that the electrical protection of downstream system components is activated before the engine stalls. This margin may be 10% of the engine power but at least 10% of the PTO power.

4.3.3.6 Engines driving auxiliaries

4.3.3.6.1 100% power (MCR) at corresponding speed

n_0 :

at least 30 min.

4.3.3.6.2 110% power at engine speed n_0 :

15 min. - after having reached steady conditions.

4.3.3.6.3 Approved intermittent overload (if applicable):

testing for duration as agreed with the manufacturer.

4.3.3.6.4 For variable speed engines, 75%, 50% and 25% power in accordance with the nominal power consumption curve, the sequence to be selected by the engine manufacturer.

Note:

After running on the test bed, the fuel delivery system is normally to be so adjusted that overload power cannot be delivered in service, unless intermittent overload power is approved. In that case, the fuel delivery system is to be blocked to that power.

4.3.4 Turbocharger matching with engine

4.3.4.1 Compressor chart

Turbochargers shall have a compressor characteristic that allows the engine, for which it is intended, to operate without surging during all operating conditions and also after extended periods in operation.

For abnormal, but permissible, operation conditions, such as misfiring and sudden load reduction, no continuous surging shall occur.

In this section, *surging* and *continuous surging* are defined as follows:

Surging means the phenomenon, which results in a high pitch vibration of an audible level or explosion-like noise from the scavenger area of the engine.

Continuous surging means that surging happens repeatedly and not only once.

4.3.4.2 Surge margin verification

Category C turbochargers used on propulsion engines are to be checked for surge margins during the engine workshop testing as specified below. These tests may be waived if successfully tested earlier on an identical configuration of engine and turbocharger (including same nozzle rings).

For 4-stroke engines:

The following shall be performed without indication of surging:

- With maximum continuous power and speed (=100%), the speed shall be reduced with constant torque (fuel index) down to 90% power.
- With 50% power at 80% speed (= propeller characteristic for fixed pitch), the speed shall be reduced to 72% while keeping constant torque (fuel index).

For 2-stroke engines:

The surge margin shall be demonstrated by at least one of the following methods:

- The engine working characteristic established at workshop testing of the engine shall be plotted into the compressor chart of the turbocharger (established in a test rig). There shall be at least 10% surge margin in the full load range, i.e. working flow shall be 10% above the theoretical (mass) flow at surge limit (at no pressure fluctuations).
- Sudden fuel cut-off to at least one cylinder shall not result in continuous surging and the turbocharger shall be stabilised at the new load within 20 seconds. For applications with more than one turbocharger the fuel shall be cut-off to the cylinders closest upstream to each turbocharger.

This test shall be performed at two different engine loads:

- The maximum power permitted for one cylinder misfiring.
- The engine load corresponding to a charge air pressure of about 0.6 bar (but without auxiliary blowers running).
- No continuous surging and the turbocharger shall be stabilised at the new load within 20 seconds when the power is abruptly reduced from 100% to 50% of the maximum continuous power.

4.3.5 Integration tests

For electronically controlled engines, integration tests are to be made to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes and the tests considered as a system are to be carried out at the works. If such tests are technically unfeasible at the works, however, these tests may be conducted during sea trial. The scope of these tests is to be agreed with **BCS** for selected cases based on the FMEA required in Table 2.1, Table 2.2 and Table 2.3.

4.3.6 Component inspections

Random checks of components to be presented for inspection after works trials are left to the discretion of **BCS**.

4.4 Shipboard trials(*)

4.4.1 Objectives

The purpose of the shipboard testing is to verify compatibility with power transmission and driven machinery in the system, control systems and auxiliary systems necessary for the engine and integration of engine / shipboard control systems, as well as other items that had not been dealt with in the FAT (Factory Acceptance Testing).

4.4.2 Starting capacity

Starting manoeuvres are to be carried out in order to verify that the capacity of the starting media satisfies the required number of start attempts.

(*) *The requirements of Item 4.4 Shipboard trials are to be uniformly implemented by **BCS** to engines:*

- i) with an application for certification dated on or after 1 July 2016; or*
- ii) installed on ships contracted for construction on or after 1 July 2016.*

4.4.3 Monitoring and alarm system

The monitoring and alarm systems are to be checked to the full extent for all engines, except items already verified during the works trials.

4.4.4 Test loads

4.4.4.1 Test loads for various engine applications are given below. In addition, the scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

4.4.4.2 The suitability of the engine to operate on fuels intended for use is to be demonstrated.

Note:

Tests other than those listed below may be required by statutory instruments (e.g. EEDI verification).

4.4.4.3 Propulsion engines driving fixed pitch propeller or impeller

4.4.4.3.1 At rated engine speed n_0 :

at least 4 hours.

4.4.4.3.2 At engine speed $1.032n_0$ (if engine adjustment permits, see 4.3.3.1):

30 min.

4.4.4.3.3 At approved intermittent overload (if applicable):

testing for duration as agreed with the manufacturer.

4.4.4.3.4 Minimum engine speed to be determined.

4.4.4.3.5 The ability of reversible engines to be operated in reverse direction is to be demonstrated.

Note:

During stopping tests according to Resolution MSC.137 (76), see 4.4.5.1 for additional requirements in the case of a barred speed range.

4.4.4.4 Propulsion engines driving controllable pitch propellers.

4.4.4.4.1 At rated engine speed n_0 with a propeller pitch leading to rated engine power (or to the maximum achievable power if 100% cannot be reached):

at least 4 hours.

4.4.4.4.2 At approved intermittent overload (if applicable):

testing for duration as agreed with the manufacturer.

4.4.4.4.3 With reverse pitch suitable for manoeuvring, see 4.4.5.1 for additional requirements in the case of a barred speed range.

4.4.4.5 Engine(s) driving generator(s) for electrical propulsion and/or main power supply

4.4.4.5.1 At 100% power (rated electrical power of generator):

at least 60 min.

4.4.4.5.2 At 110% power (rated electrical power of generator):

at least 10 min.

Note:

Each engine is to be tested 100% electrical power for at least 60 min and 110% of rated electrical power of the generator for at least 10 min. This may, if possible, be done during the electrical propulsion plant test, which is required to be tested with 100% propulsion power (i.e. total electric motor capacity for propulsion) by distributing the power on as few generators as possible. The duration of this test is to be sufficient to reach stable operating temperatures of all rotating machines or for at least 4 hours. When some of the gen. set(s) cannot be tested due to insufficient time during the propulsion system test mentioned above, those required tests are to be carried out separately.

4.4.4.5.3 Demonstration of the generator prime movers' and governors' ability to handle load steps as described in Item F.

4.4.4.6 Propulsion engines also driving power take off (PTO) generator

4.4.4.6.1 100% engine power (MCR) at corresponding speed n_0 :
at least 4 hours.

4.4.4.6.2 100% propeller branch power at engine speed n_0 (unless already covered in A):

2 hours.

4.4.4.6.3 100% PTO branch power at engine speed n_0 :
at least 1 hour.

4.4.4.7 Engines driving auxiliaries

4.4.4.7.1 100% power (MCR) at corresponding speed n_0 :
at least 30 min.

4.4.4.7.2 Approved intermittent overload:
testing for duration as approved.

4.4.5 Torsional vibrations

4.4.5.1 Barred speed range

Where a barred speed range (bsr) is required, passages through this bsr, both accelerating and decelerating, are to be demonstrated. The times taken are to be recorded and are to be equal to or below those times stipulated in the approved documentation, if any. This also includes when passing through the bsr in reverse rotational direction, especially during the stopping test.

Note:

Applies both for manual and automatic passing-through systems.

The ship's draft and speed during all these demonstrations is to be recorded. In the case of a controllable pitch propeller, the pitch is also to be recorded.

The engine is to be checked for stable running (steady fuel index) at both upper and lower borders of the bsr. Steady fuel index means an oscillation range less than 5% of the effective stroke (idle to full index).

4.4.6 Earthing

It is necessary to ensure that the limits specified for main engines by the engine manufacturers for the difference in electrical potential (Voltage) between the crankshaft/shafting and the hull are not exceeded in service. Appropriate earthing devices including limit value monitoring of the permitted voltage potential are to be provided.

5. Certification of AC Generating Sets

5.1 General

5.1.1 This item provides requirements for AC generating sets (i.e. Reciprocating Internal Combustion engines a), b), alternators c) and couplings) in addition to those stated in BCS-R E13, BCS-R M3, BCS-R M 51, and BCS-R M53.

- a)** Reciprocating Internal Combustion engines are to comply with the requirements in BCS-R M 51 and M53.
- b)** The reciprocating internal combustion engine speed governor and overspeed protective device are to comply with the requirements of BCS-R M 3.
- c)** Alternators are to comply with the requirements in BCS-R E13

5.1.2 The requirements are applicable to AC generating sets driven by reciprocating internal combustion engines irrespective of their types (i.e. diesel engine, dual fuel engine, gasfuel engine), except for those sets consisting of a propulsion engine which also drives power take off (PTO) generator(s).

5.2 Generating sets - requirements

5.2.1 For diesel generator sets with a mechanical output of more than 110 kW torsional vibration calculations must be submitted to BCS for approval. (See, Section 6, F.2).

5.2.2 The rated power shall be appropriate for the actual use of the generator set.

5.3 Marking

The entity responsible of assembling the generating set shall install a rating plate marked with at least the following information:

- (i) the generating set manufacturer's name or mark;
- (ii) the set serial number;
- (iii) the set date of manufacture (month/year);
- (iv) the rated power (both in kW and KVA) with one of the prefixes COP, PRP (or, only for emergency Generating sets, LTP) as defined in ISO 8528-1:2018;
- (v) the rated power factor;
- (vi) the set rated frequency (Hz);
- (vii) the set rated voltage (V);
- (viii) the set rated current (A);
- (ix) the mass (kg).

F. Safety Devices

1. Speed Control and Engine Protection Against Over speed

1.1 Main and auxiliary engines

1.1.1 Each diesel engine not used to drive an electric generator must be equipped with a speed governor or regulator so adjusted that the engine speed cannot exceed the rated speed by more than 15%.

1.1.2 In addition to the normal governor, each main engine with a rated power of 220 kW or over which can be declutched in service or which drives a variable-pitch propeller must be fitted with an independent over speed protection device so adjusted that the engine speed cannot exceed the rated speed by more than 20%. Equivalent equipment may be approved by **BCS**. The overspeed protective device, including its driving mechanism, has to be independent from the required governor.

1.1.3 When electronic speed governors of main internal combustion engines form part of a remote control system, they are to comply with **BCS** Rules, Chapter 4-1, Section 5, A.1 or 5, A.2 and namely with the following conditions:

- if lack of power to the governor may cause major and sudden changes in the present speed and direction of thrust of the propeller, back up power supply is to be provided
- local control of the engines is always to be possible, as required by Chapter 4-1, Section 5, A.1, and, to this purpose, from the local control position it is to be possible to

disconnect the remote signal, bearing in mind that the speed control according to subparagraph 1.1.1, is not available unless an additional separate governor is provided for such local mode of control.

- In addition, electronic speed governors and their actuators are to be type tested according to **TL**Add. Rules Regulations for the Performance of Type Tests, Part 1

Note:

The rated power and corresponding rated speed are those for which classification of the installation has been requested.

1.2 Engines driving electric generators

1.2.1 Each diesel engine used to drive an electric main or emergency generator must be fitted with a governor which will prevent transient frequency variations in the electrical network in excess of $\pm 10\%$ of the rated frequency with a recovery time to steady state conditions not exceeding 5 seconds when the maximum electrical step load is switched on or off.

In the case when a step load equivalent to the rated output of the generator is switched off, a transient speed variation in excess of 10% of the rated speed may be acceptable, provided this does not cause the intervention of the overspeed device as required by 1.2.2.

1.2.2 In addition to the normal governor, each diesel engine with a rated power of 220 kW or over must be equipped with an over speed protection device independent of the normal governor which prevents the engine speed from exceeding the rated speed by more than 15%.

1.2.3 The diesel engine must be suitable and designed for the special requirements of the ship's electrical system.

Where connection of loads is envisaged in two stages, the following procedure is to be applied: Sudden loading from no-load to 50%, followed by the remaining 50% of the rated generator power, duly observing the requirements of 1.2.1 and 1.2.4.

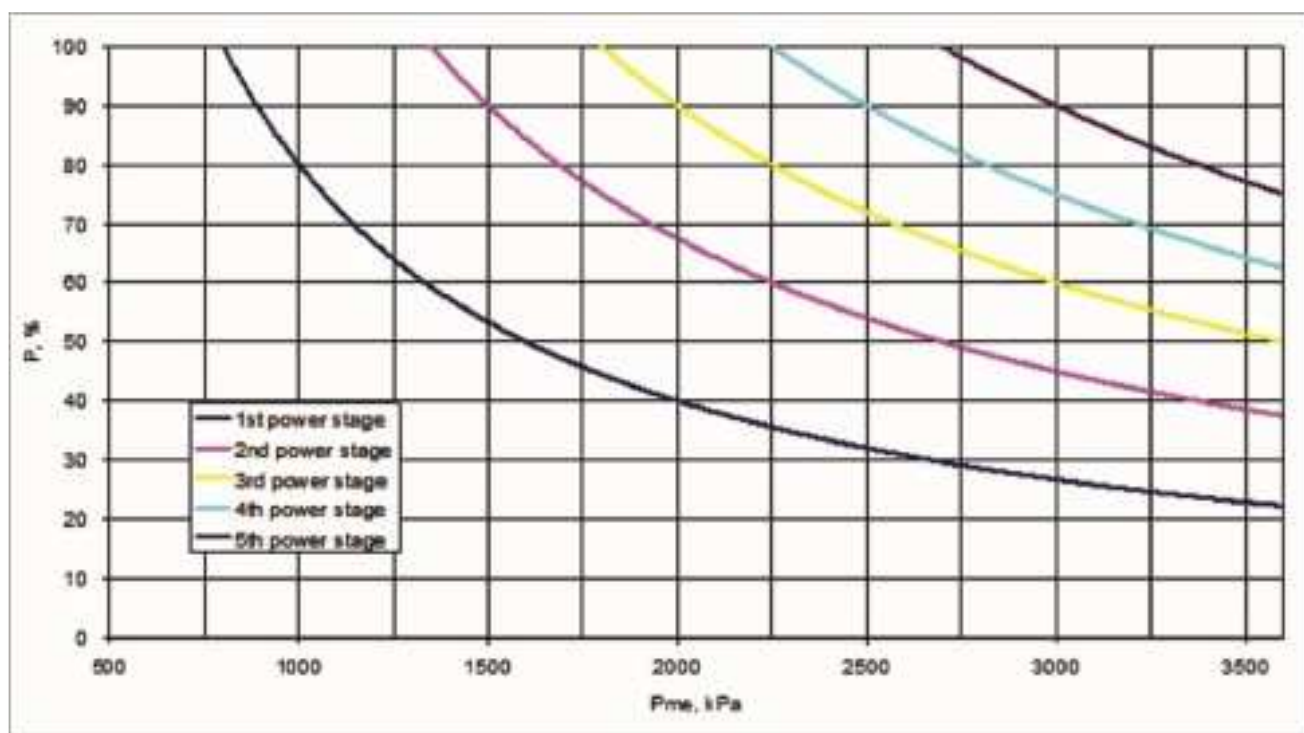
Application of the load in more than two steps (see Fig.2.9 for guidance on 4-stroke diesel engines expected maximum possible sudden power increase) is acceptable on condition that:

- The design of the ship's electrical system enables the use of such generator sets;
- Load application in more than two steps is considered in the design of the ship's electrical system and is approved when the drawings are reviewed;
- During shipboard trials the functional tests are carried out without objections. Here the loading of the ship's electrical net while sequentially connecting essential equipment after breakdown and during recovery of the net is to be taken into account.
- The safety of the ship's electrical system in the event of parallel generator operation and failure of a generator is to be demonstrated.

1.2.4 Speed must be stabilized and in steady-state condition within 5 seconds, inside the permissible range for the permanent speed variation δ_r . The steady-state condition n is considered to have been reached when the residual speed variation does not exceed $\pm 1\%$ of the speed associated with the set power.

1.2.5 The characteristic curves of the governors of diesel engines of generator sets operating in parallel must not exhibit deviations larger than those specified in the Rules for Electrical Installation.

1.2.6 Generator sets which are installed to serve stand-by circuits must satisfy the corresponding requirements even when the engine is cold. The start-up and loading sequence is to be concluded in about 30 seconds.



Legend:

P_{me} : declared power mean effective pressure

P : power increase referred to declared power at site conditions 1 : first power stage

2 : second power stage

3 : third power stage

4 : fourth power stage

5 : fifth power stage

Fig. 2.9 Reference values for maximum possible sudden power increases as a function of brake mean effective pressure, P_{me} , at declared power (four-stroke diesel engines)

1.2.7 Emergency generator sets must satisfy the above governor conditions even when:

- Their total consumer load is applied suddenly, or
- Their total consumer load is applied in steps, subject to:
- The total load is supplied within 45 seconds since power failure on the main switchboard
- The maximum step load is declared and demonstrated
- The power distribution system is designed such that the declared maximum step loading is not exceeded
- The compliance of time delays and loading sequence with the above is to be demonstrated at ship's trials.

1.2.8 The governors of the engines mentioned in 1.2 must enable the rated speed to be adjusted over the entire power range with a maximum deviation of 5%.

1.2.9 The rate of speed variation of the adjusting mechanisms must permit satisfactory synchronization in a sufficiently short time.

The speed characteristic should be as linear as possible over the whole power range. The permanent deviation

from the theoretical linearity of the speed characteristic may, in the case of generating sets intended for parallel operation, in no range exceed 1% of the rated speed.

1.2.10 For a.c. generating sets operating in parallel, the governing characteristics of the prime movers shall be such that within the limits of 20% and 100% total load the load on any generating set will not normally differ from its proportionate share of the total load by more than 15% of the rated power of the largest machine or

25% of the rated power of the individual machine in question, whichever is the less.

For an a.c. generating set intended to operate in parallel, facilities are to be provided to adjust the governor sufficiently fine to permit an adjustment of load not exceeding 5% of the rated load at normal frequency.

Notes relating to 1.1 and 1.2:

- *The rated power and the corresponding rated speed relate to the conditions under which the engines are operated in the system concerned.*
- *An independent over speed protection device means a system all of whose component parts, including the drive, function independently of the normal governor.*

1.3 Use of electrical / electronic governors

1.3.1 The governor and the associated actuator must, for controlling the respective engine, be suitable for the operating conditions laid down in the Construction Rules and for the requirements specified by the engine manufacturer. For single propulsion drives it has to be ensured that in case of a failure of the governor or actuator the control of the engine can be taken over by another control device.

The regulating conditions required for each individual application as described in 1.1 and 1.2 are to be satisfied by the governor system.

Electronic governors and the associated actuators are subject to type testing.

For the power supply, see the Rules for Electrical Installation, Section 9, B.8.

1.3.2 Requirements applying to main engines

For propulsion installations, to ensure continuous speed control or immediate resumption of control after a fault at least one of the following requirements is to be satisfied:

- The governor system has an independent back-up system, or,
- There is a redundant governor assembly for manual change-over with a separately protected power supply, or,
- The engine has a manually operated fuel admission control system suitable for manoeuvring.

In the event of a fault in the governor system the operating condition of the engine must not become dangerous, that is, the engine speed and power must not increase.

Alarms to indicate faults in the governor system are to be fitted.

1.3.3 Requirements applying to auxiliary engines for driving generators

Each auxiliary engine must be equipped with its own governor system.

In the event of a fault in the governor system, the fuel admission in the injection pumps must be set to "0". Alarms to indicate faults in the governor system are to be fitted.

1.3.4 The special conditions necessary to start operation from the dead ship condition are to be observed (see **BCS** Rules for Electrical Installation).

2. Cylinder Overpressure Warning Device

2.1 All the cylinders of engines with a cylinder bore of > 230 mm. are to be fitted with cylinder overpressure warning devices. The response threshold of these valves shall be set at not more than 40% above the combustion pressure at the rated power.

2.2 A warning device may be dispensed with if it is ensured by an appropriate engine design or by control functions that an increased cylinder pressure cannot create danger.

3. Crankcase Ventilation

3.1 The ventilation of crankcases and any arrangement which could produce air intake within the crankcase is not allowed. For gas engines, see **BCS** Part

C, Chapter 10 – Liquefied Gas Carriers, Section 16.

3.2 Crankcase ventilation pipes

3.2.1 Where crankcase ventilation pipes are provided, their clear opening is to be dimensioned as small as possible, to minimize the inrush of air after a crankcase explosion.

3.2.2 Where forced provision has been made for extracting the lubricating oil vapours, e.g. for monitoring the oil vapour concentration, the vacuum in the crankcase is not to exceed 2.5 mbar.

3.2.3 The crankcase ventilation pipes for each engine are to be independent of any other engine. Exemptions may be approved if an interaction of the combined systems is inhibited by suitable means and possible spread of fire is prevented.

3.2.4 In the case of two-stroke engines the lubricating oil vapours from the crankcase must not be admitted into the scavenge manifolds respectively the air intake pipes of the engine.

4. Crankcase Safety Devices

4.1 Relief valves

4.1.1 Crank safety case devices shall be type approved.

See **BCS** "Type Testing Procedure for Crankcase Explosion Relief Valves".

4.1.2 Safety valves to safeguard against overpressure in the crankcase are to be fitted to all engines with a cylinder bore of > 200 mm. or a crankcase volume of $\geq 0.6 \text{ m}^3$.

All separated spaces within the crankcase, e.g. gear or chain casings for camshafts or similar drives, if the volume of these spaces exceeds 0.6 m^3 , and scavenge spaces in open connection to the cylinders are to be equipped with additional safety devices.

4.1.3 Engines with a cylinder bore of > 200 mm. $\leq 250 \text{ mm}$. must be equipped with at least one safety valve at each end of the crankcase. If the crankshaft has more than 8 throws, an additional safety valve is to be fitted near the middle of the crankcase.

Engines with a cylinder bore of > 250 mm. $\leq 300 \text{ mm}$. must have at least one safety valve close to every second crank throw, subject to a minimum number of two.

Engines with a cylinder diameter of > 300 mm. must have at least one safety valve close to each crank throw.

4.1.4 Each safety valve must have a free relief area of at least 45 cm^2 .

The total free cross-sectional area of the safety valves fitted to an engine to safeguard against overpressure in the crankcase may not be less than $115 \text{ cm}^2/\text{m}^3$ of crankcase volume.

Notes relating to 4.1.2 and 4.1.4:

- *In estimating the gross volume of the crankcase, the volume of the fixed parts which it contains may be deducted.*
- *A space communicating with the crankcase via a total free cross-sectional area of $> 115 \text{ cm}^2/\text{m}^3$ of volume need not be considered as a separate space. In*

calculating the total free cross-sectional area, individual sections of $< 45 \text{ cm}^2$ are to be disregarded.

- *Each safety valve required may be replaced by not more than two safety valves of smaller cross-sectional area provided that the free cross-sectional area of each safety valve is not less than 45 cm^2 .*

4.1.5 The safety devices are to be quick acting and self closing devices to relieve a crankcase of pressure at a crankcase explosion. In service they shall be oil tight when closed and have to prevent air inrush into the crankcase. The gas flow caused by the response of the safety device must be deflected, e. g. by means of a baffle plate, in such a way as not to endanger persons standing nearby. It has to be demonstrated that the baffle plate does not adversely affect the operational effectiveness of the device. For relief valves the discs are to be made of ductile material capable of withstanding the shock load at the full open position of the valve.

Relief valves shall be fully opened at a differential pressure in the crankcase not greater than 0.2 bar.

4.1.6 The relief valves are to be provided with a flame arrester that permits crankcase pressure relief and prevents passage of flame following a crankcase explosion.

4.1.7 Safety devices are to be provided with suitable markings that include the following information:

- Name and address of manufacturer,
- Designation and size,
- Relief area,
- Month/year of manufacture,
- Approved installation orientation.

4.2 Crankcase doors and sight holes

4.2.1 Crankcase doors and their fittings shall be so dimensioned as not to suffer permanent deformation due to the overpressure occurring during the response of the safety equipment. Crankcase doors are to be fastened sufficiently securely for them not be readily displaced by a crankcase explosion.

4.2.2 Crankcase doors and hinged inspection ports are to be equipped with appropriate latches to effectively prevent unintended closing.

4.2.3 A warning notice is to be fitted either on the control stand or, preferably, on a crankcase door on each side of the engine. The warning notice is to specify that whenever overheating is suspected within the crankcase, the crankcase doors or sight holes are not to be opened before a reasonable time, sufficient to permit adequate cooling after stopping the engine.

4.3 Oil mist detection/monitoring and alarm system (Oil mist detector)

4.3.1 Engines with a cylinder diameter > 300 mm or a rated power of 2250 kW and above are to be fitted with crankcase oil mist detectors or engine bearing temperature monitors (all bearings i.e. journal and connecting rod bearings) or equivalent devices (See also BCS- I SC228). The oil mist detectors are to be type tested in accordance with Type Testing Procedure for Crankcase Oil Mist Detection and Alarm Equipment.

Engine bearing temperature monitors or equivalent devices used as safety devices have to be of a type approved by **BCS** for such purposes.

Measures applied to high speed engines where specific design features to preclude the risk of crankcase explosions are incorporated, can be accepted by **BCS** as equivalent device.

4.3.2 For multiple engine installations each engine is to be provided with a separate oil mist detector and a dedicated alarm.

4.3.3 Oil mist detectors are to be type approved.

Oil mist detection arrangements are to be tested in accordance with "Type Testing Procedure for Crankcase Oil Mist Detection and Alarm Equipment" and comply with 4.3.2 to 4.3.13.

Alarms and shutdowns for the oil mist detection system are to be in accordance with Chapter 4-1 - Automation, Section 4 and Section 8, also Table 2.7 and the system arrangements are to comply with Chapter 4-1 - Automation.

4.3.4 The oil mist detector is to be installed in accordance with the engine designer's and the system manufacturer's instructions and recommendations.

4.3.5 Function tests and equipment together with detectors to demonstrate that the detection and alarm system functionally operates are to be performed on the engine test bed at manufacturer's workshop and on board under the conditions of "engine at standstill" and "engine running at normal operating conditions" in accordance with test procedures to be agreed with **BCS**.

4.3.6 Alarms and shutdowns for the detector are to be in accordance with Table 2.7.

4.3.7 Functional failures at the devices and equipment are to be alarmed.

4.3.8 The oil mist detector has to indicate that the installed lens, which is used in determination of the oil mist concentration has been partly obscured to a degree that will affect the reliability of the information and alarm indication.

4.3.9 Where the detector includes the use of programmable electronic systems, the arrangements are in accordance with the requirements of **BCS** Rules for Electrical Installations, Section 10.

4.3.10 Where sequential oil mist detection / monitoring arrangements are provided, the sampling frequency and time are to be as short as reasonably practicable.

4.3.11 Plans of showing details and arrangements of the oil mist detector are to be submitted for approval.

The following particulars are to be included in the documentation:

- Schematic layout of engine oil mist detector showing location of engine crankcase sample points and piping arrangement together with pipe dimensions to detector/monitor.
- Evidence of study to justify the selected location of sample points and sample extraction rate (if applicable) in consideration of the crankcase arrangements and geometry and the predicted crankcase atmosphere where oil mist can accumulate.
- Maintenance and test manuals
- Information about type approval of the detection/monitoring system or functional tests at the particular engine

4.3.12 A copy of the documentation supplied with the system such as maintenance and test manuals are to be provided on board ship.

4.3.13 The readings and the alarm information from

the oil mist detector are to be capable of being read from a safe location away from the engine.

4.3.14 Where alternative methods are provided for the prevention of build-up a potentially explosive condition within the crankcase (independent of the reason, e.g. oil mist, gas, hot spots, etc.), details are to be submitted for consideration of **BCS**. The following

information is to be included in the details to be submitted for approval:

- Engine particulars - type, power, speed, stroke, bore and crankcase volume (including volumes of all divisions integrated with crankcase, if existing),
- Details of arrangements preventing the build-up of potentially explosive conditions within the crankcase, e.g. bearing temperature monitoring, oil splash temperature, crankcase pressure monitoring, recirculation arrangements, crankcase atmosphere monitoring,
- Evidence that the arrangements are effective in preventing the build-up of potentially explosive conditions together with details of in service experience
- Operating instructions and maintenance and test instructions

4.4 Active safety measures where it is proposed to use alternative active technologies to minimise the risk for a potential crankcase explosion, details of the arrangement and the function description are to be submitted to **BCS** for approval.

4.5 Crankcase safety devices have to be type approved.

4.6 Plans showing details and arrangements of safety devices are to be submitted for approval.

4.7 Safety devices are to be provided with a copy manufacturer's installation and maintenance manual that is pertinent to the size and type of valve being supplied for installation on a particular engine. The manual is to contain the following information:

- Description of valve with details of function and design limits.
- Copy of type test certification.
- Installation instructions.
- Maintenance in service instructions to include testing and renewal of any sealing arrangements.
- Actions required after a crankcase explosion.

A copy of this manual is to be kept on board of the ship.

4.8 Where it is proposed to use the introduction of inert gas into the crankcase to minimise a potential crankcase explosion, details of the arrangements are to be submitted to **BCS** for consideration.

5. Safety Devices in the Starting Air System

The following equipment is to be fitted to safeguard starting air system against explosions due to failure of starting valves:

5.1 An isolation non-return valve is to be fitted to the starting air line serving each engine.

5.2 Engines with cylinder bores of > 230 mm. are to be equipped with flame arresters as follows:

- On directly reversible engines immediately in front of the start-up valve of each cylinder;
- On non-reversible engines, immediately in front of the intake of the main starting air line to each engine.

5.3 Equivalent safety devices may be approved by **BCS**.

6. Safety Devices in the Lubricating Oil System

Each engine with a rated power of 220 kW or over is to be fitted with devices which automatically shut down the engine in the event of failure of the lubricating oil supply. This is not valid for engines serving solely for the drive of emergency generator sets and emergency fire pumps. For these engines an alarm has to be provided.

7. Safety Devices in Scavenging Air Ducts

For two-stroke engines scavenging air ducts are to be protected against overpressure by safety valves.

G. Auxiliary Systems

1. General

For piping systems and accessory filter arrangements Section 16 is to be applied, additionally.

2. Fuel Oil System

2.1 General

2.1.1 Only pipe connections with metal sealing surfaces or equivalent pipe connections of approved design may be used for fuel injection lines.

2.1.2 Feed and return lines are to be designed in such a way that no unacceptable pressure surges occur in the fuel supply system. Where necessary, the engines are to be fitted with surge dampers approved by **BCS**.

2.1.3 All components of the fuel system are to be designed to withstand the maximum peak pressures which will be expected in the system.

2.1.4 If fuel oil reservoirs or dampers with a limited life cycle are fitted in the fuel oil system the life cycle together with overhaul instructions is to be specified by the engine manufacturer in the corresponding manuals.

2.1.5 Oil fuel lines are not to be located immediately above or near units of high temperature, steam pipelines, exhaust manifolds, silencers or other equipment required to be insulated by 7.1. as far as practicable, oil fuel lines are to be arranged far apart from hot surfaces, electrical installations or other potential sources of ignition and are to be screened or otherwise suitably protected to avoid oil spray or oil leakage onto the sources of ignition. The number of joints in such piping systems are to be kept to a minimum.

2.2 Shielding

2.2.1 Regardless of the intended use and location of internal combustion engines, all external fuel injection lines (high pressure lines between injection pumps and injection valves) are to be shielded by jacket pipes in such a way that any leaking fuel is:

- Safely collected,
- Drained away unpressurized, and
- Efficiently monitored and alarmed.

2.2.2 If pressure variations of > 20 bar occur in fuel feed and return lines, these lines are also to be shielded.

2.2.3 The high pressure fuel pipe and the outer jacket pipe have to be permanent assembly.

2.2.4 Where, pipe sheaths in the form of hoses are provided as shielding, the hoses must be suitable for this purpose and approved by **BCS**.

2.3 Fuel leak drainage

Appropriate design measures are to be introduced to ensure generally that leaking fuel is drained efficiently and cannot enter into the engine lube oil system.

2.4 Heating, thermal insulation, re-circulation

Fuel lines, including fuel injection lines, to engines which are operated with preheated fuel are to be insulated against heat losses and, as far as necessary, provided with heating.

Means of fuel circulation are also to be provided.

2.5 Fuel oil emulsions

For engines operated on emulsion of fuel oil and other liquids, it has to be ensured that engine operation can be resumed after failures to the fuel oil treatment system.

3. Filter Arrangements for Fuel Oil and Lubricating Oil Systems

3.1 Fuel and lubricating oil filters which are to be mounted directly on the engine are not to be located above rotating parts or in the immediate proximity of hot components.

3.2 Where the arrangement stated in 3.1 is unfeasible, the rotating parts and the hot components are to be sufficiently shielded.

3.3 Filters have to be so arranged that fluid residues can be collected by adequate means. The same applies to lubricating oil filters if oil can escape when the filter is opened.

3.4 Switch-over filters with two or more filter chambers are to be fitted with devices which safely ensure a relief of pressure before opening and venting when a chamber is placed in service. Shutoff valves shall normally be used for this purpose. It must be clearly discernible which filter chambers are in service and which are out of operation at any time.

3.5 Oil filters fitted parallel for the purpose of enabling cleaning without disturbing oil supply to engines (e.g. duplex filters) are to be provided with arrangements that will minimize the possibility of a filter under pressure being opened by mistake. Filters/ filter chambers shall be provided with suitable means for:

- Venting when put into operation.
- Depressurizing before being opened.

Valves or cocks with drain pipes led to a safe location shall be used for this purpose.

For oil filters of generator diesel engines for ships with more than a single generator set, requirements in Section 16, H-3.4.1 may be applied.

3.6 For filters, requirements in Section 14 shall be taken into consideration.

4. Lubricating Oil System

4.1 General requirements relating to lubricating oil systems and to the cleaning, cooling etc. of the lubricating oil are contained in Section 16, H. For piping arrangement 2.1.3 is to be applied.

4.1.1 Engines whose sumps serve as oil reservoirs must be so equipped that the oil level can be established and, if necessary, topped up during operation. Means must be provided for completely draining the oil sump.

4.1.2 The oil drain pipes for each engine are to be independent of any other engine.

4.1.3 Drain lines from the engine sump to the drain tank are to be submerged at their outlet ends.

4.2 The equipment of engines fitted with lubricating oil pumps is subject to Section 16, H.3.

4.2.1 Main lubricating oil pumps driven by the engine are to be designed to maintain the supply of lubricating oil over the entire operating range

4.2.2 Main engines which drive main lubricating oil pumps are to be equipped with independently driven stand-by pumps.

4.2.3 In multi-engine installations having separate lubricating oil systems approval may be given for the carriage on board of reserve pumps ready for mounting provided that the arrangement of the main lubricating oil pumps enables the change to be made with the means available on board.

4.2.4 Lubricating oil systems for cylinder lubrication which are necessary for the operation of the engine and which are equipped with electronic dosing units have to be approved by **BCS**.

5. Cooling System

5.1 For the equipment of engines with cooling water pumps and for the design of cooling water systems, see Section 16, I and K.

5.1.1 Main cooling water pumps driven by the engine are to be designed to maintain the supply of cooling water over the entire operating range.

5.1.2 Main engines which drive main cooling water pumps are to be equipped with independently driven stand-by pumps or with means for connecting the cooling water system to independently driven stand-by pumps.

5.1.3 In installations comprising more than one main engine and with separate fresh cooling water systems approval may be given for the carriage on board of reserve pumps ready for mounting provided that the arrangement of the main fresh cooling water pumps enables the change to be made with the means available on board. Shutoff valves must be provided enabling the main pumps to be isolated from the fresh cooling water system.

5.2 If cooling air is drawn from the engine room, the design of the cooling system is to be based on a room temperature of at least 45°C.

The exhaust air of air-cooled engines may not cause any unacceptable heating of the spaces in which the plant is installed. The exhaust air is normally to be led to the open air through special ducts.

5.3 Where engines are installed in spaces which oil-firing equipment is operated, Section 15, A.5. is also to be complied with.

6. Charge Air System

6.1 Exhaust gas turbochargers

6.1.1 The construction and testing of exhaust gas turbochargers are subject to Section 4.

6.1.2 Exhaust gas turbochargers may exhibit no critical speed ranges over the entire operating range of the engine.

6.1.3 The lubricating oil supply must also be ensured during start-up and run-down of the exhaust gas turbochargers.

6.1.4 Even at low engine speeds, main engines must be supplied with charge air in a manner to ensure reliable operation.

Where necessary, two-stroke engines are to be equipped with directly or independently driven scavenging air blowers.

6.1.5 If, in the lower speed range or when used for manoeuvring, an engine can be operated only with a charge air blower driven independently of the engine, as stand-by charge air blower is to be installed or an equivalent device of approved design.

6.1.6 With main engines emergency operation must be possible in the event of a turbocharger failure.

6.2 Charge air cooling

6.2.1 The construction and testing of charge air coolers are subject to Section 14.

6.2.2 Means are to be provided for regulating the temperature of the charge air within the temperature range specified by the engine manufacturer.

6.2.3 The charge air lines of engines with charge air coolers are to be provided with sufficient means of drainage.

6.3 Fire extinguishing equipment

The charge air receivers of crosshead engines which have open connection to the cylinders are to be connected to an approved fire extinguishing system which is independent of the engine room fire extinguishing system. (See Section 18, Table 18.2)

7. Exhaust Gas Lines

7.1 Exhaust gas lines are to be insulated and/or cooled in such a way that the surface temperature cannot exceed 220°C at any point.

Insulating materials must be non-combustible.

7.2 General rules relating to exhaust gas lines are contained in Section 16, M.

H. Starting Equipment

1. General

Engine starting equipment shall enable engines to be started up from "dead ship" condition according to Section 1, D.10.1 using only the means available on board.

2. Starting With Compressed Air

2.1 Main engines which are started with compressed air are to be equipped with at least two starting air compressors. At least one of the air compressors must be driven independently of the main engine and must supply at least 50% of the total capacity.

2.2 The total capacity of the starting air compressors is to be such that the starting air receivers designed in accordance with 2.4 or 2.5, as applicable, can be charged from atmospheric pressure to their final pressure within one hour.

Normally, compressors of equal capacity are to be installed. This does not apply to an emergency air compressor which may be provided to meet the requirement stated in H.1.

2.3 If the main engine is started with compressed air, the available starting air is to be divided between at least two starting air receivers of approximately equal size which can be used independently of each other.

2.4 The total capacity of air receivers is to be sufficient to provide, without their being replenished, not less than 12 consecutive starts alternating between Ahead and Astern of each main engine of the reversible type, and not less than six starts of each main non-reversible type engine connected to a controllable pitch propeller or other device enabling the start without opposite torque.

2.5 With multi-engine installations the number of start -up operations per engine may, with **BCS** agreement, be reduced according to the concept of the propulsion plant.

2.6 If starting air systems for auxiliaries or for supplying pneumatically operated regulating and manoeuvring equipment or tyfon units are to be fed from the main starting air receivers, due attention is to be paid to the air consumption of this equipment when calculating the capacity of the main starting air receivers.

2.7 Other consumers with a high air consumption apart from those mentioned in 2.6 may not be connected to the main starting air system. Separate air supplies are to be provided for these units. Deviations to this require the agreement of **BCS**.

2.8 If auxiliary engines are started by compressed air, sufficient air capacity for three consecutive starts of each auxiliary engine is to be provided.

2.9 If starting air systems of different engines are fed by one receiver, it is to be ensured that the receiver air pressure cannot fall below the highest of the different systems minimum starting air pressures.

2.10 Calculation of starting air capacity

2.10.1 Calculation of starting air capacity for installations with reversible engines

Assuming an initial pressure of 30 bar and a final

pressure of 9 bar in the starting air receivers, the preliminary calculation of the starting air supply for a reversible main engine may be performed as follows:

$$J = a \cdot \sqrt[3]{\frac{H}{D}} \cdot (z + b \cdot p_{e,e} \cdot n_A + 0.9) \cdot V_h \cdot c$$

J = Total capacity of the starting air receivers [dm³],

D = Cylinder bore [mm],

H = Stroke [mm],

V_h = Swept volume of one cylinder (in the case of double-acting engines, the swept volume of the upper portion of the cylinder) [dm³],

p_{e,zul} = Maximum permissible working pressure of the starting air receiver [bar],

z = Number of cylinders [–],

p_{e,e} = Mean effective working pressure in cylinder at rated power [bar].

The following values of "a" are to be used:

a = 0.4714 for two-stroke engines:

a = 0.4190 for four-stroke engines:

The following values of "b" are to be used:

b = 0.059 for two-stroke engines:

b = 0.056 for four-stroke engines:

The following values of "c" are to be used:

c = 1, where p_{e,zul} = 30 bar

$$c = \frac{0.0584}{1 - e^{0.11 - 0.05 \cdot \ln p_{e,zul}}}$$

where $p_{e,zul} > 30$ bar, if no pressure-reducing valve is fitted.

e = Euler's number (2.718....) [-]

Where $p_{e,zul} > 30$ bar, if a pressure-reducing valve is fitted, which reduces the pressure $p_{e,zul}$ to the starting pressure P_A , the value of "c" shown in Fig. 2.10 is to be used.

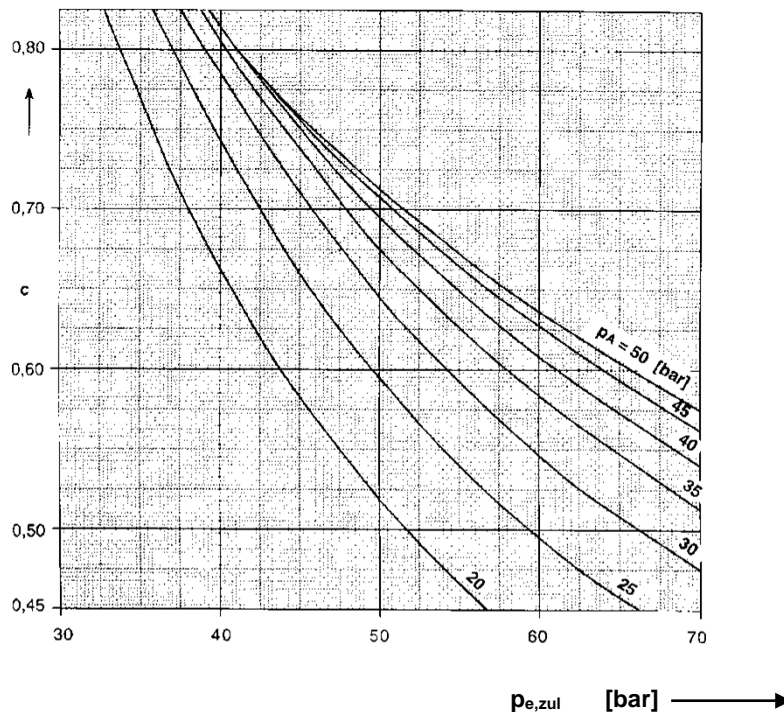


Fig. 2.10 The value of "c" where a pressure-reducing valve is fitted

The following values of n_A are to be applied:

$$n_A = 0.06 \cdot n_o + 14 \text{ where } n_o \leq 1000$$

and

$$n_A = 0.25 \cdot n_o - 176 \text{ where } n_o > 1000$$

$$n_o = \text{rated speed [min}^{-1}\text{]}$$

2.10.2 Calculation of starting air capacity for installations with nonreversible engines

For each non-reversible main engine driving a controllable pitch propeller or where starting without torque resistance is possible the calculated starting air supply may be reduced to $0.5 \cdot J$ though not less than

that needed for six start-up operations.

2.11 For additional rules with ice class notation see also Section 19, D.1.

3. Electrical Starting Equipment

3.1 Where main engines are started electrically, two mutually independent starter batteries are to be installed. The batteries are to be so arranged that they cannot be connected in parallel with each other. Each battery must enable the main engine to be started from cold.

The total capacity of the starter batteries must be sufficient for the execution within 30 minutes, without

recharging the batteries, of the same number of start-up operations as is prescribed H.2.4 or H.2.5, as appropriate, for starting with compressed air.

3.2 If two or more auxiliary engines are started electrically, at least two mutually independent batteries are to be provided. Where starter batteries for the main engine are fitted, the use of these batteries is acceptable.

The capacity of the batteries must be sufficient for at least three start-up operations per engine.

If only one of the auxiliary engines is started electrically, one battery is sufficient.

3.3 The starter batteries may only be used for starting (and preheating where applicable) and for monitoring equipment belonging to the engine.

3.4 Steps are to be taken to ensure that the batteries are kept charged and the charge level is monitored.

4. Start-up of Emergency Generating Sets

4.1 Emergency generating sets are to be so designed that they can be started up readily even at a temperature of 0°C.

If the set can be started only at higher temperatures, or where there is a possibility that lower ambient temperatures may occur, heating equipment is to be fitted to ensure ready reliable starting.

The operational readiness of the set must be guaranteed under all weather and seaway conditions.

Fire flaps required in air inlet and outlet openings may only be closed in case of fire and are to be kept open at other times. Warning signs to this effect are to be applied. No alarm is required in the case of automatic fire flap actuation dependent on the operation of the set. Air inlet and outlet openings must not be fitted with weatherproof covers.

4.2 Each emergency generating set required to be capable of automatic starting is to be equipped with an automatic starting system approved by **BCS**, the

capacity of which is sufficient for at least three successive starts see **BCS** Rules for Electrical Installations Section 7, D.6.

Additionally a second source of energy is to be provided capable of three further starting operations within 30 minutes. This requirement is not applicable if the set can be started manually.

4.3 In order to guarantee the availability of the starting equipment, steps are to be taken to ensure that:

- Electrical and hydraulic starting systems are supplied with energy from the emergency switchboard;
- Compressed air starting systems are supplied via a non-return valve from the main and auxiliary compressed air receivers or by an emergency air compressor, the energy for which is provided via the emergency switchboard; and
- The starting, charging and energy storage equipment is located in the emergency generator room.

4.4 Where automatic starting is not specified, reliable manual starting systems may be used, e.g. by means of hand cranks, spring-loaded starters, hand-operated hydraulic starters or starters using ignition cartridges.

4.5 Where direct manual starting is not possible, starting systems in accordance with 4.2 and 4.3 are to be provided, in which case the starting operation may be initiated manually.

4.6 The starters of emergency generator sets may be used only for the purpose of starting the emergency generators sets.

5. Start-up of Emergency Fire-Extinguisher Sets

5.1 Diesel engines driving emergency fire pumps are to be so designed that they can still be reliably started by hand at a temperature of 0°C.

If the engine can be started only at higher temperatures, or where there is a possibility that lower temperatures

may occur, heating equipment is to be fitted to ensure reliable starting.

5.2 If manual start-up using a head crank is not possible, the emergency fire-extinguisher set is to be fitted with a starting device approved by **BCS** which enables at least 6 starts to be performed within 30 minutes, two of these being carried out within the first 10 minutes.

I. Control Equipment

1. General

For unmanned machinery installations, Chapter 4-1 - Automation is to be observed in addition to the following requirements.

2. Main Engines

2.1 Local control station

To provide emergency operation of the propulsion plant a local control station is to be installed from which the plant can be operated and monitored.

2.1.1 Indicators according to Table 2.7 are to be clearly sited on the local main engine control station.

2.1.2 Temperature indicators are to be provided on the local control station or directly on the engine.

2.1.3 In the case of gear and controllable pitch propeller systems, the local control indicators and control equipment required for emergency operation are to be installed at the main engines local control station.

2.1.4 Critical speed ranges are to be marked in red on the tachometers.

2.2 Machinery control room / control centre

For remotely operated or controlled machinery installations the indicators listed in Table 2.7 are to be installed, see Chapter 4-1 - Automation

2.3 Bridge / navigation center

2.3.1 The essential operating parameters for the propulsion system are to be provided in the control

station area.

2.3.2 The following stand-alone control equipment is to be installed:

- Speed/direction of rotation of main engine,
- Speed/direction of rotation of shafting,
- Propeller pitch (controllable pitch propeller),
- Starting air pressure,
- Control air pressure.

2.3.3 In the case of engine installations up to a total output of 600 kW, simplifications can be agreed with **BCS**.

3. Auxiliary Engines

For auxiliary engines and emergency application engines the controls according to Table 2.7 are to be provided as a minimum.

J. Alarms

1. General

1.1 The following requirements apply to machinery installations which have been designed for conventional operation without any degree of automation.

1.2 Within the context of these Rules, the word alarm is understood to mean the visual and audible warning of abnormal operating parameters.

2. Scope of Alarms

Alarms have to be provided for main, auxiliary and emergency engines according to Table 2.7.

Table 2.7 Alarm and indicators

Description	Propulsion engines	Auxiliary engines	Emergency engines
Speed / direction of rotation	I		
Engine overspeed (5)	A, S	A, S	A, S
Lubricating oil pressure at engine inlet	I, L(9), S	I, L(9), S	I, L(9)
Lubricating oil temperature at engine inlet	I, H	I (5), H (5)	I (5), H (5)
Fuel oil pressure at engine inlet	I	I	
Fuel oil temperature at engine inlet (1)	I	I	
Fuel oil leakage from high pressure pipes	A	A	A
Cylinder cooling water pressure at engine inlet	I, L	I(4), L (4)	I(4), L (4)
Cylinder cooling water /air temperature at engine outlet	I, H	I, H	I, H
Cylinder pressure (10)	H	H	H
Piston coolant pressure at engine inlet	I, L		
Piston coolant temperature at engine outlet	I, H		
Charge air pressure at cylinder inlet	I		
Charge air temperature at charge air cooler inlet	I		
Charge air temperature at charge air cooler outlet	I, H		
Starting air pressure	I, L		
Control air pressure	I, L		
Exhaust gas temperature (2)	I, H (3)		
Oil mist concentration in crankcase or alternative monitoring system (6)(7) (8)	I, H	I, H	I, H
<p>(1) For engines running on heavy fuel oil only.</p> <p>(2) Wherever the dimensions permit, at each cylinder outlet and at the turbo charger inlet and outlet.</p> <p>(3) At turbo charger outlet only.</p> <p>(4) Cooling water pressure or flow.</p> <p>(5) Only for an engine output ≥ 220 kW.</p> <p>(6) For engines having an output > 2250 kW or a cylinder bore > 300 mm.</p> <p>(7) Alternative methods of monitoring may be approved by BCS. See F-4.3.1.</p> <p>(8) Engine slowdown function for low speed engines and shutdown function for medium and high speed engines to be provided.</p> <p>(9) Only for an engine output > 37 kW</p> <p>(10) Only for engines having cylinder bore > 230 mm.</p>		<p>I : Indicator</p> <p>A : Alarm</p> <p>H : Alarm for upper limit</p> <p>L : Alarm for lower limit</p> <p>S : Shutdown</p>	

K. Engine Alignment / Seating

For the purpose of subsequent alignments, note is to be taken of:

For engine alignment / seating see **BCS** Additional Rules, Seating of Propulsion Plant.

- The draught / load condition of the vessel

1. Crankshaft Alignment

- The condition of the engine-cold / preheated / hot

The crankshaft alignment is to be checked every time an engine has been aligned on its foundation by measurement of the crank web deflection and/or other suitable means.

2. Permissible Crank Web Deflection

Where the engine manufacturer has not specified values for the permissible crank web deflection, assessment is to be based on **BCS** 's reference values.

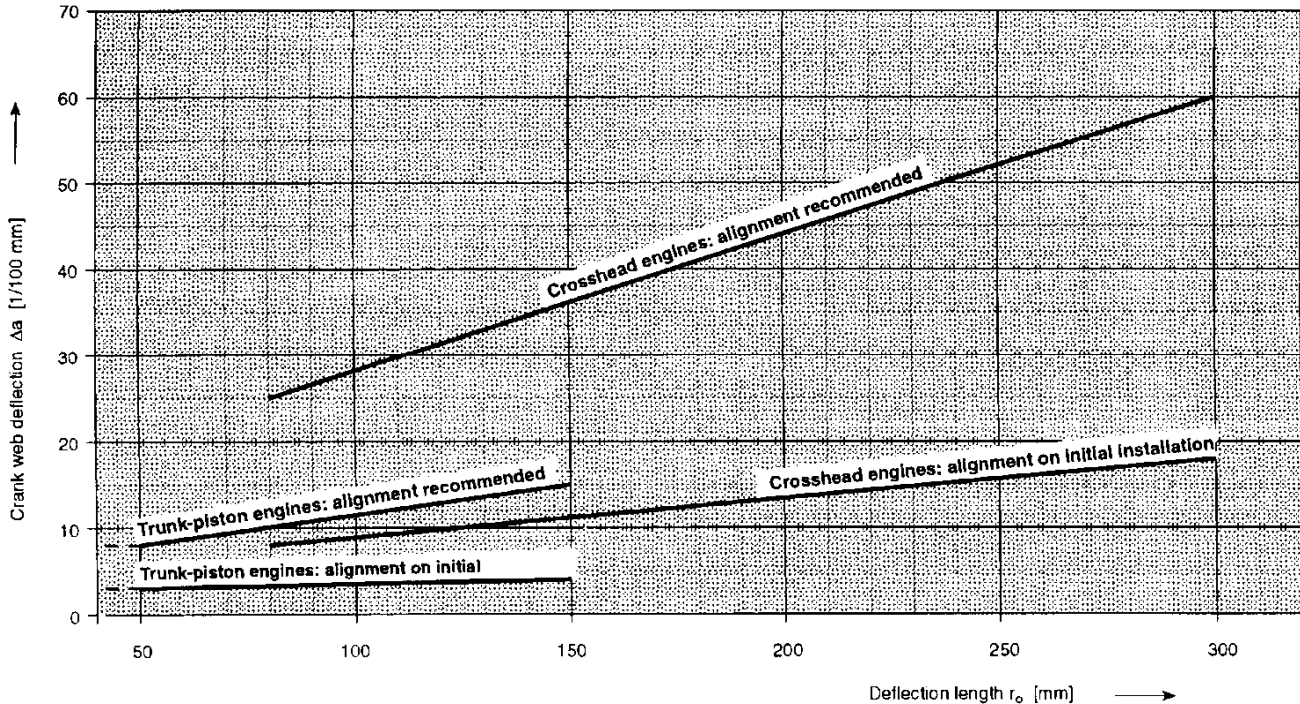


Fig. 2.11 Reference values for crank web deflection

3. Reference Values for Crank Web Deflection

3.1 Irrespective of the crank web deflection figures quoted by the manufacturers of the various engine types, reference values for assessing the crank web deflection in relation to the deflection length r_o can be taken from Fig. 2.12.

Provided that these values are not exceeded, it may be assumed that neither the crankshaft nor the crankshaft bearings are subjected to any unacceptable additional stresses.

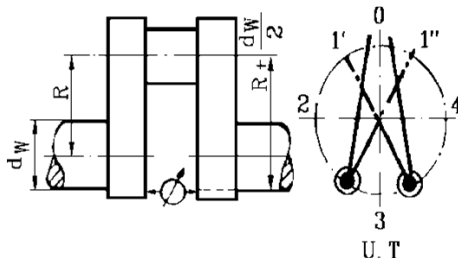


Fig. 2.12 Measurements of crank web deflections

3.2 Notes on the measurement of crank web deflections

Crank web deflections are to be measured at distance $R + d_w/2$ from the crankpin centre line (see Fig. 2.19).

Crank web deflection Δa is only meaningful as measured between opposite crank positions (see Fig. 2.19), i.e. between 0-3 for evaluating vertical alignment and bearing location, and between 2-4 for evaluating lateral bearing displacement when aligning the crankshaft and assessing the bearing wear.

For measuring point 0, which is obstructed by the connecting rod, the mean value of the measurements made at 1' and 1'' is to be applied.

3.3 Determining the crank web deflection length r_o

- Solid-forged and drop-forged crankshafts in Fig. 2.13, parts A, B and C;

- Semi-built crankshafts, Fig 2.20, D.

Symbols:

R = Crank radius, [mm]

H = Stroke (2R), [mm]

d_k = Crank pin diameter, [mm]

d_w = Journal diameter, [mm]

d_N = Shrink annulus diameter, [mm]

W = Axial web thickness, [mm]

B = Web width at distance R/2, [mm]

T_i = Depth of web undercut (on crank pin side), mm]

T_a = Depth of web undercut (on journal side), [mm]

s = Pin/journal overlap [mm].

$$= \frac{\left(\frac{d_k + d_w}{2} \right) W}{k} - R$$

Where there is a negative pin/journal overlap ($s < 0$), the deflection length r_o in accordance with Fig. 2.13, A is determined by applying the following crank web deflection length formula:

$$r_o = 0,5 \cdot (H + d_k + d_w) - W \left[\sqrt{\frac{2 \cdot d_k}{W} - 1} + \sqrt{\frac{2 \cdot d_w}{W} - 1} \right]$$

In case of web undercut, W in crank web deflection length formula is to be replaced by the following value:

$$W^* = \frac{W \cdot (T_i + T_a)}{2}$$

In the case of semi-built crankshafts in accordance with Fig. 2.13, D, the value d_w under the root sign only in crank web deflection length formula is to be replaced by the following value.

$$d_w^* = 1/3(d_N - d_w) + d_w$$

Where there is a positive pin/journal overlap ($s \geq 0$) according to Fig 2.20, C, the value in crank web deflection length formula is to be replaced by:

$$W^* = \sqrt{(W - T_i - T_a)^2 + [0,5 (d_k + d_w - H)]^2}$$

For the conventional design, where

$B/d_w = 1.37$ to 1.51 in case of solid-forged crankshafts, and

$B/d_w = 1.51$ to 1.63 in case of semi-built crankshafts,

the influence of B in the normal calculations of r_o is already taken into account in the values of Δ_a in Fig. 2.11. Where the values of B/d_w depart from the above (e.g. in the case of discs, oval webs etc.), the altered stiffening effect of B is to be allowed for by a fictitious web thickness W^{**} , which is to be calculated by applying the following equations and is to be substituted for W in crank web deflection length formula:

$$W^{**} = W^* \cdot \sqrt[3]{B/d_w - 0,44} \quad \text{for solid - forged crankshafts}$$

$$W^{**} = W^* \cdot \sqrt[3]{B/d_w - 0,57} \quad \text{for semi - built crankshafts}$$

L. Air Compressors

1. General

1.1 Scope

These Rules apply to reciprocating compressors of the normal marine types. Where it is intended to install compressors to which the following Rules and calculation formulae cannot be applied, **BCS** requires proof of their suitability for shipboard use.

1.2 Documents for approval

Drawings showing longitudinal and transverse cross-sections, the crankshaft and the connecting rod are to be submitted to **BCS** in triplicate for each compressor type.

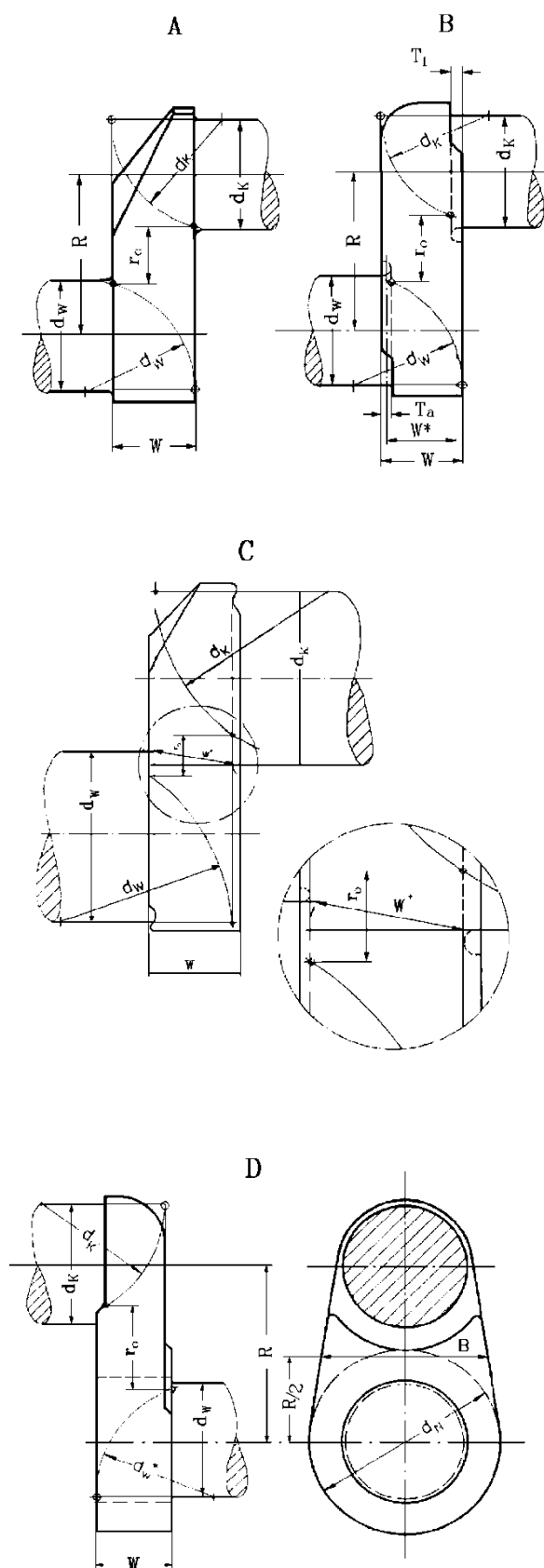


Fig. 2.13 Solid-forged (A, B ve C) and semi-built (D) crankshafts

2. Materials

2.1 Approved materials

In general, the crankshafts and connecting rods of reciprocating compressors shall be made of steel, cast steel or nodular cast iron. The use of special cast iron alloys is to be agreed with **BCS**.

2.2 Material testing

Material tests are to be performed on crankshafts with a calculated crank pin diameter > 50 mm. For crank pin diameters of ≤ 50 mm, works certificates are sufficient.

3. Crankshaft Dimensions

3.1 The diameters of journals and crank pins are to be determined as follows:

$$d_k = 0.126 \cdot \sqrt[3]{D^2 \cdot p_c \cdot C_1 \cdot C_w \cdot (2 \cdot H + f \cdot L)}$$

where;

d_k = Minimum pin/journal diameter, [mm]

D = Cylinder bore for single-stage compressors, [mm]

= D_{Hd} = cylinder bore of the second stage two-stage compressors with separate pistons,

= $1.4 \times D_{Hd}$ for two stage compressors with a stepped piston as in Fig. 2.14,

= $\sqrt{D_{Nd}^2 - D_{Hd}^2}$ for two-stage compressors with a differential piston as in Fig. 2.15.

p_c = Design pressure PR, applicable up to 40 bar, [bar]

H = Piston stroke, [mm]

L = Distance between main bearing center where one crank is located between two bearings. L is to be substituted by $L_1 = 0.85 \cdot L$ where two cranks at different angles are

located between two main bearings, or by $L_2 = 0.95 \cdot L$ where 2 or 3 connecting rods are mounted on one crank [mm].

$f = 1.0$ where the cylinders are in line

$= 1.2$ where the cylinders are at 90°
 $= 1.5$ where the cylinders are at 60°
 $= 1.8$ where the cylinders are at 45°

} V or W type

$C_1 =$ Coefficient according to Table 2.8, [-]

$z =$ Number of cylinders, [-]

$C_w =$ Material factor according to Table 2.9 or 2.10, [-]

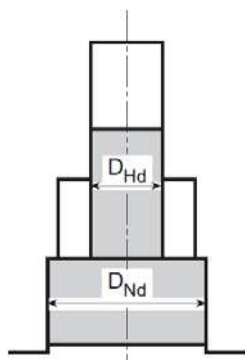


Fig. 2.14

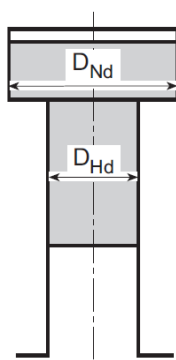


Fig. 2.15

$R_m =$ Minimum tensile strength. [N/mm²]

Table 2.8 Values of C_1

z	1	2	4	6	≥ 8
C_1	1.0	1.1	1.2	1.3	1.4

3.2 Where increased strength is achieved by a favourable configuration of the crankshaft, smaller values of d_k may be approved.

Table 2.9 Values of C_w for steel shafts

R_m	400	440	480	520	560	600	640	≥ 680	(1)	(1)
C_w	1.03	0.94	0.91	0.85	0.79	0.77	0.74	0.70	0.66	0.64
(1) Only for drop-forged crankshafts										

Table 2.10 Values of C_w for nodular cast iron shafts

R_m	370	400	500	600	700	≥ 800
C_w	1.20	1.10	1.08	0.98	0.94	0.90

4. Construction and Equipment

4.1 General

4.1.1 Cooler dimensions are to be based on a seawater temperature of at least 32°C in case of water cooling, and on an air temperature of at least 45°C in case of air cooling, unless higher temperatures are dictated by the temperature conditions attaching to the ship's trade or by the location of the compressors or cooling air intakes.

Where fresh water cooling is used, the cooling water inlet temperature shall not exceed 40°C .

4.1.2 Unless they are provided with open discharges, the cooling water spaces of compressors and coolers must be fitted with safety valves or rupture discs of sufficient cross-sectional area.

4.1.3 High-pressure stage air coolers shall not be located in the compressor cooling water space.

4.2 Safety valves and pressure gauges

4.2.1 Every compressor stage must be equipped with a suitable safety valve which cannot be blocked and which prevents the maximum permissible working pressure from being exceeded by more than 10% even when the delivery line has been shut off. The setting of the safety valve must be secured to prevent unauthorized alteration.

4.2.2 Each compressor stage must be fitted with a suitable pressure gauge, the scale of which must indicate the relevant maximum permissible working pressure.

4.2.3 Where one compressor stage comprises several cylinders which can be shut off individually, each cylinder must be equipped with a safety valve and a pressure gauge.

4.3 Air compressors with oil-lubricated pressure spaces

4.3.1 The compressed air temperature, measured directly at the discharge from the individual stages, may not exceed 160°C for multi-stage compressors or 200°C for single-stage compressors. For discharge pressures of up to 10 bar, temperatures may be higher by 20 °C.

4.3.2 Compressors with a power consumption of more than 20 kW should be fitted with thermometers at the individual discharge connections, wherever this is possible. If this is not practicable, they are to be mounted at the inlet end of the pressure line. The thermometers are to be marked with the maximum permissible temperatures.

4.3.3 After the final stage, all compressors are to be equipped with a water trap and an aftercooler.

4.3.4 Water traps, aftercoolers and the compressed air spaces between the stages must be provided with discharge devices at their lowest points.

For automatically starting compressors, in the event of failure of the pressurized lubrication system, independently driven compressors must shut down automatically and a suitable automatic drain facility must be provided for the cooler and water traps (where appropriate also during operation).

4.4 Name plate

Every compressor is to carry a name plate with the following information:

- Manufacturer,

- Year of construction,
- Effective suction rate [m³/h],
- Discharge pressure [bar],
- Speed [rev/min],
- Power consumption [kW].

5. Tests

5.1 Pressure tests

5.1.1 Cylinders and cylinder liners are to be subjected to hydraulic pressure tests at 1.5 times the final pressure of the stage concerned.

5.1.2 The compressed air chambers of the intercoolers and aftercoolers of air compressors are to be subjected to hydraulic pressure tests at 1.5 times the final pressure of the stage concerned.

5.2 Final inspections and testing

Compressors are to be subjected to a performance test at the manufacturer 's works under supervision of **BCS** and are to be presented for final inspection.

M. Exhaust Gas Cleaning Systems

1. General

Exhaust gas cleaning systems shall comply with the applicable statutory requirements. In case of sea going ships requirements stipulated in the MARPOL Convention are to be observed. In case of wet exhaust gas cleaning systems (scrubber systems) IMO Resolution MEPC 259(68) applies.

In case of Exhaust Gas Recirculation (EGR) method is used Resolution MEPC 307(73) should be considered. In case of engines fitted with Selective Catalytic Reduction system, Resolution MEPC.291(71) as amended by MEPC 313(74) should be taken into account in addition to NOx Technical Code 2008.

For detailed requirements for Exhaust Gas Cleaning Systems, refer to **BCS** Guidelines, Guidelines for Exhaust Gas Cleaning Systems.

1.1 Application

The following requirements apply to exhaust gas cleaning systems which reduce the amount of nitrogen oxides (NOx), sulphur oxides (SOx) or particulate matter from the exhaust gases of internal combustion engines, incinerators or steam boilers.

2. Approval

Where an exhaust gas cleaning system is installed details of the arrangement and a description of the function are to be submitted to **BCS** for approval.

2.1 Documents for approval

For approval, drawings showing the main dimensions of the systems shall be submitted including documentation concerning installation requirements and operational features. An operation manual shall include instructions for emergency operation, if applicable.

2.2 Approval certificate

After successful appraisal of the required documents and successful conclusion of the shipboard test in presence of a Surveyor **BCS** issues an Approval Certificate.

3. Layout

3.1 System layout and installation

Exhaust gas cleaning systems shall be independent for each combustion engine or combustion plant. General

requirements on the use of combustible materials and on structural fire protection are to be observed. In cases where urea or sodium hydroxide solution tanks are installed in a space separated from engine room, for fire integrity of solution tank space see Chapter 1 – Hull, Section 21. Thermal expansion of the system and its mechanical connections to both the ship's structure and the exhaust pipes has to be considered. The requirements for exhaust gas lines set out in Section 16, M shall be taken into account. The aftertreatment system is to be equipped with at least one inspection port.

Exhaust gas cleaning systems are to be accessible for inspection and maintenance. A change or removal of internal components shall be possible, where applicable.

3.2 Bypass

Where an exhaust gas cleaning system is installed with a single main propulsion engine a bypass, controlled by flap valves or other suitable cut-off devices, is required in order to allow unrestricted engine operation in case of system failure. The bypass shall be designed for the maximum exhaust gas mass flow at full engine load.

In case of an exhaust gas cleaning system installed on an engine of a multi engine plant a bypass system may be dispensed with.

3.3 Additional pressure loss

The total pressure loss in the exhaust gas system, including the additional pressure loss from the exhaust gas cleaning system, shall not exceed the maximum allowable exhaust gas back pressure as specified by the engine manufacturer at any load condition.

3.4 Maximum gas pressure

The maximum pressure in the system of the exhaust pipes as specified by the manufacturer shall not be exceeded. Care is to be taken in particular where the exhaust gas cleaning system is located upstream of the

turbocharger of the combustion engine (e.g. Selective Catalytic Reduction systems in conjunction with large bore 2-stroke Diesel engines).

3.5 Oscillation characteristics of the exhaust gas column

The installation and operation of the exhaust gas cleaning system shall not have an adverse effect on the oscillation characteristics of a combustion engine's exhaust gas column in order to avoid unsafe engine operation.

3.6 Deposition of soot

The deposition of soot within or in the proximity of the exhaust gas cleaning system should be avoided. Where this may lead to additional fire hazards the deposition of soot is not acceptable.

3.7 Vibrations in piping system

The design and installation of the exhaust gas cleaning system including the exhaust gas piping system shall account for vibrations induced by the ship's machinery, the pulsation of the exhaust gas or vibrations transmitted through the ship's structure in order to prevent mechanical damage to the piping system. Consideration should be given to the installation of damping systems and/or compensators.

3.8 Monitoring of the operating parameters

The main operating parameters of the exhaust gas cleaning system have to be monitored and should serve as indicators for possible abnormalities. As a minimum, the following operating parameters shall be monitored:

- Gas temperature upstream of the exhaust gas cleaning system
- Gas temperature downstream of the exhaust gas cleaning system

- Pressure drop across the exhaust gas cleaning system
- Engine exhaust gas back pressure
- Position of flap valves

4. Materials

All materials of the exhaust gas cleaning system, connecting pipes and chemically reactive agent dosing units shall be non-combustible. The requirements relating to exhaust gas lines as contained in Section 16, M are to be observed, as applicable.

5. Chemically reactive agents

5.1 Reducing agent

For Selective Catalytic Reduction (SCR) type exhaust gas cleaning systems the reducing agent (Ammonia, dissolved Ammonia, Urea or the like) has to be stored and pumped in tanks and pipes made of approved materials for these types of agents, see Section 16.

For more details see BCS- I MPC 105.

5.2 Ammonia slip

Where Selective Catalytic Reduction (SCR) type exhaust gas cleaning systems are applied excessive slip of ammonia has to be prevented.

5.3 Washwater criteria

Where the exhaust gases are washed with water, discharged wash water has to comply with criteria as specified in IMO Resolution MEPC 259(68).

5.4 Storage and use of SCR reductants

5.4.1 General

The NO_x Technical Code, in 2.2.5 and elsewhere, provides for the use of NO_x Reducing Devices of which Selective Catalytic Reduction (SCR) is one option. SCR requires the use of a reductant which may be a

urea/water solution or, in exceptional cases, aqueous ammonia or even anhydrous ammonia. These requirements apply to the arrangements for the storage and use of SCR reductants which are typically carried on board in bulk quantities.

5.4.2 For detailed requirements in respect of storage and use of SCR reductants, are to be applied **BCS** Guidelines, Guidelines for Exhaust Gas Cleaning Systems, item B.6.2.

6. Shipboard testing

The exhaust gas cleaning and bypass system is subject to inspection and functional tests in each case in the presence of a Surveyor.

N. Gas or Other Low-Flashpoint Fuels Fuelled Engines

1. Scope and application

1.1 For internal combustion engines using gas or other low-flashpoint fuels as fuel the following requirements are to be observed. These requirements are applicable to gas or other low-flashpoint fuels fuelled engines meeting the following criteria:

- Engines using natural gas or other low-flashpoint fuels as fuel
- Engines burning fuel gas and fuel oil (dual-fuel engines), or single gas fuel engines (operating on gas-only)
- Engines with low or high pressure gas supply systems

1.2 Special design features will be considered on a case by case basis, taking into account the basic engine design and the engine safety concept.

2. Further Rules and Guidelines

2.1 The gas or other low-flashpoint fuels fuelled

engine requirements defined in **TLRules** Chapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels are generally to be fulfilled.

2.2 Requirements for internal combustion engines as defined in these rules from A to N are to be followed for gas-fuelled engines as far as applicable.

2.3 **TLRules** Chapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels apply to gas fuel supplied from gas fuel storage tanks.

2.4 **BCS** Part C, Chapter 10 – Liquefied Gas Carriers apply to gas fuel supplied from liquefied gas carrier cargo boil-off.

3. Definitions

3.1 Definitions addressing gas as fuel as given in **TLRules** Chapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels apply.

3.2 Gas admission valve: Valve or injector on the engine which controls gas supply to the engine according to the engine's actual gas demand.

3.3 Safety concept: The safety concept is a document describing the safety philosophy with regard to gas as fuel.

It describes how risks associated with this type of fuel are controlled under normal operating conditions as well as possible failure scenarios and their control measures.

4. General and operational availability

4.1 The safety, operational reliability, and dependability of a gas-fuelled engine shall be equivalent to that of a conventional oil-fuelled marine diesel engine.

4.2 The engine shall be capable of safe and reliable operation throughout the entire power range under all expected operation conditions.

4.3 Composition and minimum methane number of gas fuel supplied to the engine shall be in accordance with the engine manufacturer's specification. If gas composition or methane number exceeds specified limits, no dangerous situation shall arise.

4.4 General requirements regarding redundancy of essential systems (main propulsion, electrical power generation, etc.) are to be considered. The same basic requirements apply to gas-fuelled engine installations as for oil-fuelled engine installations.

4.5 Arrangements of the gas-fuelled installation for sustained or restored operation following blackout and dead ship condition shall be carefully evaluated.

4.6 Overall operational availability of the gasfuelled engine installation shall not be reduced by engine safety functions, such as automatic shutdown of external gas supply, to a level lower than achieved by oil-fuelled engine installations. Furthermore, gas leakages anywhere in the gas storage system, gas supply system, or gas engine components shall not cause automatic shutdown of other engines in order to maintain essential functions such as main propulsion power and electrical power generation.

4.7 For single engine main propulsion plants the entire system, including gas supply, machinery space safety concept, and gas engine design shall be evaluated with regard to operational availability and redundancies.

4.8 In general, dual-fuel engines suitable for change-over to oil fuel mode in case of failure in the gas supply system are considered to be the only gas fuelled engines practicable for single engine main propulsion plants.

5. Documents to be submitted

5.1 In addition to the documents defined in B and **BCS** Rules Chapter 78 – Rules for Classification of Ships Using Gases or Other Low -Flashpoint Fuels the documents as listed in Table 2.11 shall be submitted for approval respectively review. Following prior agreement with **BCS** they shall be submitted in paper form in triplicate.

6. General requirements

Requirements as specified in the **TL** Rules Chapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels , Part A-1 shall be observed.

6.1 Gas supply concept

6.1.1 Gas-fuelled engines shall either be designed according to Emergency Shut-down Concept (ESD) or Gas Safe Concept (definition and requirements see **TL** Rules Chapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels.

6.1.2 The general design principle (ESD or Gas Safe Concept) will influence the range of acceptable applications with regard to engine room arrangements, engine room safety concept, redundancy concept, propulsion plant, etc.

6.2 Requirements for single gas fuel engines

6.2.1 In general, single gas fuel engines are only considered suitable for electric power generating plants.

6.2.2 The application of single gas fuel engines for mechanical propeller drives requires special evaluation and consideration.

6.3 Requirements for dual-fuel engines

6.3.1 Dual-fuel engines are to be of the dual-fuel type employing pilot fuel ignition and to be capable of immediate change-over to oil fuel only.

Table 2.11 Documents to be submitted for gas-fuelled engines

Item No.	Description
1	General engine concept with regard to gas as fuel (description)
2	Engine specification sheet and technical data
3	Specification of permissible fuel gas properties
4	Engine safety concept, including system FMEA with regard to gas as fuel
5	Definition of hazardous areas
6	General installation manual for the engine type with regard to machinery space layout and equipment
7	Fuel gas system for the engine, including double wall piping system and ventilation system (schematic layout, details, assembly, functional description)
8	Charge air system (schematic layout, functional description, assembly)
9	Engine exhaust gas system (schematic layout, assembly)
10	Explosion relief valves for crankcase, air intake manifold and exhaust manifold (specification, arrangement, determination of minimum number and size required, operating parameters of protected manifolds) refer also to 8.3.3.4
11	Engine control system (schematic layout, functional description, specification)
12	Ignition system (schematic layout, functional description, specification)
13	Combustion monitoring system (schematic layout, functional description, specification)
14	Engine monitoring system (schematic layout, functional description, specification)
15	Engine alarm and safety system (schematic layout, functional description, specification)
16	Gas detection system for the engine (schematic layout, functional description)
17	Electronic components of engine control-, ignition-, alarm-, safety-, monitoring system, etc. (specification, type approvals)
18	List of type approved equipment
19	List of explosion-proof electrical equipment incl. specification of certifications
20	Testing procedure for gas detection system
21	Testing procedure for gas tightness
22	General concept regarding training measures for operating personnel

6.3.2 Only oil fuel is to be used when starting the engine.

6.3.3 Only oil fuel is, in principle, to be used when the operation of an engine is unstable, and/or during manoeuvring and port operations.

6.3.4 In case of shut-off of the gas fuel supply or engine failure related to gas operation, engines are to be capable of continuous operation by oil fuel only.

6.3.5 In general, engine power and speed shall not be influenced during fuel change-over process. An automatic system shall provide for a change-over procedure with minimal fluctuations in engine power and speed.

6.3.6 The change-over process from gas mode to oil mode shall be possible at all operating conditions.

7. Systems

Requirements as specified in the **TLRulesChapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels** shall be observed.

7.1 Cooling water system

7.1.1 Means are to be provided to degas the cooling water system from fuel gas if the possibility is given that fuel gas can leak directly into the cooling water system.

7.1.2 Suitable gas detectors are to be provided.

7.1.3 Flame arrestors are to be provided at the vent pipes.

7.2 Lubrication oil system

7.2.1 Means are to be provided to degas the lubrication oil system from fuel gas if the possibility is given that fuel gas can leak directly into the lubrication oil system.

7.2.2 Suitable gas detectors are to be provided.

7.2.3 Flame arrestors are to be provided at the vent pipes.

7.3 Fuel oil system

7.3.1 Means are to be provided to degas the fuel oil system from fuel gas if the possibility is given that fuel gas can leak directly into the fuel oil system.

7.3.2 Suitable gas detectors are to be provided.

7.3.3 Flame arrestors are to be provided at the vent pipes.

7.4 External gas supply system

7.4.1 The external gas supply system shall be designed such that the required gas conditions and properties (temperature, pressure, etc.) as specified by the engine maker at engine inlet are adhered to under all possible operating conditions.

7.4.2 Arrangements are to be made to ensure that no gas in liquid state is supplied to the engine, unless the engine is designed to operate with gas in liquid state.

7.4.3 In addition to the automatic shut off supply valve a manually operated valve shall be installed in series in the gas supply line to each engine.

7.5 Gas system on the engine

7.5.1 General requirements

7.5.1.1 Gas piping on an engine shall be designed and installed taking due account of vibrations and movements during engine operation.

7.5.1.2 In case of rupture of a gas pipe or excessive pressure loss, automatic shutdown of the gas supply shall be activated.

7.5.2 Low pressure gas supply

7.5.2.1 Flame arresters shall be provided in the gas supply system on the engine as determined by the system FMEA.

7.5.2.2 Gas admission valves shall be located directly at each cylinder inlet. In general, mixing of fuel gas with combustion air shall not take place before the cylinder inlet.

7.5.2.3 Gas admission by a common gas admission valve and mixing of gas with combustion air before the cylinder inlet may be acceptable subject to an acceptable level of risk being determined in the safety concept and system FMEA.

7.5.3 High pressure gas supply

7.5.3.1 Flame arresters shall be provided at the inlet to the gas supply manifold of dual-fuel engines.

7.5.3.2 The high pressure gas is to be blown directly into the cylinders without prior mixing with combustion air.

7.5.3.3 High pressure gas pipes on the engine shall be carried out in double wall design with leakage detection. The outer pipe is to be designed to withstand serious leakage of the inner high pressure pipe. Gas pressure and temperature is to be considered.

7.5.4 Gas admission valve

7.5.4.1 The gas admission valve shall be controlled by the engine control system according to the actual gas demand of the engine.

7.5.4.2 Uncontrolled gas admission shall be prevented by design measures or indicated by suitable detection and alarm systems. Measures to be taken following detection and alarm are to be examined as part of the system FMEA.

7.6 Ignition system**7.6.1 General requirements**

Ignition systems commonly use either electrical spark plugs (single gas fuel engines) or pilot fuel oil injection (dual fuel engines).

7.6.1.1 The ignition system has to ensure proper ignition of the gas at all operating conditions and must be able to provide sufficient ignition energy.

7.6.1.2 Before starting the engine, the engine has to be ventilated without injection or supplying any fuel.

7.6.1.3 Before activating the gas admission to the engine, the ignition system has to be checked automatically to verify correct functioning.

7.6.1.4 Combustion of each cylinder is to be monitored. Misfiring and knocking combustion is to be detected.

7.6.1.5 Safe and reliable operation of the ignition system shall be demonstrated and documented by a system FMEA.

7.6.1.6 During stopping of the engine the fuel gas supply shall be shut off automatically before the ignition source.

7.6.2 Spark ignition

For a spark ignition engine, if ignition has not been detected on each cylinder by the engine monitoring system within an engine specific time after operation of the gas admission valve, gas supply shall be automatically shut off and the starting sequence terminated. Any unburned gas mixture is to be purged from the exhaust system.

7.6.3 Ignition by pilot injection

7.6.3.1 Prior to admission of fuel gas the correct operation of the pilot oil injection system on each cylinder shall be verified.

7.6.3.2 An engine shall always be started using fuel oil only.

7.7 Electrical systems

7.7.1 Care shall be taken to prevent any possible sources of ignition caused by electrical equipment, electrical sensors, etc. installed in hazardous areas.

7.7.2 For electrical equipment and sensors in hazardous areas the explosion protection requirements in the **BCS** Rules for Electrical Installations, Section 1 are to be observed.

7.7.3 Systems that shall remain operational when the safety system triggers shut off of the gas supply are to be determined by the system FMEA. Systems to be considered shall include, but not be limited to, the ventilation system, inert gas system and gas detection system.

7.8 Engine control-, monitoring-, alarm-, and safety systems

7.8.1 General requirements

7.8.1.1 General requirements regarding gas supply and automatic activation of gas supply valves (double block and bleed valves, master gas valve) to the engine as defined in the **TLRulesChapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels** and **BCS Part C , Chapter 10 – Liquefied Gas Carriers** shall be observed.

7.8.1.2 Knocking combustion and misfiring is to be detected and combustion conditions are to be automatically controlled to prevent knocking and misfiring.

7.8.1.3 The engine operating mode shall always be clearly indicated to the operating personnel.

7.8.1.4 Guidance for the scope of instrumentation for monitoring, alarm, and safety systems is given in Table 2.12. Depending on engine design, safety concept, and

system FMEA examining all possible failure modes, deviations from Table 2.12 may be agreed.

7.8.2 Gas detection

7.8.2.1 A continuous gas detection system shall be provided (see **TLRulesChapter 78 Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels, Part A-1**).

7.8.2.2 The gas detection system shall be in operation as long as fuel gas is supplied to the engine.

7.8.2.3 As guidance, the gas detection system shall cover the spaces of the engine as specified in Table 2.12. Depending on engine design, safety concept, and system FMEA deviations from Table 2.12 may be agreed.

7.8.2.4 Manual gas detection may be installed in lieu of continuous gas detection for certain spaces if this is shown to be acceptable by the system FMEA.

7.8.3 Speed control and load acceptance

7.8.3.1 In general, the requirements in F.1 shall be observed.

7.8.3.2 The basic requirements of F.1.2.3 regarding design of the ship's power management system apply.

7.8.3.3 Exemptions from minimum required step loading capability of engines driving electrical generators as shown in Fig. 2.16 can be agreed for gasfuelled engines of limited step loading capability.

7.9 Exhaust gas system and ventilation system

7.9.1 Exhaust gas pipes from gas-fuelled machinery are to be installed separately from each other, taking into account structural fire protection requirements.

Table 2.12 Indicative scope of instrumentation for gas-fuelled engines

	Indicator, alarm shutdown (1)	Shut off of gas supply to individual engine (double block and bleed valves) (1)	Shut off of gas supply to machinery space (master gas valve) (1)	Comment
Gas supply				
Gas pressure	I.L.H			
Gas temperature	I.L.H			
Gas admission valve(s) failure	A.S (2)	X		Incl. failure of sealing oil cooling etc.
Pressure of inert gas supply	I.L			
Rupture of gas pipe or excessive gas leakage	A.S	X	X	
Failure containment or vacuum of shielded gas piping system	A.S (2)	X	X	Gas safe concept
Gas detection				
Gas concentration in air manifold	H			
Gas concentration in crankcase	H			
Gas concentration in exhaust manifold	H			
Gas concentration in below each piston (3)	H			
Gas concentration in shielded gas piping system	H.S (2)	X	X	
Gas concentration in engine room	H.S	X	X	
Crankcase				
Pressure	H.S	X	X	
Temperature (4)	H.S	X	X	
Oil mist concentration	H.S	X	X	
Combustion monitoring				
Misfiring each cylinder	A.S (2)	X		
Knocking each cylinder	A.S (2)	X		
Cylinder pressure	H.L.S (2)	X		
Load deviation	A.S (2)	X		
Spark ignition system or pilot injection system failure	A.S (2)	X		
Exhaust gas				
Exhaust gas temperature turbocharger inlet and outlet	I.H			
Exhaust gas temperature each cylinder	I.L.H.S (2)	X		
Deviation from exhaust gas mean temperature	L.H.S (2)	X		
Miscellaneous				
Failure in gas combustion control system	A.S (2)	X		
Failure ventilation of shielded gas piping system	A			Gas safe concept
Failure exhaust gas ventilation system	A			
Engine shutdown	A.S	X		Externally or manually activated
<p><i>I : Indicator</i> <i>A : Alarm</i> <i>L : Alarm for lower limit</i> <i>H : Alarm for upper limit</i> <i>S : Shutdown</i> <i>X : Activation</i></p> <p>(1) In general, shut off gas supply and engine shutdown shall not be activated at initial trigger level without pre-alarm. (2) Automatic shutdown shall be replaced by automatic change-over to fuel oil mode for dual-fuel engines subjected to a continued safe (3) Cross-Head type engines (4) Temperature of liners and bearings</p>				

7.9.2 Machinery, including the exhaust gas system, is to be ventilated:

- Prior to each engine start,
- After starting failure,
- After each gas operation of gas-fuelled machinery not followed by an oil fuel operation.

7.9.3 Control of the ventilation system shall be included in the automation system. Failures shall be alarmed.

8. Safety equipment and safety systems

Basic requirements as specified in the TLRulesChapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels shall be observed.

8.1 Safety concept and system FMEA

8.1.1 The safety concept shall describe the safety philosophy with regard to gas as fuel and in particular address how risks associated with this type of fuel are controlled. The safety concept shall also describe possible failure scenarios and the associated control measures.

8.1.2 In the system FMEA possible failure modes related to gas as fuel shall be examined and evaluated in detail with respect to their consequences on the engine and the surrounding systems as well as their likelihood of occurrence and mitigating measures.

Verification tests are to be defined. Aspects to be examined include, but shall not be limited to:

- Gas leakage, both engine internal and release of gas to the engine room – shut off of gas supply (inter alia with respect to systems that shall remain operational, refer 7.7.3)
- Incomplete/ knocking combustion

- Deviation from the specified gas composition
- Malfunction of the ignition system
- Uncontrolled gas admission to engine
- Switch over process from gas to fuel and vice versa for dual fuel engines
- Explosions in crankcase, scavenging air system and exhaust gas system
- Uncontrolled gas air mixing process, if outside cylinder
- Interfaces to other ship systems, e.g. control system, gas supply

8.2 Crankcase safety equipment

8.2.1 Piston failure

Piston failure and abnormal piston blow-by shall be detected and alarmed.

8.2.2 Crankcase

8.2.2.1 Crankcase venting pipes are to be equipped with flame arrestors.

8.2.2.2 A detailed evaluation regarding the hazard potential of fuel gas accumulation in the crankcase is to be carried out and included in the safety concept (see 8.1).

8.2.3 Removal of fuel gas from crankcase and inert gas injection

8.2.3.1 Means shall be provided to measure the fuel gas concentration in the crankcase.

8.2.3.2 Suitable measures, such as inert gas injection, shall be provided to remove fuel gas – air mixtures from the crankcase at engine standstill.

8.2.3.3 Suitable means shall be available to purge inert gas from the crankcase before opening the crankcase for maintenance.

8.2.3.4 Signs requiring a fuel and inert gas free atmosphere in the crankcase before opening of crankcase doors shall be placed in conspicuous locations.

Note:

Means for automatic injection of inert gas into the crankcase are recommended, e.g. in case of:

- *Engine emergency shutdown*
- *Oil mist detection as well as bearing and liner temperature alarm*
- *Fire detection in engine room*

8.3 Explosion relief valves

8.3.1 General requirements

8.3.1.1 Explosion relief devices shall close firmly after an explosion event.

8.3.1.2 The outlet of explosion relief devices shall discharge to a safe location remote from any source of ignition. The arrangement shall minimize the risk of injury to personnel.

8.3.2 Crankcase explosion relief valves

8.3.2.1 For crankcase safety devices (e.g. explosion relief valves, oil mist detection, etc.) the requirements specified in F.4. are to be observed.

8.3.2.2 Crankcase explosion relief valves are to be provided at each crank throw.

8.3.2.3 The minimum required total relief area of crankcase explosion relief valves is to be evaluated by engine maker considering explosions of fuel gas –air mixtures and oil mist.

8.3.3 Other explosion relief valves

8.3.3.1 As far as required in the TLRulesChapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels, explosion relief valves are to be

provided for combustion air inlet manifolds and exhaust manifolds.

8.3.3.2 Explosion relief valve shall generally be approved by **BCS** for the application on inlet manifolds and exhaust manifolds of gas-fuelled engines

.

8.3.3.3 For the approval of relief valves the following documentation is to be submitted (usually by the maker of explosion relief valve):

- Drawings of explosion relief valve (sectional drawings, details, assembly, etc.)
- Specification data sheet of explosion relief valve (incl. specification of operation conditions such as max. working pressure, max. working temperature, opening pressure, effective relief area, etc.)
- Test reports

8.3.3.4 In addition to the approval under 8.3.3.3 the arrangement of explosion relief valves shall be approved for each engine type. The following documents are to be submitted (usually by the engine manufacturer):

- Drawing of arrangement of explosion relief valves (incl. number, type, locations, etc.)
- Drawings of protected component (air inlet manifold, exhaust manifold, etc.) (incl. specification of max. working pressure, max. working temperature, max. permissible explosion pressure, etc.)
- Evidence for effectiveness of flame arrestor at actual arrangement
- Evidence for effectiveness of pressure relief at explosion (sufficient relief velocity, sufficient relief pressure)

Note:

Evidence can be provided by suitable tests or by theoretical analysis.

9. Tests**9.1 Type approval test for gas-fuelled engines**

9.1.1 Gas-fuelled engines shall be type approved by **BCS**.

9.1.2 The scope of type approval testing stated in E.4. applies as far as pertinent also to gas-fuelled engines. Additional or differing requirements reflecting gas specific aspects are listed below. The type test program is to be agreed with **BCS**.

9.1.3 Tests:

- Load acceptance test and load cut off
- Fuel change-over procedures (for dual fuel engines)
- Combustion monitoring
- Safety system
- Alarm system
- Monitoring system
- Control system
- Gas detection
- Tightness tests of gas piping and double wall pipes and ducts
- Ignition system
- Automatic gas shut off
- Turbocharger waste gate, by-pass, etc.
- Ventilation system
- Start, stop, emergency stop
- Verification tests resulting from the system FMEA

9.2 Works trials

In addition to the requirements of E.5., the following items shall be tested during works trials of gas fuelled engines:

- Tightness test of gas system
- Testing of systems for combustion monitoring
- Testing of gas shut off and fuel change-over (dual-fuel engines) procedures

9.3 Shipboard trials

In addition to the requirements of E.6., during shipboard trials the following items shall be tested:

- Tightness test of gas system
- Testing of systems for combustion monitoring
- Testing of gas shut off and fuel change-over (dual-fuel engines) procedures
- Testing of ventilation systems and gas detection systems

10. Machinery spaces

10.1 Sufficient air exchange and air flow shall be ensured around the engine to prevent accumulation of explosive, flammable, or toxic gas concentrations.

10.2 Direction of air flow in machinery spaces shall be directed in such way as to avoid flow of any leaking gas towards potential sources of ignition.

10.3 Machinery spaces shall have sufficient openings to the outside to allow pressure relief from the machinery space in case of an explosion event inside a gas-fuelled engine installed in the space.

10.4 Sign plates shall be fixed at adequate locations to make notice of gas-fuelled machinery to persons entering the relevant machinery spaces. Instructions regarding operation as well as behavior in

case of gas leaks and failure of machinery are to be provided at prominent positions in machinery spaces.

11. Training

Personnel operating gas-fuelled engines aboard a vessel shall be duly trained regarding operation of the specific engine, gas supply systems, safety- and control systems, etc. installed on the vessel.

12. Spare parts

Spare parts, which are of major importance for the safety and operational reliability of the gas-fuelled engine, as well as parts with limited lifetime, shall be provided on board in addition to those required in Section 17.

13. Retrofit

Acceptance criteria and procedure for conversion of existing oil-fuelled diesel engines into gas-fuelled or dual-fuel engines are to be individually agreed with **BCS**.

O. Safety of Internal Combustion Engines Supplied with Low Pressure Gas (up to 10 bar)

1. General

1.1 Scope

1.1.1 Type of engines

This subsection addresses the requirements for trunk piston internal combustion engines supplied with low pressure natural gas as fuel. This subsection is to be applied in association with other relevant **BCS** internal combustion engine requirements, as far as found applicable to the specific natural gas burning engine design.

The mandatory international codes for gas carriers (IGC Code) and for other ships burning low flashpoint fuels (IGF Code) must also be considered, as applicable.

Specific requirements of the IGF Code as referenced in this subsection shall be applied to engine types covered

by this subsection installed on any ship, regardless of type, size and trading area, as long as the IGC Code is not referenced or explicitly specified otherwise. Engines can be either dual fuel engines (hereinafter referred to as DF engines) or gas fuel only engines (hereinafter referred to as GF engines).

Gas can be introduced as follows:

- into the air inlet manifold, scavenge space, or cylinder air inlet channel port; or
- mixed with air before the turbo-charger ("pre-mixed engines").

The gas / air mixture in the cylinder can be ignited by the combustion of a certain amount of fuel (pilot injection) or by extraneous ignition (sparking plug).

The scope of the subsection is limited to natural gas fuelled engines

1.1.2 Applications

This subsection covers the following applications, but is not limited to:

- Mechanical propulsion
- Generating sets intended for main propulsion and auxiliary applications.
- Single engine or multi-engine installations.

1.2 Definitions

1.2.1 Certified safe type means electrical equipment that is certified in accordance with the recommendation published by the International Electrotechnical Commission (IEC), in particular publication IEC 60092-502, or with recognized standards at least equivalent. The certification of electrical equipment is to correspond to the category and group for methane gas.

1.2.2 Double block and bleed valves means the set of valves referred to in:

- Chapter 10 - Liquefied Gas Carriers, Section 16, Item 16.4.5 (IGC Code, 16.4.5)

- Chapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels, Item 2.2.9 and Items 9.4.4 to 9.4.6 (IGF Code, 2.2.9 and 9.4.4 to 9.4.6)

1.2.3 Dual fuel engine (“DF engine”) means an engine that can burn natural gas as fuel simultaneously with liquid fuel, either as pilot oil or bigger amount of liquid fuel (gas mode), and also has the capability of running on liquid diesel fuel oil only (Diesel mode).

1.2.4 Engine room is a machinery space or enclosure containing gas fuelled engine(s).

1.2.5 Gas means a fluid having a vapour pressure exceeding 2.8 bar absolute at a temperature of 37.8°C.

1.2.6 Gas admission valve is a valve or injector on the engine, which controls gas supply to the cylinder(s) according to the cylinder(s) actual gas demand.

1.2.7 Gas engine means either a DF engine or a GF engine.

1.2.8 Gas fuel only engine (“GF engine”) means an engine capable of operating on gas fuel only and not able to switch over to oil fuel operation.

1.2.9 Gas piping means piping containing gas or air / gas mixtures, including venting pipes.

1.2.10 Gas Valve Unit (GVU) is a set of manual shutoff valves, actuated shut-off and venting valves, gas pressure sensors and transmitters, gas temperature sensors and transmitters, gas pressure control valve and gas filter used to control the gas supply to each gas consumer. It also includes a connection for inert gas purging.

1.2.11 IGC Code means the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (as amended by IMO Resolution MSC.370(93)).

1.2.12 IMO means the International Maritime Organisation

1.2.13 IGF Code means the International Code of Safety for Ships Using Gases or other Low-Flashpoint Fuels (IMO Resolution MSC.391(95)).

1.2.14 Low pressure gas means gas with a pressure up to 10 bar.

1.2.15 Lower Heating Value (“LHV”) means the amount of heat produced from the complete combustion of a specific amount of fuel, excluding latent heat of vaporization of water.

1.2.16 Methane Number is a measure of resistance of a gas fuel to knock, which is assigned to a test fuel based upon operation in knock testing unit at the same standard knock intensity.

Note:

Pure methane is used as the knock resistant reference fuel, that is, methane number of pure methane is 100, and pure hydrogen is used as the knock sensitive reference fuel, methane number of pure hydrogen is 0.

1.2.17 Pilot fuel means the fuel oil that is injected into the cylinder to ignite the main gas-air mixture on DF engines.

1.2.18 Pre-mixed engine means an engine where gas is supplied in a mixture with air before the turbocharger.

1.2.19 Recognized standards means applicable international or national standards acceptable to **BCS** or standards laid down and maintained by an organisation which complies with the standards adopted by IMO and which are recognized by **BCS**.

1.2.20 Safety Concept is a document describing the safety philosophy with regard to gas as fuel. It describes how risks associated with this type of fuel are controlled under reasonably foreseeable abnormal conditions as well as possible failure scenarios and their control measures.

Note:

A detailed evaluation regarding the hazard potential of injury from a possible explosion is to be carried out and reflected in the safety concept of the engine.

1.3 Documents and drawings to be submitted

1.3.1 Documents and drawings to be submitted for the approval of DF and GF engines

The following documents are to be submitted for the approval of DF and GF engines, in addition to those required in Table 2.1, 2.2 and 2.3.

No.	Item
1	Schematic layout or other equivalent documents of gas system on the engine
2	Gas piping system (including double-walled arrangement where applicable)
3	Parts for gas admission system (3)
4	Arrangement of explosion relief valves (crankcase (1) , charge air manifold, exhaust gas manifold) as applicable
5	List of certified safe equipment and evidence of relevant certification
6	Safety concept (for information)
7	Report of the risk analysis (2) (for information)
8	Gas specification (for information)
(1) If required by Table 2.2 and 2.3.	
(2) See 1.4.	
(3) The documentation to contain specification of pressures, pipe dimensions and materials.	

1.3.2 Documents and drawings to be submitted for the approval of DF engine

No.	Item
9	Schematic layout or other equivalent documents of fuel oil system (main and pilot fuel systems) on the engine
10	Shielding of high pressure fuel pipes for pilot fuel system, assembly
11	High pressure parts for pilot fuel oil injection system (3)
(3) The documentation to contain specification of pressures, pipe dimensions and materials.	

1.3.3 Documents and drawings to be submitted for the approval of GF engine

No.	Item
12	Ignition system

1.3.4 Where considered necessary, **BCS** may request further documents to be submitted.

1.4 Risk analysis

1.4.1 Scope of the risk analysis

The risk analysis is to address:

- a failure or malfunction of any system or component involved in the gas operation of the engine
- a gas leakage downstream of the gas valve unit
- the safety of the engine in case of emergency shutdown or blackout, when running on gas
- the inter-actions between the gas fuel system and the engine.

Note:

With regard to the scope of the risk analysis it shall be noted that failures in systems external to the engine, such as fuel storage or fuel gas supply systems, may require action from the engine control and monitoring system in the event of an alarm or fault condition. Conversely failures in these external systems may, from the vessel perspective, require additional safety actions from those required by the engine limited risk analysis required by this subsection.

1.4.2 Form of the risk analysis

The risk analysis is to be carried out in accordance with international standard ISO 31010 Risk management - Risk assessment techniques, or other recognized standards.

The required analysis is to be based on the single failure concept, which means that only one failure needs to be considered at the same time. Both detectable and non-detectable failures are to be considered. Consequences failures, i.e. failures of any component directly caused by a single failure of another component, are also to be considered.

1.4.3 Procedure for the risk analysis

The risk analysis is to:

- a) Identify all the possible failures in the concerned equipment and systems which could lead:
 - to the presence of gas in components or locations not designed for such purpose, and/or

- to ignition, fire or explosion.
- b)** Evaluate the consequences
- c)** Where necessary, identify the failure detection method
- d)** Where the risk cannot be eliminated, identify the corrective measures:
 - in the system design, such as:
 - redundancies
 - safety devices, monitoring or alarm provisions which permit restricted operation of the system
 - the system operation, such as:
 - initiation of the redundancy
 - activation of an alternative mode of operation.

The results of the risk analysis are to be documented.

1.4.4 Equipment and systems to be analysed

The risk analysis required for engines is to cover at least the following aspects:

- a)** failure of the gas-related systems or components, in particular:
 - gas piping and its enclosure, where provided
 - cylinder gas supply valves

Note:

Failures of the gas supply components not located directly on the engine, such as block-and-bleed valves and other components of the Gas Valve Unit (GVU), are not to be considered in the analysis.

- b)** failure of the ignition system (oil fuel pilot injection or sparking plugs)
- c)** failure of the air to fuel ratio control system (charge air by-pass, gas pressure control valve, etc.)

- d)** for engines where gas is injected upstream of the turbocharger compressor, failure of a component likely to result in a source of ignition (hot spots)
- e)** failure of the gas combustion or abnormal combustion (misfiring, knocking)
- f)** failure of the engine monitoring, control and safety systems

Note:

Where engines incorporate electronic control systems, a failure mode and effects analysis (FMEA) is to be carried out in accordance with Table 2.1, Footnote 5.

- g)** abnormal presence of gas in engine components (e.g. air inlet manifold and exhaust manifold of DF or GF engines) and in the external systems connected to the engines (e.g. exhaust duct).
- h)** changes of operating modes for DF engines
- i)** hazard potential for crankcase fuel gas accumulation, for engines where the space below the piston is in direct communication with the crankcase, refer to Chapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels, Item 10.3.1.2 (IGF Code 10.3.1.2)

2. Design Requirements

2.1 General Principles

2.1.1 The manufacturer is to declare the allowable gas composition limits for the engine and the minimum and (if applicable) maximum methane number.

2.1.2 Components containing or likely to contain gas are to be designed to:

- a)** minimise the risk of fire and explosion so as to demonstrate an appropriate level of safety commensurate with that of an oil-fuelled engine;
- b)** mitigate the consequences of a possible explosion to a level providing a tolerable degree

of residual risk, due to the strength of the component(s) or the fitting of suitable pressure relief devices of an approved type.

Also refer to the Chapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels, Item 10.2 and 10.3 (IGF Code 10.2 and 10.3).

Note:

- *Discharge from pressure relief devices shall prevent the passage of flame to the machinery space and be arranged such that the discharge does not endanger personnel or damage other engine components or systems”*
- *Relief devices shall be fitted with a flame arrester.*

2.2 Design Requirements

2.2.1 Gas piping

2.2.1.1 General

The requirements of this section apply to engine-mounted gas piping. The piping shall be designed in accordance with the criteria for gas piping (design pressure, wall thickness, materials, piping fabrication and joining details etc.) as given in the Chapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels, Section 7 (IGF Code chapter 7). For gas carriers, Chapter 10 - Liquefied Gas Carriers, Section 5, Item 5.1 to 5.9 and Section 16 (IGC Code chapter 5.1 to 5.9 and 16) applies.

2.2.2 Arrangement of the gas piping system on the engine

Pipes and equipment containing fuel gas are defined as hazardous area Zone 0 (refer to Chapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels, Item 12.5.1 (IGF Code 12.5.1)).

The space between the gas fuel piping and the wall of the outer pipe or duct is defined as hazardous area Zone 1 (refer to Chapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels, Item 12.5.2.6 (IGF Code 12.5.2.6)).

2.2.2.1 Normal “double wall” arrangement

The gas piping system on the engine shall be arranged according to the principles and requirements of Chapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels, Item 9.6 (IGF Code 9.6). For gas carriers, Chapter 10 - Liquefied Gas Carriers, Item 16.4.3 (IGC Code 16.4.3) applies.

The design criteria for the double pipe or duct are given in the Chapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels, Item 9.8 and 7.4.1.4 (IGF Code 9.8 and 7.4.1.4).

In case of a ventilated double wall, the ventilation inlet is to be located in accordance with the provisions of Chapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels, Item 13.8.3 (IGF Code, regulation 13.8.3). For gas carriers, Chapter 10 - Liquefied Gas Carriers, Item 16.4.3.2 (IGC Code 16.4.3.2) applies.

The pipe or duct is to be pressure tested in accordance with B.4.2.1 of Section 16 to ensure gas tight integrity and to show that it can withstand the expected maximum pressure at gas pipe rupture.

2.2.2.2 Alternative arrangement

Single walled gas piping is only acceptable

- a) for engines installed in ESD protected machinery spaces, as defined in Chapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels, Item 5.4.1.2 (IGF Code 5.4.1.2) and in compliance with other relevant parts of the Chapter 78 (e.g. 5.6) (IGF Code (e.g. 5.6));
- b) in the case as per footnote(19) of to item 9.6.2 of Chapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels (footnote 18 to paragraph 9.6.2 of IGF Code).

For gas carriers, the IGC Code applies.

In case of gas leakage in an ESD-protected machinery space, which would result in the shutdown of the

engine(s) in that space, a sufficient propulsion and manoeuvring capability including essential and safety systems is to be maintained.

Therefore the safety concept of the engine is to clearly indicate application of the “double wall” or “alternative” arrangement.

Note:

The minimum power to be maintained is to be assessed on a case-by-case basis from the operational characteristics of the ship.

2.2.3 Charge air system on the engine

The charge air system on the engine is to be designed in accordance with 2.1.2 above. In case of a single engine installation, the engine is to be capable of operating at sufficient load to maintain power to essential consumers after opening of the pressure relief devices caused by an explosion event. Sufficient power for propulsion capability is to be maintained.

Note:

Load reduction is to be considered on a case by case basis, depending on engine configuration (single or multiple) and relief mechanism (self-closing valve or bursting disk).

2.2.4 Exhaust system on the engine

The exhaust gas system on the engine is to be designed in accordance with 2.1.2 above. In case of a single engine installation, the engine is to be capable of operating at sufficient load to maintain power to essential consumers after opening of the pressure relief devices caused by an explosion event. Sufficient power for propulsion capability is to be maintained.

Continuous relief of exhaust gas (through open rupture disc) into the engine room or other enclosed spaces is not acceptable.

2.2.5 Engine crankcase

2.2.5.1 Crankcase explosion relief valves

Crankcase explosion relief valves are to be installed in accordance with F.4. Refer also to Chapter 78 – Rules

for Classification of Ships Using Gases or Other Low-Flashpoint Fuels, Item 10.3.1.2 (IGF Code 10.3.1.2).

2.2.5.2 Inerting

For maintenance purposes, a connection, or other means, are to be provided for crankcase inerting and ventilating and gas concentration measuring.

2.2.6 Gas ignition in the cylinder

2.2.6.1 Requirements of Chapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels, Item 10.3(IGF Code 10.3) apply. For gas carriers, Chapter 10 - Liquefied Gas Carriers, Item 16.7 (IGC Code 16.7) applies.

2.2.7 Control, monitoring, alarm and safety systems

The engine control system is to be independent and separate from the safety system.

The gas supply valves are to be controlled by the engine control system or by the engine gas demand.

Combustion is to be monitored on an individual cylinder basis.

In the event that poor combustion is detected on an individual cylinder, gas operation may be allowed in the conditions specified in item 10.3.1.6 of Chapter 78 – Rules for Classification of Ships Using Gases or Other Low-Flashpoint Fuels (IGF Code 10.3.1.6).

If monitoring of combustion for each individual cylinder is not practicable due to engine size and design, common combustion monitoring may be accepted.

Unless the risk analysis required by 1.4 of this subsection proves otherwise, the monitoring and safety system functions for DF or GF engines are to be provided in accordance with Table 1 of this subsection in addition to the general monitoring and safety system functions given by **BCS**.

Note:

For DF engines, Table 1 applies only to the gas mode.

Table 2.13 Monitoring and Safety System Functions for DF and GF Engines

Parameter	Alarm	Alarm Automatic activation of the double block-and-bleed valves	Automatic switching over to oil fuel mode (1)	Engine shutdown
Abnormal pressures in the gas fuel supply line	X	X	X	X (5)
Gas fuel supply systems - malfunction	X	X	X	X (5)
Pilot fuel injection or spark ignition systems - malfunction	X	X (2)	X	X (2)(5)
Exhaust gas temperature after each cylinder - high	X	X (2)	X	X (2)(5)
Exhaust gas temperature after each cylinder, deviation from average – low (3)	X	X (2)	X	X (2)(5)
Cylinder pressure or ignition - failure, including misfiring, knocking and unstable combustion	X	X (2)(4)	X (4)	X (2)(4)(5)
Oil mist concentration in crankcase or bearing temperature (6) - high	X	X		X
Pressure in the crankcase – high (4)	X	X	X	
Engine stops - any cause	X	X		
Failure of the control-actuating medium of the block and bleed valves	X	X	X	
Footnotes: (1) DF engine only, when running in gas mode (2) For GF engines, the double block-and-bleed valves and the engine shutdown may not be activated in case of specific failures affecting only one cylinder, provided that the concerned cylinder can be individually shutoff and the safe operation of the engine in such conditions is demonstrated by the risk analysis. (3) Required only if necessary for the detection of misfiring (4) In the case where the failure can be corrected by an automatic mitigation action, only the alarm may be activated. If the failure persists after a given time, the safety actions are to be activated. (5) GF engine only (6) Where required by BCS-R M10				

2.2.8 Gas admission valves

Gas admission valves shall be certified safe as follows:

- The inside of the valve contains gas and shall therefore be certified for Zone 0.
- When the valve is located within a pipe or duct in accordance with 2.2.2.1, the outside of the valve shall be certified for Zone 1.
- When the valve is arranged without enclosure in accordance with the “ESD-protected machinery space” (see 2.2.2.2) concept, no certification is required for the outside of the valve, provided that the valve is de-energized upon gas detection in the space.

However, if they are not rated for the zone they are intended for, it shall be documented that they are suitable for that zone. Documentation and analysis is to be based on IEC 60079-10-1 or IEC 60092-502.

3. Specific Design Requirements

3.1 DF Engines

3.1.1 General

The maximum continuous power that a DF engine can develop in gas mode may be lower than the approved MCR of the engine (i.e. in oil fuel mode), depending in particular on the gas quality.

This maximum power available in gas mode and the corresponding conditions shall be stated by the engine manufacturer and demonstrated during the type test.

3.1.2 Starting, changeover and stopping

DF engines are to be arranged to use either oil fuel or gas fuel for the main fuel charge and with pilot oil fuel for ignition. The engines are to be arranged for rapid changeover from gas use to fuel oil use. In the case of changeover to either fuel supply, the engines are to be capable of continuous operation using the alternative fuel supply without interruption to the power supply.

Changeover to gas fuel operation is to be only possible at a power level and under conditions where it can be done with acceptable reliability and safety as demonstrated through testing.

Changeover from gas fuel operation mode to oil fuel operation mode is to be possible at all situations and power levels.

The changeover process itself from and to gas operation is to be automatic but manual interruption is to be possible in all cases.

In case of shut-off of the gas supply, the engines are to be capable of continuous operation by oil fuel only.

3.1.3 Pilot injection

Gas supply to the combustion chamber is not to be possible without operation of the pilot oil injection.

Note:

Pilot injection is to be monitored for example by fuel oil pressure and combustion parameters.

3.2 GF Engines

3.2.1 Spark ignition system

In case of failure of the spark ignition, the engine is to be shut down except if this failure is limited to one cylinder, subject to immediate shut off of the cylinder gas supply and provided that the safe operation of the engine is substantiated by the risk analysis and by tests.

3.3 Pre-Mixed Engines

3.3.1 Charge air system

Inlet manifold, turbo-charger, charge air cooler, etc. are to be regarded as parts of the fuel gas supply system. Failures of those components likely to result in a gas leakage are to be considered in the risk analysis (see 1.4).

Flame arresters are to be installed before each cylinder head, unless otherwise justified in the risk analysis, considering design parameters of the engine such as

the gas concentration in the charge air system, the path length of the gas-air mixture in the charge air system, etc.

4. Type Testing, Factory Acceptance Tests and Shipboard Trials

4.1 Type Testing

4.1.1 General

Type approval of DF and GF engines is to be carried out in accordance with E.3, taking into account the additional requirements below.

4.1.2 Type of engine

In addition to the criteria given in E.3.3.3 the type of engine is defined by the following:

- gas admission method (direct cylinder injection, charge air space or pre-mixed)
- gas supply valve operation (mechanical or electronically controlled)
- ignition system (pilot injection, spark ignition, glow plug or gas self-ignition)
- ignition system (mechanical or electronically controlled)

4.1.3 Safety precautions

In addition to the safety precautions mentioned in E.3.4, measures to verify that gas fuel piping on engine is gas tight are to be carried out prior to start-up of the engine.

4.1.4 Test programme

The type testing of the engine is to be carried out in accordance with E.3.5.

For DF engines, the load tests referred to in E.3.5 are to be carried out in gas mode at the different percentages of the maximum power available in gas mode (see 3.1.1).

The 110% load tests are not required in the gas mode.

The influence of the methane number and LHV of the fuel gas is not required to be verified during the Stage B type tests. It shall however be justified by the engine designer through internal tests or calculations and documented in the type approval test report.

4.1.5 Measurements and records

In addition to the measurements and records required in E.3.6, the following engine data are to be measured and recorded:

- Each fuel index for gas and diesel as applicable (or equivalent reading)
- Gas pressure and temperature at the inlet of the gas manifold
- Gas concentration in the crankcase

Additional measurements may be required in connection with the design assessment.

4.1.6 Stage A – internal tests

In addition to tests required in E.3.7, the following conditions are to be tested:

- DF engines are to run the load points defined in E.3.7 in both gas and diesel modes (with and without pilot injection in service) as found applicable for the engine type.
- For DF engines with variable liquid / gas ratio, the load tests are to be carried out at different ratios between the minimum and the maximum allowable values.
- For DF engines, switch over between gas and diesel modes are to be tested at different loads.

4.1.7 Stage B – witnessed tests

4.1.7.1 General

Gas engines are to undergo the different tests required in E.3.8.

In case of DF engine, all load points must be run in both gas and diesel modes that apply for the engine type as defined by the engine designer (see 4.1.4). This also applies to the overspeed test.

In case of DF engines with variable liquid / gas ratio, the load tests are to be carried out at different ratios between the minimum and the maximum allowable values.

4.1.7.2 Functional tests

In addition to the functional tests required in E.3.8.3, the following tests are to be carried out:

- For DF engines, the lowest specified speed is to be verified in diesel mode and gas mode.
- For DF engines, switch over between gas and diesel modes are to be tested at different loads.
- The efficiency of the ventilation arrangement of the double walled gas piping system is to be verified.
- Simulation of a gas leakage in way of a cylinder gas supply valve.

Engines intended to produce electrical power are to be tested as follows:

- Capability to take sudden load and loss of load in accordance with the provisions of BCS-R M3.2.3
- For GF and premixed engines, the influences of LHV, methane number and ambient conditions on the dynamic load response test results are to be theoretically determined and specified in the test report. Referring to the limitations as specified in 2.1.2, the margin for satisfying dynamic load response is to be determined.

Note:

1. For DF engines, switchover to oil fuel during the test is acceptable.

2. Application of electrical load in more than 2 load steps can be permitted in the conditions stated in BCS-R M3.2.3.

4.1.7.3 Integration Tests

GF and DF engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic engine system is as predicted for all intended operational modes. The scope of these tests is to be agreed with **BCS** for selected cases based on the risk analysis required in 1.4 of this subsection, and shall at least include the following incidents:

- Failure of ignition (spark ignition or pilot injection systems), both for one cylinder unit and common system failure
- Failure of a cylinder gas supply valve
- Failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.)
- Abnormal gas pressure
- Abnormal gas temperature **(4)**

4.1.8 Stage C – Component inspection

Component inspection is to be carried out in accordance with the provisions of E.3.9.

The components to be inspected after the test run are to include also:

- gas supply valve including pre-chamber as found applicable
- spark igniter (for GF engines)
- pilot fuel injection valve (for DF engines)

(4) This test may be carried out using a simulation signal of the temperature.

4.2 Factory Acceptance Test

4.2.1 General

Factory acceptance tests of DF and GF engines are to be carried out in accordance with E.4, taking into account the additional requirements below.

For DF engines, the load tests referred to in E.4.3.3 are to be carried out in gas mode at the different percentages of the maximum power available in gas mode (see 3.1.1). The 110% load test is not required in the gas mode.

4.2.2 Safety precautions

In addition to the safety precautions mentioned in E.4.1, measures to verify that gas fuel piping on engine is gas tight are to be carried out prior to start-up of the engine.

4.2.3 Records

In addition to the records required in E.4.3.2, the following engine data are to be recorded:

- Fuel index, both gas and diesel as applicable (or equivalent reading)
- Gas pressure and temperature

4.2.4 Test loads

Test loads for various engine applications are given in E.4.3.3. DF engines are to be tested in both diesel and gas mode as found applicable. In addition the scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

4.2.5 Integration tests

GF and DF engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes.

The scope of these tests is to be agreed with **BCS** for selected cases based on the risk analysis required in

1.4 of this subsection and shall at least include the following incidents:

- Failure of ignition (spark ignition or pilot injection systems), for one cylinder unit
- Failure of a cylinder gas supply valve
- Failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.)
- Abnormal gas pressure
- Abnormal gas temperature

The above tests may be carried out using simulation or other alternative methods, subject to special consideration by **BCS**.

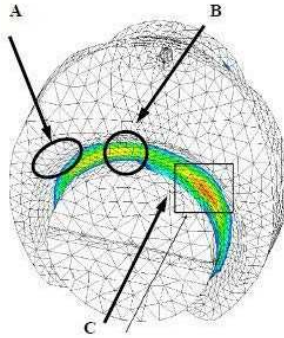
4.3 Shipboard Trials

Shipboard trials are to be carried out in accordance with the provisions of E.4.4.

For DF engines, the test loads required in E.4.4.4 are to be carried out in all operating modes (gas mode, diesel mode, etc.).

APPENDIX I

DEFINITION OF STRESS CONCENTRATION FACTORS IN CRANKSHAFT FILLETS



Stress		Max $\ \sigma_3\ $	Max σ_1	
Torsional loading	Location of maximal stresses	A	C	B
	Typical principal stress System			
	Mohr's circle diagram With $\sigma_2 = 0$	$\ \sigma_3\ > \sigma_1$	$\sigma_1 > \ \sigma_3\ $	$\sigma_1 = \ \sigma_3\ $
	Equivalent stress and S.C.F.	$\tau_{equiv} = \frac{\sigma_1 - \sigma_3}{2}$ $S.C.F. = \frac{\tau_{equiv}}{\tau_n} \text{ for } \alpha, \beta_T$		
Bending loading	Location of maximal stresses	B	B	B
	Typical principal Stress system			
	Mohr's circle diagram With $\sigma_3 = 0$	$\sigma_2 \neq 0$		
	Equivalent stress And S.C.F	$\sigma_{equiv} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1 \sigma_2}$ $S.C.F. = \frac{\sigma_{equiv}}{\sigma_n} \text{ for } \alpha_B, \beta_B, \beta_Q$		

Fig. 1.1 Definition of stress concentration factors in crankshafts fillets

APPENDIX II

STRESS CONCENTRATION FACTORS AND STRESS DISTRIBUTION AT THE EDGE OF OIL DRILLINGS

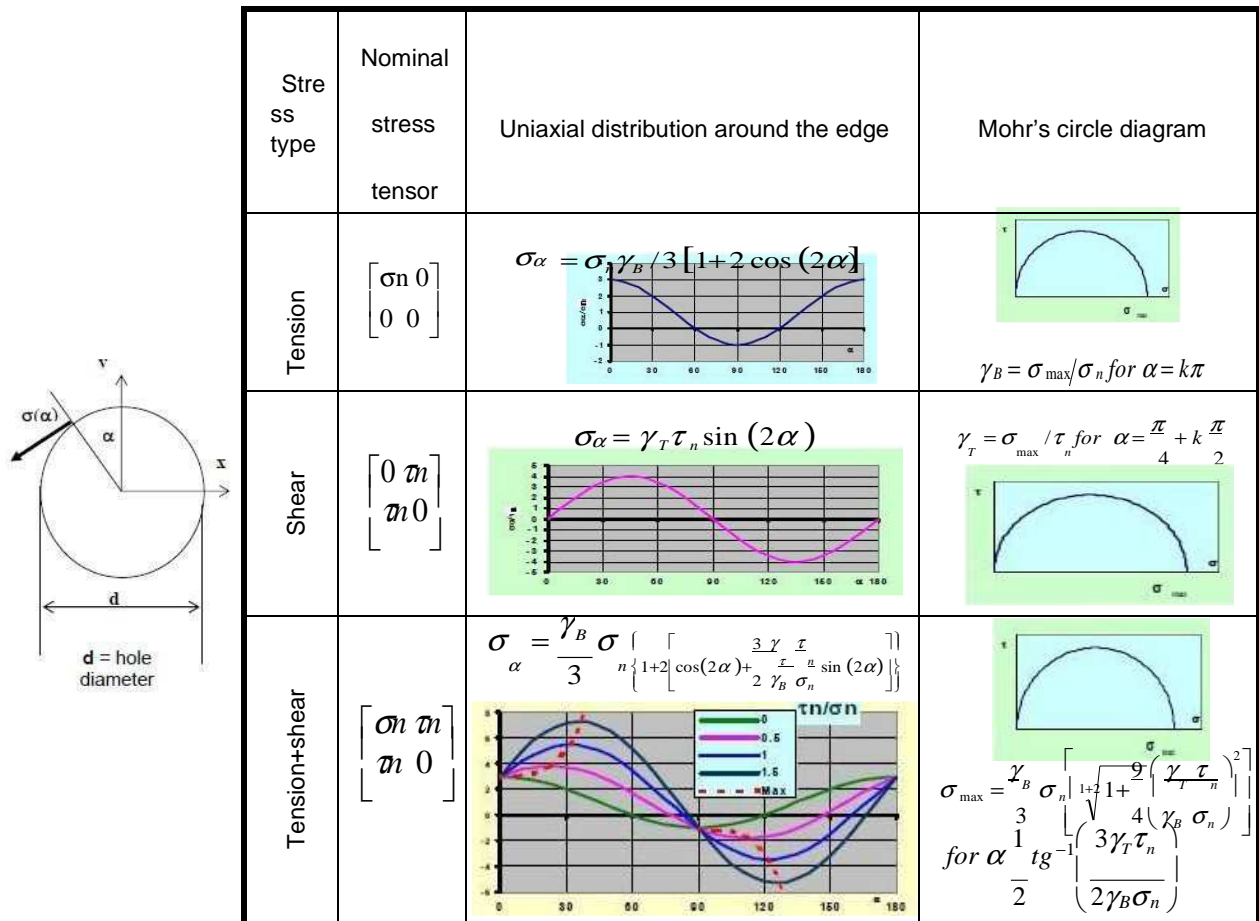


Fig. 2.1 Stress concentration factors and stress distribution at the edge of oil drillings

APPENDIX III

GUIDANCE FOR CALCULATION OF STRESS CONCENTRATION FACTORS IN THE WEB FILLET RADII OF CRANKSHAFTS BY UTILIZING FINITE ELEMENT METHOD

1. General

The objective of the analysis is to develop Finite Element Method (FEM) calculated figures as an alternative to the analytically calculated Stress Concentration Factors (SCF) at the crankshaft fillets. The analytical method is based on empirical formulae developed from strain gauge measurements of various crank geometries and accordingly the application of these formulae is limited to those geometries.

The SCF's calculated according to the rules of this document are defined as the ratio of stresses calculated by FEM to nominal stresses in both journal and pin fillets. When used in connection with the present method in this section or the alternative methods, von Misses stresses shall be calculated for bending and principal stresses for torsion.

The procedure as well as evaluation guidelines are valid for both solid cranks and semi-built cranks (except journal fillets).

The analysis is to be conducted as linear elastic FE analysis, and unit loads of appropriate magnitude are to be applied for all load cases.

The calculation of SCF at the oil bores is not covered by this document.

It is advised to check the element accuracy of the FE solver in use, e.g. by modeling a simple geometry and comparing the stresses obtained by FEM with the analytical solution for pure bending and torsion.

Boundary Element Method (BEM) may be used instead of FEM.

2. Model requirements

The basic recommendations and perceptions for building

the FE-model are presented in 2.1. It is obligatory for the final FE-model to fulfill the requirement in 2.3.

2.1 Element mesh recommendations

In order to fulfil the mesh quality criteria it is advised to construct the FE model for the evaluation of Stress Concentration Factors according to the following recommendations:

- The model consists of one complete crank, from the main bearing centerline to the opposite side main bearing centerline
- Element types used in the vicinity of the fillets:
 - 10 node tetrahedral elements
 - 8 node hexahedral elements
 - 20 node hexahedral elements
- Mesh properties in fillet radii. The following applies to ± 90 degrees in circumferential direction from the crank plane:
- Maximum element size $a=r/4$ through the entire fillet as well as in the circumferential direction. When using 20 node hexahedral elements, the element size in the circumferential direction may be extended up to $5a$. In the case of multi-radii fillet r is the local fillet radius. (If 8 node hexahedral elements are used even smaller element size is required to meet the quality criteria.)
- Recommended manner for element size in fillet depth direction
 - First layer thickness equal to element size of a
 - Second layer thickness equal to element to size of $2a$

- Third layer thickness equal to element to size of 3a
- Minimum 6 elements across web thickness.
- Generally the rest of the crank should be suitable for numeric stability of the solver.
- Counterweights only have to be modeled only when influencing the global stiffness of the crank significantly.
- Modeling of oil drillings is not necessary as long as the influence on global stiffness is negligible and the proximity to the fillet is more than 2r, see figure 2.1.
- Drillings and holes for weight reduction have to be modeled.
- Sub-modeling may be used as far as the software requirements are fulfilled.

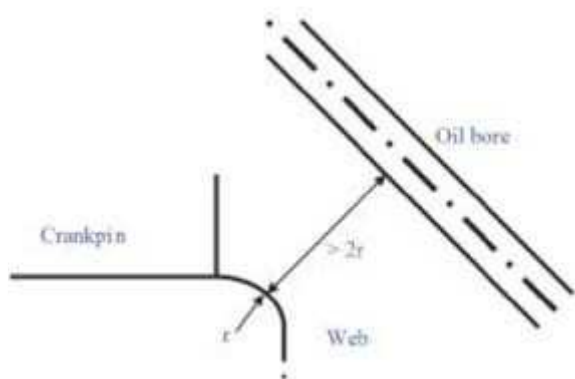


Fig. 2.1 Oil bore proximity to fillet

2.2 Material

In FE analysis, Young's Modulus (E) and Poisson's ratio (ν) are required, as strain is primarily calculated and stress is derived from strain using those material parameters.

Reliable values for material parameters have to be used, either as quoted in literature or as measured on representative material samples.

For steel the following is advised:

$E = 2.05 \cdot 10^5$ MPa and $\nu = 0.3$.

2.3 Element mesh quality criteria

If the actual element mesh does not fulfill any of the following criteria at the examined area for SCF evaluation, then a second calculation with a refined mesh is to be performed.

2.3.1 Principal stresses criterion

The quality of the mesh should be assured by checking the stress component normal to the surface of the fillet radius. Ideally, this stress should be zero. With principal stresses σ_1 , σ_2 and σ_3 the following criterion is required:

$$\min(|\sigma_1|, |\sigma_2|, |\sigma_3|) < 0.03 \cdot \max(|\sigma_1|, |\sigma_2|, |\sigma_3|)$$

2.3.2 Averaged/unaveraged stresses criterion

The criterion is based on observing the discontinuity of stress results over elements at the fillet for the calculation of SCF:

- Unaveraged nodal stress results calculated from each element connected to a node_i should differ less than by 5 % from the 100 % averaged nodal stress results at this node_i at the examined location.

3. Load cases

To substitute the analytically determined SCF in this section, the following load cases have to be calculated.

3.1 Torsion

In analogy to the testing apparatus used for the investigations made by FVV the structure is loaded pure torsion. In the model surface warp at the end faces is suppressed.

Torque is applied to the central node located at the crankshaft axis. This node acts as the master node with 6 degrees of freedom and is connected rigidly to all nodes of the end face.

Boundary and load conditions are valid for both in-line and V-type engines.

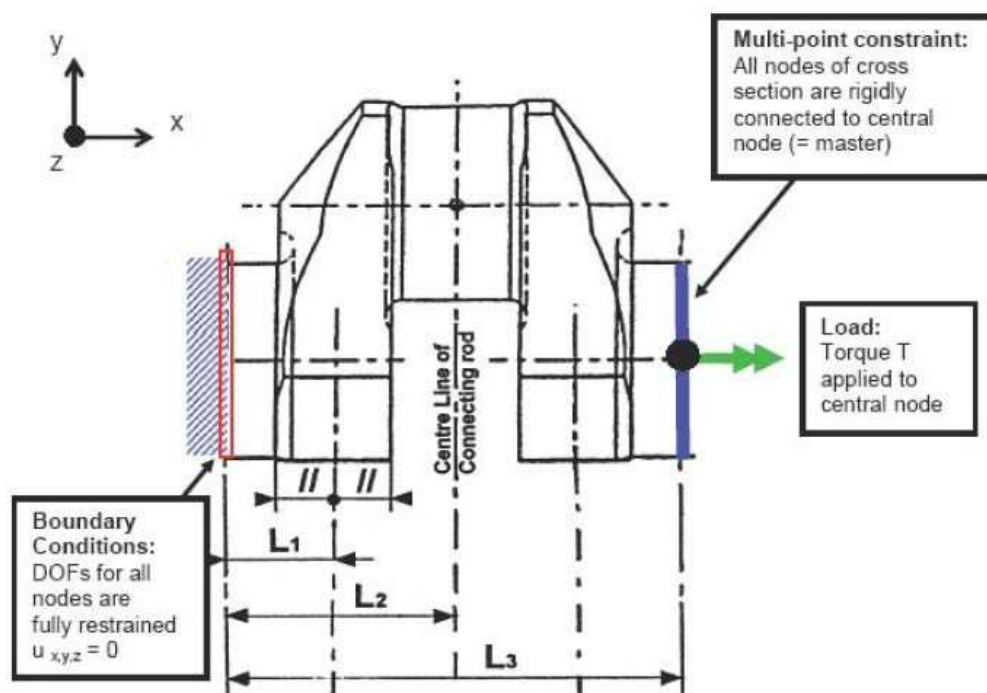


Fig. 3.1 Boundary and load conditions for the torsion load case

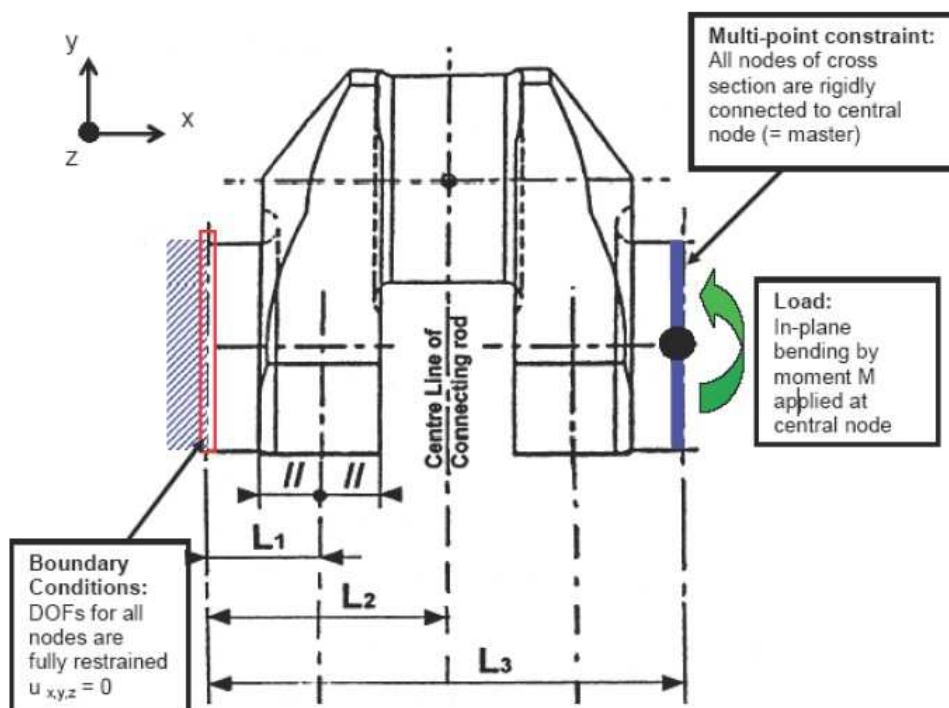


Fig. 3.2 Boundary and load conditions for the pure bending load case

For all nodes in both the journal and crank pin fillet principal stresses are extracted and the equivalent torsional stress is calculated:

$$\tau_{equiv} = \max \left(\frac{|\sigma_1 - \sigma_2|}{2}, \frac{|\sigma_2 - \sigma_3|}{2}, \frac{|\sigma_1 - \sigma_3|}{2} \right)$$

The maximum value taken for the subsequent calculation of the SCF:

$$\alpha = \frac{\tau_{equiv,\alpha}}{\tau_N}$$

$$\beta = \frac{\tau_{equiv,\beta}}{\tau_N}$$

where τ_N is nominal torsional stress referred to the crankpin and respectively journal as per D-2.2.2 with the torsional torque T:

$$\tau_N = \frac{T}{W_p}$$

3.2 Pure bending (4 point bending)

In analogy to the testing apparatus used for the investigations made by FVV the structure is loaded in pure bending. In the model surface warp at the end faces is suppressed. The bending moment is applied to the central node located at the crankshaft axis. This node acts as the master node with 6 degrees of freedom and is connected rigidly to all nodes of the end face. Boundary and load conditions are valid for both in-line- and V- type engines.

For all nodes in both the journal and pin fillet von Mises equivalent stresses σ_{equiv} are extracted. The maximum value is used to calculate the SCF according to:

$$\alpha = \frac{\sigma_{equiv,\alpha}}{\sigma_N}$$

$$\beta = \frac{\sigma_{equiv,\beta}}{\sigma_N}$$

Nominal stress σ_N is calculated as per D-2.1.2.1 with the bending moment M:

$$\sigma_N = \frac{M}{W_{eqw}}$$

3.3 Bending with shear force (3-point bending)

This load case is calculated to determine the SCF for pure transverse force (radial force, β_Q) for the journal fillet.

In analogy to the testing apparatus used for the investigations made by FVV, the structure is loaded in 3-point bending. In the model, surface warp at the both end faces is suppressed. All nodes are connected rigidly to the centre node; boundary conditions are applied to the centre nodes. These nodes act as master nodes with 6 degrees of freedom.

The force is applied to the central node located at the pin centre-line of the connecting rod. This node is connected to all nodes of the pin cross sectional area. Warping of the sectional area is not suppressed.

Boundary and load conditions are valid for in-line and V-type engines. V-type engines can be modeled with one connecting rod force only. Using two connecting rod forces will make no significant change in the SCF.

The maximum equivalent von Mises stress σ_{3P} in the journal fillet is evaluated. The SCF in the journal fillet can be determined in two ways as shown below.

3.3.1 Method 1

This method is analogue to the FVV investigation. The results from 3-point and 4-point bending are combined as follows:

$$\sigma_{3P} = \sigma_{N3P} \cdot \beta_B + \sigma_{Q3P} \cdot \beta_Q$$

where:

σ_{3P} = As found by the FE calculation.

σ_{N3P} = Nominal bending stress in the web centre due to the force F_{3P} [N] applied to the centre-line of the actual connecting rod, see figure 3.4.

β_B = As determined in paragraph 3.2.

$$\sigma_{Q3P} = \frac{Q_{3P}}{(B.W)}$$

where Q_{3P} is the radial (shear) force in the web due to the force F_{3P} [N] applied to the centre-line of the actual connecting rod, see also figures 2.3 and 2.4.

3.3.2 Method 2

This method is not analogous to the FVV investigation. In a statically determined system with one crank throw supported by two bearings, the bending moment and radial (shear) force are proportional. Therefore the journal fillet SCF can be found directly by the 3-point bending FE calculation. The SCF is then calculated according to

$$\beta_{BQ} = \frac{\sigma_{3P}}{\sigma_{N3P}}$$

For symbols see 3.3.1.

When using this method the radial force and stress determination in this section becomes superfluous. The alternating bending stress in the journal fillet as per D-2.1.3 is then evaluated:

$$\sigma_{BG} A_{-} \pm \beta_{BQ} \cdot \sigma_{BFN}$$

Note that the use of this method does not apply to the crankpin fillet and that this SCF must not be used in connection with calculation methods other than those assuming a statically determined system as in this section.

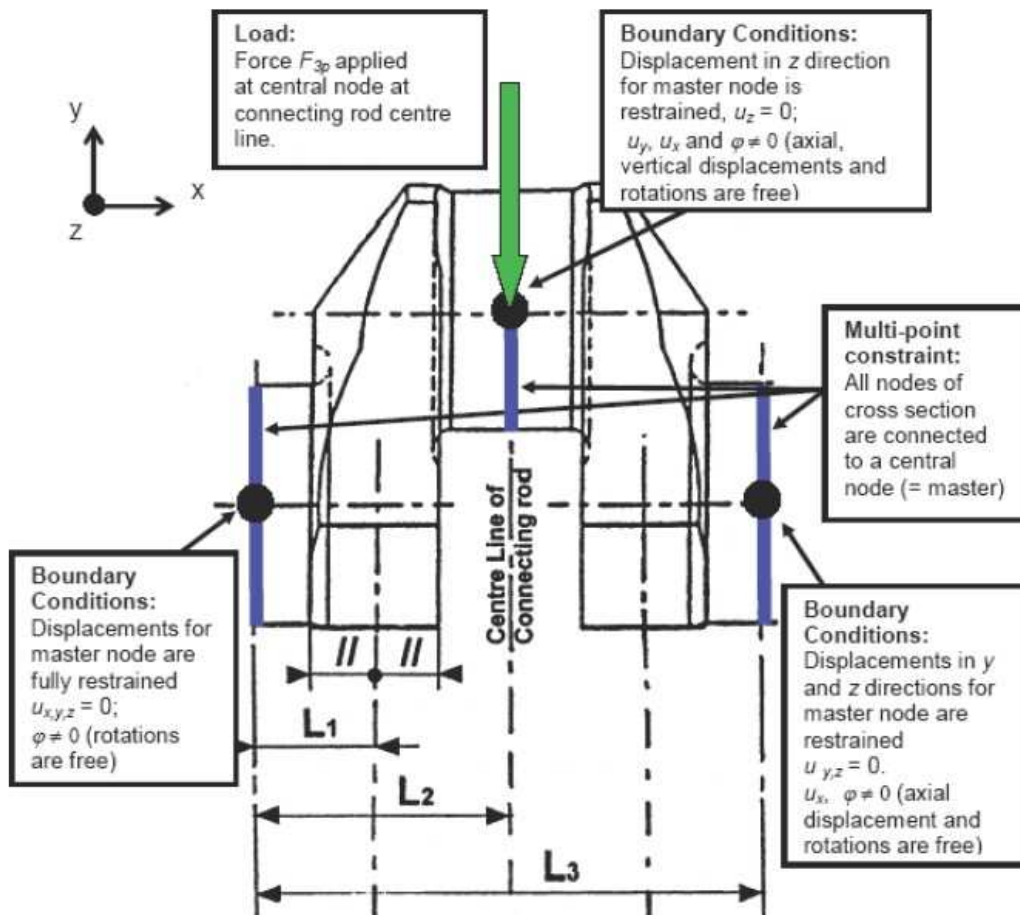


Fig. 3.3 Boundary and load conditions for the 3-point bending load case of an inline engine

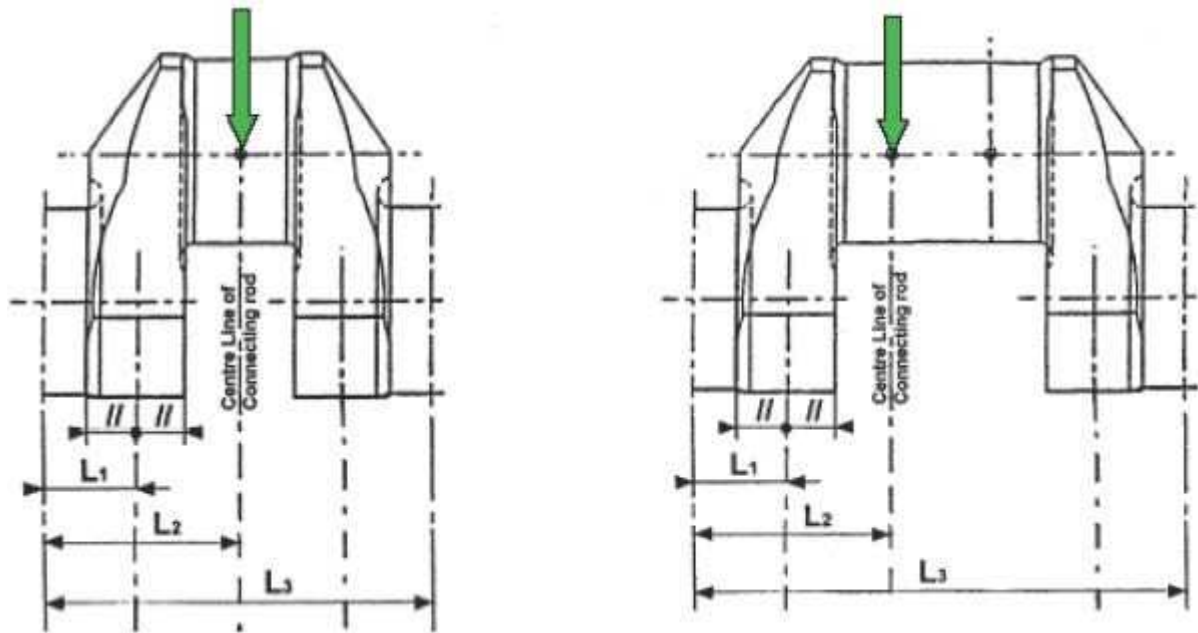


Fig. 3.4 Load applications for in-line and V-type engines

APPENDIX IV

GUIDANCE FOR EVALUATION OF FATIGUE TESTS

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A. Introduction

Fatigue testing can be divided into two main groups; testing of small specimens and full-size crank throws. Testing can be made using the staircase method or a modified version thereof which is presented in this document. Other statistical evaluation methods may also be applied.

1. Small specimen testing

For crankshafts without any fillet surface treatment, the fatigue strength can be determined by testing small specimens taken from a full-size crank throw. When other areas in the vicinity of the fillets are surface treated introducing residual stresses in the fillets, this approach cannot be applied.

One advantage of this approach is the rather high number of specimens which can be then manufactured. Another advantage is that the tests can be made with different stress ratios (R-ratios) and/or different modes e.g. axial, bending and torsion, with or without a notch. This is required for evaluation of the material data to be used with critical plane criteria.

2. Full-size crank throw testing

For crankshafts with surface treatment the fatigue strength can only be determined through testing of full size crank throws. For cost reasons, this usually means a low number of crank throws. The load can be applied by hydraulic actuators in a 3- or 4- point bending arrangement, or by an exciter in a resonance test rig. The latter is frequently used, although it usually limits the stress ratio to $R = -1$.

B. Evaluation of Test Results

1. Principles

Prior to fatigue testing the crankshaft must be tested as required by quality control procedures, e.g. for chemical composition, mechanical properties, surface hardness, hardness depth and extension, fillet surface finish, etc.

The test samples should be prepared so as to represent the “lower end” of the acceptance range e.g. for induction hardened crankshafts this means the lower range of acceptable hardness depth, the shortest extension through a fillet, etc. Otherwise the mean value test results should be corrected with a confidence interval: a 90% confidence interval may be used both for the sample mean and the standard deviation.

The test results, when applied in Section 2 item D (BCS -R M53), shall be evaluated to represent the mean fatigue strength, with or without taking into consideration the 90%

confidence interval as mentioned above. The standard deviation should be considered by taking the 90% confidence into account. Subsequently the result to be used as the fatigue strength is then the mean fatigue strength minus one standard deviation.

If the evaluation aims to find a relationship between (static) mechanical properties and the fatigue strength, the relation must be based on the real (measured) mechanical properties, not on the specified minimum properties.

The calculation technique presented in item 2.4 was developed for the original staircase method. However, since there is no similar method dedicated to the modified staircase method the same is applied for both.

2. Staircase method

In the original staircase method, the first specimen is subjected to a stress corresponding to the expected average fatigue strength. If the specimen survives 10^7 cycles, it is discarded and the next specimen is subjected to a stress that is one increment above the previous, i.e. a survivor is always followed by the next using a stress one increment above the previous. The increment should be selected to correspond to the expected level of the standard deviation.

When a specimen fails prior to reaching 10^7 cycles, the obtained number of cycles is noted and the next specimen is subjected to a stress that is one increment below the previous. With this approach, the sum of failures and run-outs is equal to the number of specimens.

This original staircase method is only suitable when a high number of specimens are available. Through simulations it has been found that the use of about 25 specimens in a staircase test leads to a sufficient accuracy in the result.

3. Modified staircase method

When a limited number of specimens are available, it is advisable to apply the modified staircase method. Here the first specimen is subjected to a stress level that is most likely well below the average fatigue strength. When this specimen has survived 10^7 cycles, this same specimen is subjected to a stress level one increment above the previous. The increment should be selected to correspond to the expected level of the standard deviation. This is continued with the same specimen until failure.

Then the number of cycles is recorded and the next specimen is subjected to a stress that is at least 2 increments below the level where the previous specimen failed.

With this approach, the number of failures usually equals the number of specimens. The number of run-outs, counted as the highest level where 10^7 cycles were reached, also equals the number of specimens.

The acquired result of a modified staircase method should be used with care, since some results available indicate that testing a runout on a higher test level, especially at high mean stresses, tends to increase the fatigue limit. However, this “training effect” is less pronounced for high strength steels (e.g. UTS > 800 MPa).

If the confidence calculation is desired or necessary, the minimum number of test specimens is 3.

4. Calculation of sample mean and standard deviation

A hypothetical example of tests for 5 crank throws is presented further in the subsequent text. When using the modified staircase method and the evaluation method of Dixon and Mood, the number of samples will be 10, meaning 5 run-outs and 5 failures, i.e.:

Number of samples, $n=10$

Furthermore, the method distinguishes between

Less frequent event is failures $C=1$

Less frequent event is run-outs $C=2$

The method uses only the less frequent occurrence in the test results, i.e. if there are more failures than run-outs, then the number of run-outs is used, and vice versa.

In the modified staircase method, the number of run-outs and failures are usually equal.

However, the testing can be unsuccessful, e.g. the number of run-outs can be less than the number of failures if a specimen with 2 increments below the previous failure level goes directly to failure. On the other hand, if this unexpected premature failure occurs after a rather high number of cycles, it is possible to define the level below this as a run-out.

Dixon and Mood’ s approach, derived from the maximum likelihood theory, which also may be applied here, especially on tests with few samples, presented some simple approximate equations for calculating the sample mean and the standard deviation from the outcome of the staircase test. The sample mean can be calculated as follows:

$$\bar{S}_a = S_{a0} + d \cdot \left(\frac{A-1}{F-2} \right) \text{ when } C=1$$

$$\bar{S}_a = S_{a0} + d \cdot \left(\frac{A-1}{F-2} \right) \text{ when } C=2$$

The standard deviation can be found by

$$s = 1.62 \cdot d \cdot \left(\frac{F \cdot B - A^2}{F^2} + 0.029 \right)$$

where:

S_{a0} is the lowest stress level for the less frequent occurrence

d is the stress increment

$$F = \sum f_i$$

$$A = \sum i \cdot f_i$$

$$B = \sum i^2 \cdot f_i$$

i is the stress level numbering

f_i is the number of samples at stress level i

The formula for the standard deviation is an approximation and can be used when

$$\frac{B \cdot F - A^2}{F^2} > 0,3$$

and

$$0,5 \cdot s < d < 1,5 \cdot s$$

If any of these two conditions are not fulfilled, a new staircase test should be considered or the standard deviation should be taken quite large in order to be on the safe side.

If increment d is greatly higher than the standard deviation s , the procedure leads to a lower standard deviation and a slightly higher sample mean, both compared to values calculated when the difference

between the increment and the standard deviation is relatively small.

Respectively, if increment d is much less than the standard deviation s , the procedure leads to a higher standard deviation and a slightly lower sample mean.

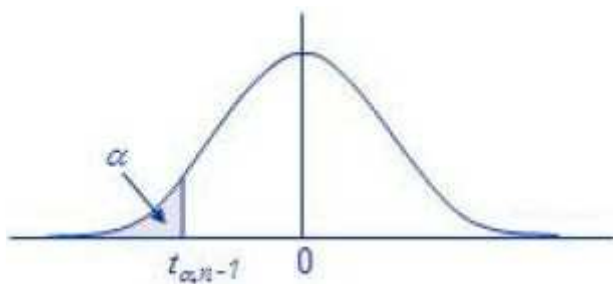
5. Confidence interval for mean fatigue limit

If the staircase fatigue test is repeated, the sample mean and the standard deviation will most likely be different from the previous test. Therefore, it is necessary to assure with a given confidence that the repeated test values will be above the chosen fatigue limit by using a confidence interval for the sample mean.

The confidence interval for the sample mean value with unknown variance is known to be distributed according to the t-distribution (also called student's t-distribution) which is a distribution symmetric around the average.

If S_a is the empirical mean and s is the empirical standard deviation over a series of n samples, in which the variable values are normally distributed with an unknown sample mean and unknown variance, the $(1 - \alpha) \cdot 100\%$ confidence interval for the mean is:

$$P \left(S_a - t_{\alpha, n-1} \cdot \frac{s}{\sqrt{n}} < S_{ax\%} \right) = 1 - \alpha$$



The confidence level normally used for the sample mean is 90 %, meaning that 90 % of sample means from repeated tests will be above the value calculated with the chosen confidence level. The figure shows the t value for $(1 - \alpha) \cdot 100$ confidence interval for the sample mean.

Figure 2.1. Student's t-distribution

The resulting confidence interval is symmetric around the empirical mean of the sample values, and the lower endpoint can be found as:

$$S_{ax\%} = S_a - t_{\alpha, n-1} \cdot \frac{s}{\sqrt{n}}$$

which is the mean fatigue limit (population value) to be used to obtain the reduced fatigue limit where the limits for the probability of failure are taken into consideration.

6. Confidence interval for standard deviation

The confidence interval for the variance of a normal random variable is known to possess a chi-square distribution with $n - 1$ degrees of freedom.

An assumed fatigue test value from n samples is a normal random variable with a variance of σ^2 and has an empirical variance s^2 . Then a $(1 - \alpha) \cdot 100\%$ confidence interval for the variance is:

$$P\left(\frac{(n-1)s^2}{\sigma^2} < \chi^2_{\alpha, n-1}\right) = 1 - \alpha$$

A $(1 - \alpha) \cdot 100\%$ confidence interval for the standard deviation is obtained by the square root of the upper limit

of the confidence interval for the variance and can be found by

$$S_{x\%} = \sqrt{\frac{n-1}{\chi^2_{\alpha, n-1}}} \cdot s$$

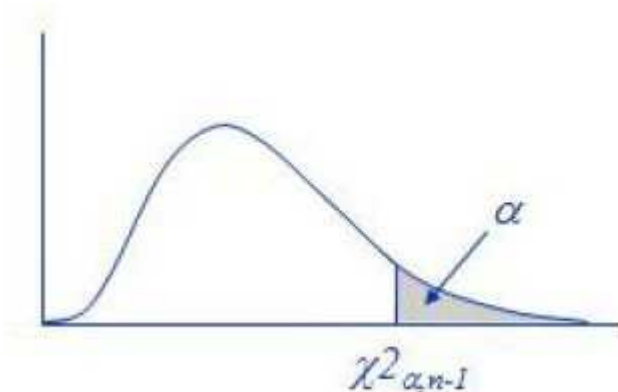
This standard deviation (population value) is to be used to obtain the fatigue limit, where the limits for the probability of failure are taken into consideration.

C. Small specimen testing

In this connection, a small specimen is considered to be one of the specimens taken from a crank throw. Since the specimens shall be representative for the fillet fatigue strength, they should be taken out close to the fillets, as shown in Figure 3.1.

It should be made certain that the principal stress direction in the specimen testing is equivalent to the full-size crank throw. The verification is recommended to be done by utilising the finite element method.

The (static) mechanical properties are to be determined as stipulated by the quality control procedures.



The confidence level on the standard deviation is used to ensure that the standard deviations for repeated tests are below an upper limit obtained from the fatigue test standard deviation with a confidence level. The figure shows the chisquare for $(1 - \alpha) \cdot 100\%$ confidence interval for the variance.

Figure 2.2. Chi-square distribution

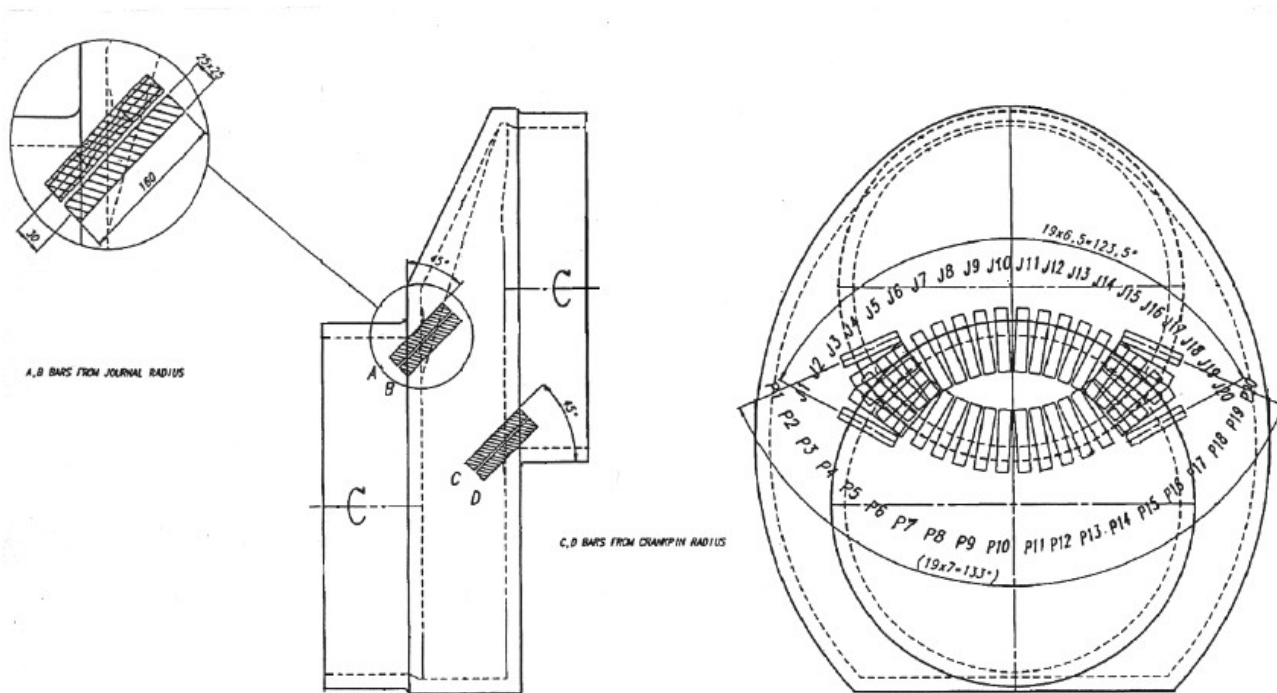


Figure 3.1. Specimen locations in a crank throw

1. Determination of bending fatigue strength

It is advisable to use un-notched specimens in order to avoid uncertainties related to the stress gradient influence. Push-pull testing method (stress ratio $R = -1$) is preferred, but especially for the purpose of critical plane criteria other stress ratios and methods may be added.

In order to ensure principal stress direction in push-pull testing to represent the full-size crank throw principal stress direction and when no further information is available, the specimen shall be taken in 45 degrees angle as shown in Figure 3.1.

- A. If the objective of the testing is to document the influence of high cleanliness, test samples taken from positions approximately 120 degrees in a circumferential direction may be used. See Figure 3.1.

- B. If the objective of the testing is to document the influence of continuous grain flow (cgf) forging, the specimens should be restricted to the vicinity of the crank plane.

2. Determination of torsional fatigue strength

- A. If the specimens are subjected to torsional testing, the selection of samples should follow the same guidelines as for bending above. The stress gradient influence has to be considered in the evaluation.

- B. If the specimens are tested in push-pull and no further information is available, the samples should be taken out at an angle of 45 degrees to the crank plane in order to ensure collinearity of the principal stress direction between the specimen and the fullsize crank throw. When taking the specimen at a distance from the (crank) middle plane of the crankshaft along the fillet, this plane rotates around the pin centre point making it possible to resample the fracture direction due to torsion (the results are to be converted into the pertinent torsional values).

3. Other test positions

If the test purpose is to find fatigue properties and the crankshaft is forged in a manner likely to lead to cgf, the specimens may also be taken longitudinally from a prolonged shaft piece where specimens for mechanical testing are usually taken. The condition is that this prolonged shaft piece is heat treated as a part of the crankshaft and that the size is so as to result in a similar quenching rate as the crank throw.

When using test results from a prolonged shaft piece, it must be considered how well the grain flow in that shaft piece is representative for the crank fillets.

4. Correlation of test results

The fatigue strength achieved by specimen testing shall be converted to correspond to the full-size crankshaft fatigue strength with an appropriate method (size effect).

When using the bending fatigue properties from tests mentioned in this section, it should be kept in mind that successful continuous grain flow (cgf) forging leading to elevated values compared to other (non cgf) forging, will normally not lead to a torsional fatigue strength improvement of the same magnitude.

In such cases it is advised to either carry out also torsional testing or to make a conservative assessment of the torsional fatigue strength, e.g. by using no credit for cgf. This approach is applicable when using the Gough Pollard criterion. However, this approach is not recognised when using the von Mises or a multi-axial criterion such as Findley.

If the found ratio between bending and torsion fatigue differs significantly from $\sqrt{3}$, one should consider replacing the use of the von Mises criterion with the Gough Pollard criterion. Also, if critical plane criteria are used, it must be kept in mind that cgf makes the material inhomogeneous in terms of fatigue strength, meaning that the material parameters differ with the directions of the planes.

Any addition of influence factors must be made with caution. If for example a certain addition for clean steel is documented, it may not necessarily be fully combined with a K-factor for cgf.

Direct testing of samples from a clean and cgf forged crank is preferred.

D. Full size testing

1. Hydraulic pulsation

A hydraulic test rig can be arranged for testing a crankshaft in 3-point or 4-point bending as well as in torsion. This allows for testing with any *R*-ratio.

Although the applied load should be verified by strain gauge measurements on plain shaft sections for the initiation of the test, it is not necessarily used during the test for controlling load. It is also pertinent to check fillet stresses with strain gauge chains.

Furthermore, it is important that the test rig provides boundary conditions as defined in Appendix III (section 3.1 to 3.3).

The (static) mechanical properties are to be determined as stipulated by the quality control procedures.

2. Resonance tester

A rig for bending fatigue normally works with an *R*-ratio of -1. Due to operation close to resonance, the energy consumption is moderate. Moreover, the frequency is usually relatively high, meaning that 10^7 cycles can be reached within some days. Figure 4.1 shows a layout of the testing arrangement.

The applied load should be verified by strain gauge measurements on plain shaft sections. It is also pertinent to check fillet stresses with strain gauge chains.

Clamping around the journals must be arranged in a way that prevents severe fretting which could lead to a failure under the edges of the clamps. If some distance between the clamps and the journal fillets is provided, the loading is consistent with 4-point bending and thus representative for the journal fillets also.

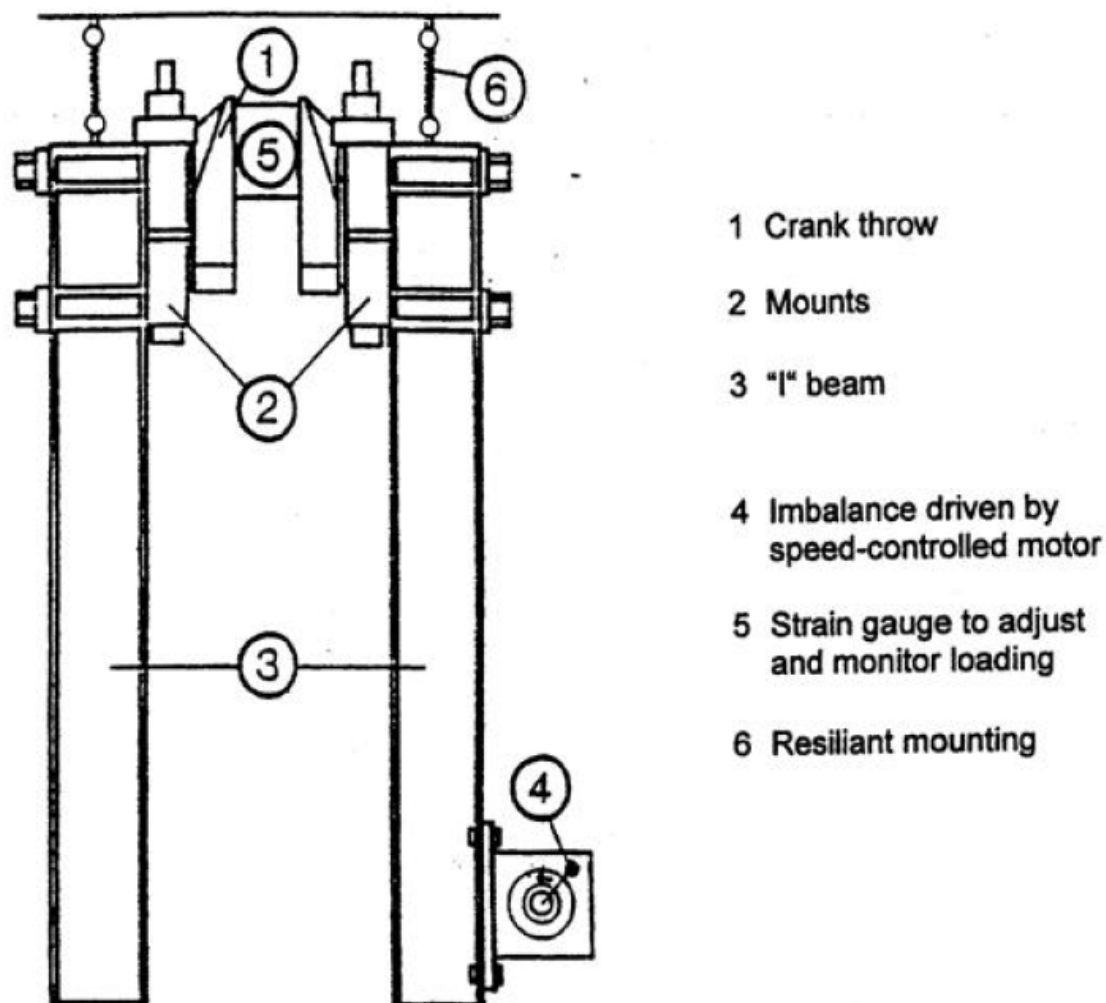


Figure 4.1. An example of testing arrangement of the resonance tester for bending loading

In an engine, the crankpin fillets normally operate with an *R*-ratio slightly above -1 and the journal fillets slightly below -1. If found necessary, it is possible to introduce a mean load (deviate from $R = -1$) by means of a spring preload.

A rig for torsion fatigue can also be arranged as shown in Figure 4.2. When a crank throw is subjected to torsion, the twist of the crankpin makes the journals move sideways. If one single crank throw is tested in a torsion resonance test rig, the journals with their clamped-on weights will vibrate heavily sideways.

This sideways movement of the clamped-on weights can be reduced by having two crank throws, especially if the

cranks are almost in the same direction. However, the journal in the middle will move more.

Since sideways movements can cause some bending stresses, the plain portions of the crankpins should also be provided with strain gauges arranged to measure any possible bending that could have an influence on the test results.

Similarly, to the bending case the applied load shall be verified by strain gauge measurements on plain shaft sections. It is also pertinent to check fillet stresses with strain gauge chains as well.

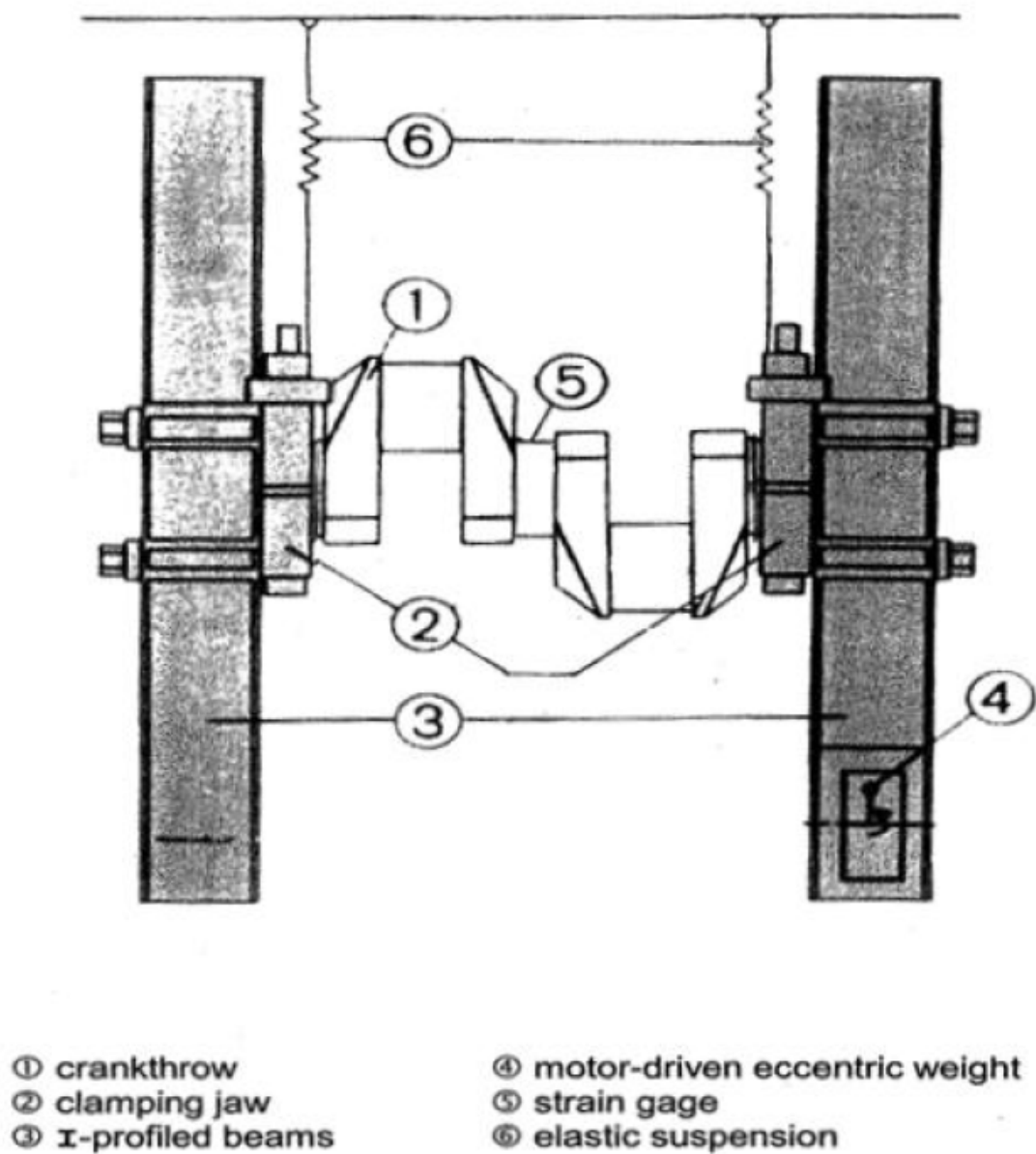


Figure 4.2. An example of testing arrangement of the resonance tester for torsion loading with double crank throw section

3. Use of results and crankshaft acceptability

In order to combine tested bending and torsion fatigue strength results in calculation of crankshaft acceptability (see Section 2 item D.7), the Gough-Pollard approach and the maximum principal equivalent stress formulation can be applied for the following cases:

Related to the crankpin diameter:

$$Q = \left(\sqrt{\left(\frac{\sigma_{BH}}{\sigma_{DWCT}} \right)^2 + \left(\frac{\tau_{BH}}{\tau_{DWCT}} \right)^2} \right)^{-1}$$

where:

σ_{DWCT} fatigue strength by bending testing

τ_{DWCT} fatigue strength by torsion testing

Related to crankpin oil bore:

$$Q = \frac{a_{DWOT}}{a_v};$$

$$a_v = \frac{1}{3} \cdot a_{BO} \cdot \left[1 + 2 \cdot \sqrt{1 + \frac{9}{4} \cdot \left(\frac{a_{TO}}{a_{BO}} \right)^2} \right]$$

where:

σ_{DWOT} fatigue strength by means of largest principal stress from torsion testing

Related to the journal diameter:

$$Q = \left(\sqrt{\left(\frac{\sigma_{BG}}{\sigma_{DWJT}} \right)^2 + \left(\frac{\tau_G}{\tau_{DWJT}} \right)^2} \right)^{-1}$$

where:

σ_{DWJT} fatigue strength by bending testing

τ_{DWJT} fatigue strength by torsion testing

In case increase in fatigue strength due to the surface treatment is considered to be similar between the above cases, it is sufficient to test only the most critical location according to the calculation where the surface treatment had not been taken into account.

E. Use of existing results for similar crankshafts

For fillets or oil bores without surface treatment, the fatigue properties found by testing may be used for similar crankshaft designs providing:

- **Material:**

- Similar material type
- Cleanliness on the same or better level
- The same mechanical properties can be granted (size versus hardenability)

- **Geometry:**

- Difference in the size effect of stress gradient is insignificant or it is considered
- Principal stress direction is equivalent. See item C.

- **Manufacturing:**

- Similar manufacturing process

Induction hardened or gas nitrided crankshafts will suffer fatigue either at the surface or at the transition to the core. The surface fatigue strength as determined by fatigue tests of full size cranks, may be used on an equal or similar design as the tested crankshaft when the fatigue initiation occurred at the surface. With the similar design, it is meant that a similar material type and surface hardness are used and the fillet radius and hardening depth are within approximately $\pm 30\%$ of the tested crankshaft.

Fatigue initiation in the transition zone can be either subsurface, i.e. below the hard layer, or at the surface where the hardening ends. The fatigue strength at the transition to the core can be determined by fatigue tests as described above, provided that the fatigue initiation occurred at the transition to the core. Tests made with the core material only will not be representative since the tension residual stresses at the transition are lacking.

It has to be noted also what some recent research has shown: The fatigue limit can decrease in the very high cycle domain with subsurface crack initiation due to trapped hydrogen that accumulates through diffusion around some internal defect functioning as an initiation point.

In these cases, it would be appropriate to reduce the fatigue limit by some percent per decade of cycles beyond 10^7 . Based on a publication by Yukitaka Murakami “Metal Fatigue: Effects of Small Defects and Non-metallic Inclusions” the reduction is suggested to be 5 % per decade especially when the hydrogen content is considered to be high.

APPENDIX V**GUIDANCE FOR CALCULATION OF SURFACE TREATED FILLETS AND OIL BORE OUTLETS**

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A. Introduction

This appendix deals with surface treated fillets and oil bore outlets. The various treatments are explained and some empirical formulae are given for calculation purposes. Conservative empiricism has been applied intentionally, in order to be on the safe side from a calculation standpoint.

Please note that measurements or more specific knowledge should be used if available. However, in the case of a wide scatter (e.g. for residual stresses) the values should be chosen from the end of the range that would be on the safe side for calculation purposes.

B. Definition of surface treatment

'Surface treatment' is a term covering treatments such as thermal, chemical or mechanical operations, leading to inhomogeneous material properties – such as hardness, chemistry or residual stresses – from the surface to the core.

1. Surface treatment methods

The following list covers possible treatment methods and how they influence the properties that are decisive for the fatigue strength.

It is important to note that since only induction hardening, nitriding, cold rolling and stroke peening are considered relevant for marine engines, other methods as well as combination of two or more of the above are not dealt with in this document. In addition, die quenching can be considered in the same way as induction hardening.

Table 2.1. Surface treatment methods and the characteristics they affect.

Treatment method

- Induction hardening
- Nitriding
- Case hardening
- Die quenching (no temper)
- Cold rolling
- Stroke peening
- Shot peening
- Laser peening
- Ball coining

Affecting

Hardness and residual stresses
 Chemistry, hardness and residual stresses
 Chemistry, hardness and residual stresses
 Hardness and residual stresses
 Residual stresses
 Residual stresses
 Residual stresses
 Residual stresses
 Residual stresses

C. Calculation principles

The basic principle is that the alternating working stresses shall be below the local fatigue strength (including the effect of surface treatment) wherein non-propagating cracks may occur, see also section F.1 for details. This is then divided by a certain safety factor. This applies through the entire fillet or oil bore contour as well as below the surface to a depth below the treatment-affected zone – i.e. to cover the depth all the way to the core.

Consideration of the local fatigue strength shall include the influence of the local hardness, residual stress and mean working stress. The influence of the 'giga-cycle effect', especially for initiation of subsurface cracks, should be covered by the choice of safety margin.

It is of vital importance that the extension of hardening/peening in an area with concentrated stresses be duly considered. Any transition where the hardening/peening is ended is likely to have considerable tensile residual stresses.

This forms a ‘weak spot’ and is important if it coincides with an area of high stresses.

Alternating and mean working stresses must be known for the entire area of the stress concentration as well as to a depth of about 1.2 times the depth of the treatment. The following figure indicates this principle in the case of induction hardening. The base axis is either the depth (perpendicular to the surface) or along the fillet contour.

The acceptability criterion should be applied stepwise from the surface to the core as well as from the point of maximum stress concentration along the fillet surface contour to the web.

1. Evaluation of local fillet stresses

It is necessary to have knowledge of the stresses along the fillet contour as well as in the subsurface to a depth somewhat beyond the hardened layer. Normally this will be found via FEA as described in Appendix III. However, the element size in the subsurface range will have to be the same size as at the surface. For crankpin hardening only the small element size will have to be continued along the surface to the hard layer.

If no FEA is available, a simplified approach may be used. This can be based on the empirically determined stress concentration factors (SCFs), as in Section 2 item D.3 if within its validity range, and a relative stress gradient inversely proportional to the fillet radius.

Bending and torsional stresses must be addressed separately. The combination of these is addressed by the acceptability criterion.

The subsurface transition-zone stresses, with the minimum hardening depth, can be determined by means of local stress concentration factors along an axis perpendicular to the fillet surface. These functions $\alpha_{B-local}$ and $\alpha_{T-local}$ have different shapes due to the different stress gradients.

The SCFs α_B and α_T are valid at the surface. The local $\alpha_{B-local}$ and $\alpha_{T-local}$ drop with increasing depth. The relative stress gradients at the surface depend on the kind of stress raiser, but for crankpin fillets they can be simplified

to $2/R_H$ in bending and $1/R_H$ in torsion. The journal fillets are handled analogously by using R_G and D_G . The nominal stresses are assumed to be linear from the surface to a midpoint in the web between the crankpin fillet and the journal fillet for bending and to the crankpin or journal centre for torsion.

The local SCFs are then functions of depth t according to Equation 3.1 as shown in Figure 3.2 for bending and respectively for torsion in Equation 3.2 and Figure 3.3.

$$\alpha_{B-local} = (\alpha_B - 1) \cdot e^{\frac{-2 \cdot t}{R_H}} + 1 - \left(\frac{2 \cdot t}{\sqrt{W^2 + S^2}} \right)^{\sqrt{\alpha_B}} \quad (3.1)$$

$$\alpha_{T-local} = (\alpha_T - 1) \cdot e^{\frac{-t}{R_H}} + 1 - \left(\frac{2 \cdot t}{D} \right)^{\sqrt{\alpha_T}} \quad (3.2)$$

If the pin is hardened only and the end of the hardened zone is closer to the fillet than three times the maximum hardness depth, FEA should be used to determine the actual stresses in the transition zone.

2. Evaluation of oil bore stresses

Stresses in the oil bores can be determined also by FEA. The element size should be less than 1/8 of the oil bore diameter D_o and the element mesh quality criteria should be followed as prescribed in Appendix III. The fine element mesh should continue well beyond a radial depth corresponding to the hardening depth.

The loads to be applied in the FEA are the torque – see Appendix III item 3.1 – and the bending moment, with four-point bending as in Appendix III item 3.2.

If no FEA is available, a simplified approach may be used. This can be based on the empirically determined SCF from Section 2 item D.3 if within its applicability range. Bending and torsional stresses at the point of peak stresses are combined as in Section 2 item D.5.

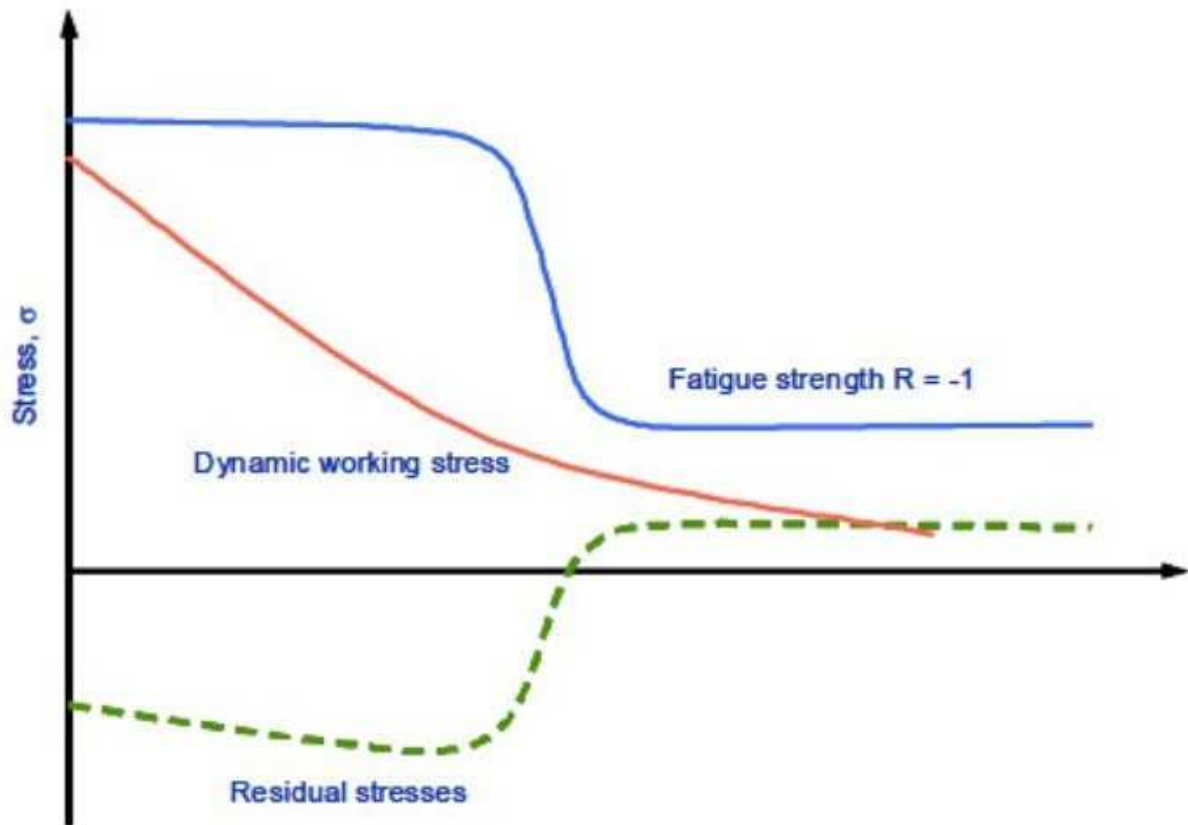


Figure 3.1. Stresses as functions of depth, general principles

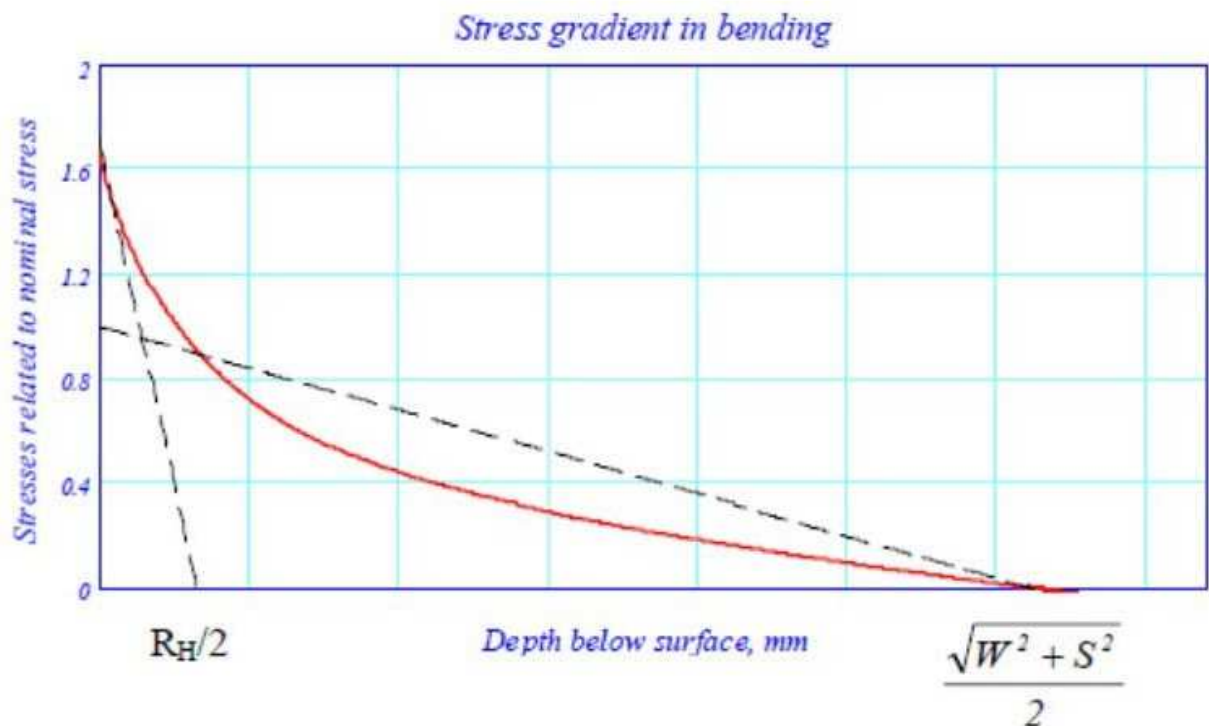
Figure 3.2. Bending SCF in the crankpin fillet as a function of depth. The corresponding SCF for the journal fillet can be found by replacing R_H with R_G

Figure 3.4 indicates a local drop of the hardness in the transition zone between a hard and soft material. Whether this drop occurs depends also on the tempering temperature after quenching in the QT process.

The peak stress in the bore occurs at the end of the edge rounding. Within this zone the stress drops almost linearly to the centre of the pin. As can be seen from Figure 3.4, for shallow (A) and intermediate (B) hardening, the transition point practically coincides with the point of maximal stresses. For deep hardening the transition point comes outside of the point of peak stress and the local stress can be assessed as a portion $(1-2tH/D)$ of the peak stresses where tH is the hardening depth.

The subsurface transition-zone stresses (using the minimum hardening depth) can be determined by means of local stress concentration factors along an axis perpendicular to the oil bore surface. These functions $\gamma_{B-local}$ and $\gamma_{T-local}$ have different shapes, because of the different stress gradients.

The stress concentration factors γ_B and γ_T are valid at the surface. The local SCFs $\gamma_{B-local}$ and $\gamma_{T-local}$ drop with increasing depth. The relative stress gradients at the surface depend on the kind of stress raiser, but for crankpin oil bores they can be simplified to $4/D_o$ in bending and $2/D_o$ in torsion. The local SCFs are then functions of the depth t .



Figure 3.3. Torsional SCF in the crankpin fillet as a function of depth. The corresponding SCF for the journal fillet can be found by replacing R_H with R_G and D with D_G

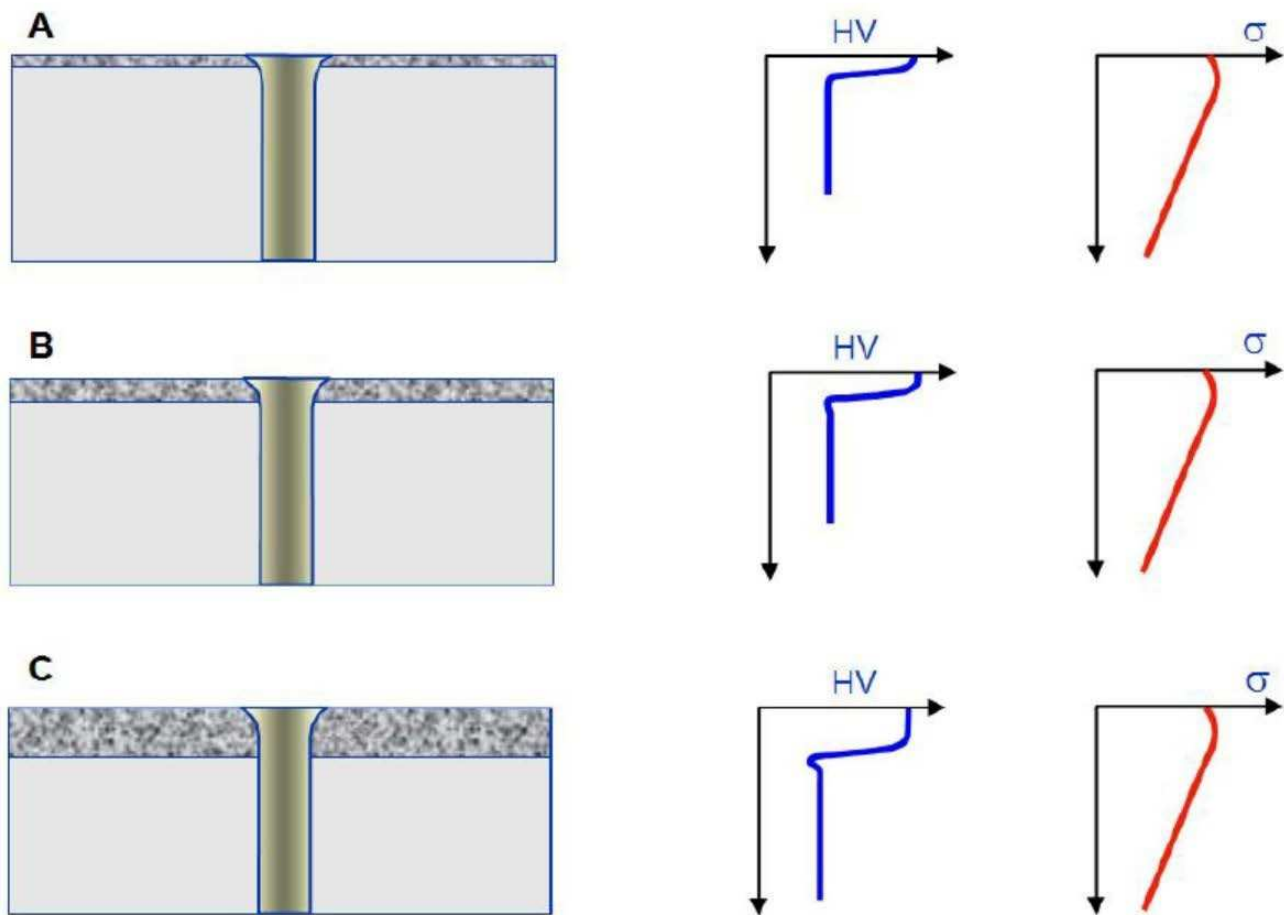


Figure 3.4. Stresses and hardness in induction hardened oil holes

$$\gamma_{B-local} = (\gamma_B - 1) \cdot e^{\frac{-4 \cdot t}{D_0} + 1} \quad (3.3)$$

$$\gamma_{B-local} = (\gamma_T - 1) \cdot e^{\frac{-2 \cdot t}{D_0} + 1} \quad (3.4)$$

3. Acceptability criteria

Acceptance of crankshafts is based on fatigue considerations ; Section 2 item D (BCS -R M 53) compares the equivalent alternating stress and the fatigue strength ratio to an acceptability factor of $Q \geq 1.15$ for oil bore outlets , crankpin fillets and journal fillets . This shall be extended to cover also surface treated areas independent of whether surface or transition zone is examined.

D. Induction hardening

Generally, the hardness specification shall specify the surface hardness range i.e. minimum and maximum values, the minimum and maximum extension in or through the fillet and also the minimum and maximum depth along the fillet contour. The referenced Vickers hardness is considered to be **HV0.5...HV5**.

The induction hardening depth is defined as the depth where the hardness is 80% of the minimum specified surface hardness.

In the case of crankpin or journal hardening only, the minimum distance to the fillet shall be specified due to the tensile stress at the heat-affected zone as shown in Figure 4.2.

If the hardness-versus-depth profile and residual stresses are not known or specified, one may assume the following:

- The hardness profile consists of two layers (see figure 4.1):
 - Constant hardness from the surface to the transition zone

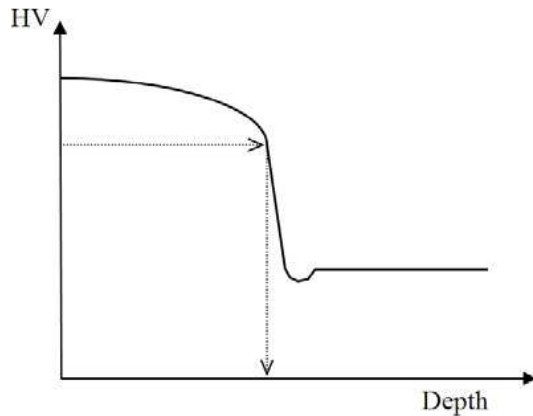


Figure 4.1. Typical hardness as a function of depth. The arrows indicate the defined hardening depth. Note the indicated potential hardness drop at the transition to the core. This can be a weak point as local strength may be reduced and tensile residual stresses may occur.

- Constant hardness from the transition zone to the core material
- Residual stresses in the hard zone of 200 MPa (compression)
- Transition-zone hardness as 90% of the core hardness unless the local hardness drop is avoided
- Transition-zone maximum residual stresses (von Mises) of 300 MPa tension

If the crankpin or journal hardening ends close to the fillet, the influence of tensile residual stresses has to be considered. If the minimum distance between the end of the hardening and the beginning of the fillet is more than 3 times the maximum hardening depth, the influence may be disregarded.

1. Local fatigue strength

Induction-hardened crankshafts will suffer fatigue either at the surface or at the transition to the core. The fatigue strengths, for both the surface and the transition zone, can be determined by fatigue testing of full size cranks as described in Appendix IV. In the case of a transition zone, the initiation of the fatigue can be either subsurface (i.e. below the hard layer) or at the surface where the hardening ends.

Tests made with the core material only will not be representative since the tensile residual stresses at the transition are lacking.

Alternatively, the surface fatigue strength can be determined empirically as follows where HV is the surface Vickers hardness. The Equation 4.1 provides a conservative value, with which the fatigue strength is assumed to include the influence of the residual stress. The resulting value is valid for a working stress ratio of $R = -1$:

$$\sigma_{\text{Fsurface}} = 400 + 0.5 \cdot (HV - 400) \quad [\text{MPa}] \quad (4.1)$$

It has to be noted also that the mean stress influence of induction-hardened steels may be significantly higher than that for QT steels.

The fatigue strength in the transition zone, without taking into account any possible local hardness drop, shall be determined by the equation introduced in BCS-R M53.6

For journal and respectively to crankpin fillet applies:

$$\sigma_{\text{Ftransition,cpin}} = \pm K \cdot \left(\frac{0.42 \cdot \sigma_B + 39.3}{0.264 + 1.073 \cdot \sqrt[0.2]{\frac{785 - \sigma_B + 196}{4900} \cdot \frac{1}{\sigma_B \cdot \sqrt{X}}}} \right) \quad (4.2)$$

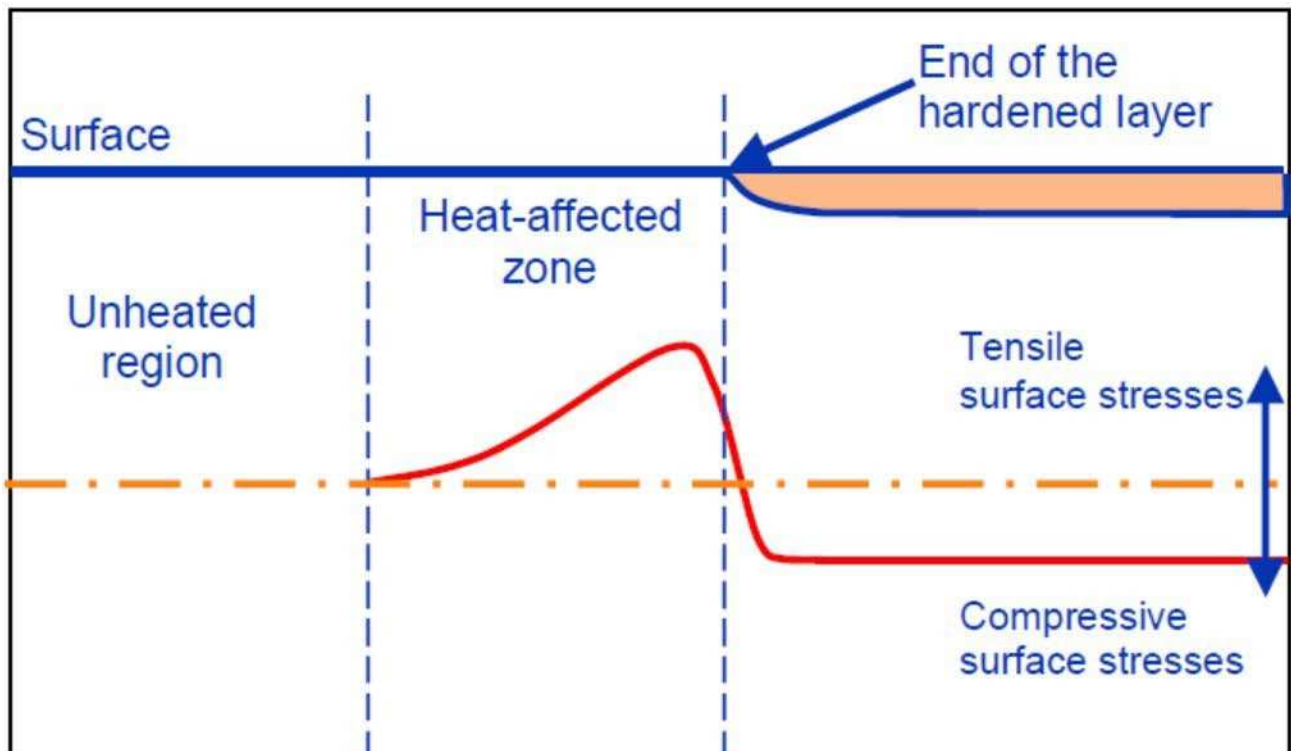


Figure 4.2. Residual stresses along the surface of a pin and fillet

where:

$Y = D_G$ and $X = R_G$ for journal fillet

$Y = D$ and $X = R_H$ for crankpin fillet

$Y = D$ and $X = D_o/2$ for oil bore outlet

The influence of the residual stress is not included in 4.2. For the purpose of considering subsurface fatigue, below the hard layer, the disadvantage of tensile residual stresses has to be considered by subtracting 20% from the value determined above. This 20% is based on the mean stress influence of alloyed quenched and tempered steel having a residual tensile stress of 300 MPa.

When the residual stresses are known to be lower, also smaller value of subtraction shall be used. For low-strength steels the percentage chosen should be higher.

For the purpose of considering surface fatigue near the end of the hardened zone – i.e. in the heat-affected zone shown in the Figure 4.2 – the influence of the tensile residual stresses can be considered by subtracting a

certain percentage, in accordance with Table 4.1, from the value determined by the above formula.

E. Nitriding

The hardness specification shall include the surface hardness range (min and max) and the minimum and maximum depth. Only gas nitriding is considered. The referenced Vickers hardness is considered to be **HV0.5**.

The depth of the hardening is defined in different ways in the various standards and the literature. The most practical method to use in this context is to define the nitriding depth t_N as the depth to a hardness of 50 HV above the core hardness.

The hardening profile should be specified all the way to the core. If this is not known, it may be determined empirically via the following formula:

$$HV(t) = HV_{core} + (HV_{surface} - HV_{core}) \cdot \left(\frac{50}{HV_{surface} - HV_{core}} \right)^{\left(\frac{t_l}{t_N} \right)^2}$$

(5.1)

where:

t = The local depth
 $HV(t)$ = Hardness at depth t
 HV_{core} = Core hardness (minimum)
 $HV_{surface}$ = Surface hardness (minimum)
 tN = Nitriding depth as defined above (minimum)

1. Local fatigue strength

It is important to note that in nitrided crankshaft cases, fatigue is found either at the surface or at the transition to the core. This means that the fatigue strength can be determined by tests as described in Appendix IV.

Alternatively, the surface fatigue strength (principal stress) can be determined empirically and conservatively as follows. This is valid for a surface hardness of 600 HV or greater:

$$\sigma_{F_{surface}} = 450 \text{ MPa} \quad (5.2)$$

Note that this fatigue strength is assumed to include the influence of the surface residual stress and applies for a working stress ratio of $R = -1$.

The fatigue strength in the transition zone can be determined by the equation introduced in BCS-R M53.6. For crankpin and respectively to journal applies:

$$\sigma_{F_{transition, cin}} = \pm K \cdot (0.42 \cdot \sigma_B + 39,3) \cdot \left[0.264 + 1.073 \cdot \gamma^{-0.2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{\chi}} \right] \quad (5.3)$$

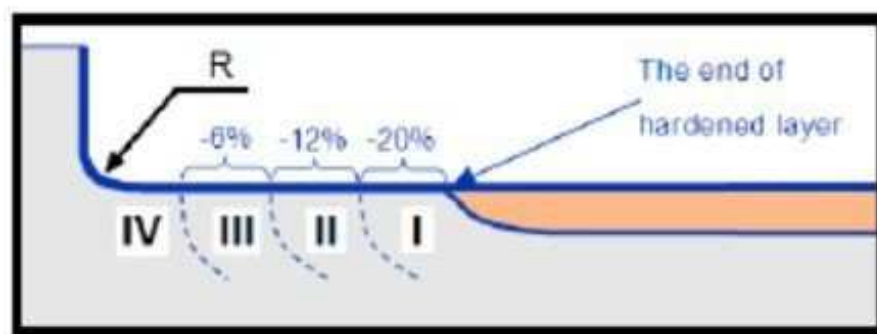
where:

$Y = D_G$ and $X = R_G$ for journal fillet

$Y = D$ and $X = R_H$ for crankpin fillet

$Y = D$ and $X = D_o/2$ for oil bore outlet

Note that this fatigue strength is **not** assumed to include the influence of the residual stresses.



I.	0 to 1.0 of the max. hardening depth:	20%
II.	1.0 to 2.0 of the max. hardening depth:	12%
III.	2.0 to 3.0 of the max. hardening depth:	6%
IV.	3.0 or more of the max. hardening depth:	0%

Table 4.1. The influence of tensile residual stresses at a given distance from the end of the hardening towards the fillet

In contrast to induction-hardening the nitrited components have no such distinct transition to the core. Although the compressive residual stresses at the surface are high, the balancing tensile stresses in the core are moderate because of the shallow depth. For the purpose of analysis of subsurface fatigue the disadvantage of tensile residual stresses in and below the transition zone may be even disregarded in view of this smooth contour of a nitriding hardness profile.

Although in principle the calculation should be carried out along the entire hardness profile, it can be limited to a simplified approach of examining the surface and an artificial transition point. This artificial transition point can be taken at the depth where the local hardness is approximately 20 HV above the core hardness. In such a case, the properties of the core material should be used. This means that the stresses at the transition to the core can be found by using the local SCF formulae mentioned earlier when inserting $t = 1.2t_N$.

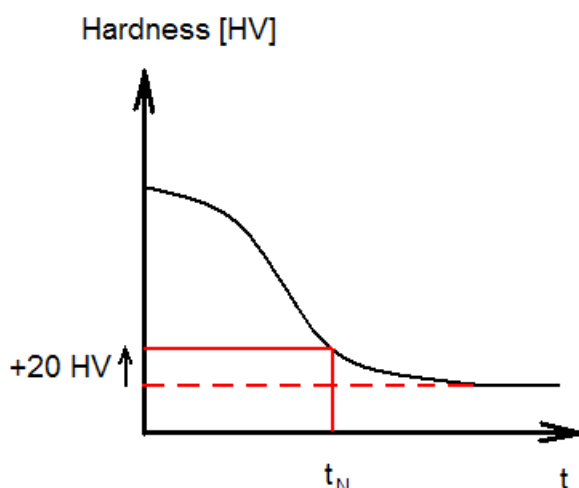


Figure 5.1. Sketch of the location for the artificial transition point in the depth direction

F. Cold forming

The advantage of stroke peening or cold rolling of fillets is the compressive residual stresses introduced in the high-loaded area. Even though surface residual stresses can be determined by X-ray diffraction technique and subsurface residual stresses can be determined through neutron diffraction, the local fatigue strength is virtually non-assessable on that basis since suitable and reliable correlation formulae are hardly known.

Therefore, the fatigue strength has to be determined by fatigue testing; see also Appendix IV.

Such testing is normally carried out as four-point bending, with a working stress ratio of $R = -1$. From these results, the bending fatigue strength – surface- or subsurface-initiated depending on the manner of failure – can be determined and expressed as the representative fatigue strength for applied bending in the fillet.

In comparison to bending, the torsion fatigue strength in the fillet may differ considerably from the ratio $\sqrt{3}$ (utilized by the von Mises criterion). The forming-affected depth that is sufficient to prevent subsurface fatigue in bending, may still allow subsurface fatigue in torsion. Another possible reason for the difference in bending and torsion could be the extension of the highly stressed area.

The results obtained in a full-size crank test can be applied for another crank size provided that the base material (alloyed Q+T) is of the similar type and that the forming is done so as to obtain the similar level of compressive residual stresses at the surface as well as through the depth. This means that both the extension and the depth of the cold forming must be proportional to the fillet radius.

1. Stroke peening by means of a ball

The fatigue strength obtained can be documented by means of full size crank tests or by empirical methods if applied on the safe side. If both bending and torsion fatigue strengths have been investigated and differ from the ratio $\sqrt{3}$ the von Mises criterion should be excluded.

If only bending fatigue strength has been investigated, the torsional fatigue strength should be assessed conservatively. If the bending fatigue strength is concluded to be x% above the fatigue strength of the non-peened material, the torsional fatigue strength should not be assumed to be more than 2/3 of x% above that of the non-peened material.

As a result of the stroke peening process the maximum of the compressive residual stress is found in the subsurface area. Therefore, depending on the fatigue testing load and the stress gradient, it is possible to have higher working stresses at the surface in comparison to the local fatigue strength of the surface. Because of this

phenomenon small cracks may appear during the fatigue testing, which will not be able to propagate in further load cycles and/or with further slight increases of the testing load because of the profile of the compressive residual stress. Put simply, the high compressive residual stresses below the surface ‘arrest’ small surface cracks.

This is illustrated in Figure 6.1 as gradient load 2.

In fatigue testing with full-size crankshafts these small “hairline cracks” should not be considered to be the failure crack. The crack that is technically the fatigue crack leading to failure, and that therefore shuts off the test-bench, should be considered for determination of the failure load level. This also applies if induction-hardened fillets are stroke-peened.

In order to improve the fatigue strength of induction-hardened fillets it is possible to apply the stroke peening process in the crankshafts’ fillets after they have been induction-hardened and tempered to the required surface hardness. If this is done, it might be necessary to adapt the stroke peening force to the hardness of the surface layer and not to the tensile strength of the basematerial. The effect on the fatigue strength of induction hardening and stroke peening the fillets shall be determined by a full-size crankshaft test.

1.1 Use of existing results for similar crankshafts

The increase in fatigue strength, which is achieved by applying stroke peening, may be utilized in another similar crankshaft if all of the following criteria are fulfilled:

- Ball size relative to fillet radius within $\pm 10\%$ in comparison to the tested crankshaft
- At least the same circumferential extension of the stroke peening
- Angular extension of the fillet contour relative to fillet radius within $\pm 15\%$ in comparison to the tested crankshaft and located to cover the stress concentration during engine operation
- Similar base material, e.g. alloyed quenched and tempered

- Forward feed of ball of the same proportion of the radius
- Force applied to ball proportional to base material hardness (if different)
- Force applied to ball proportional to square of ball radius

2. Cold rolling

The fatigue strength can be obtained by means of full size crank tests or by empirical methods, if these are applied so as to be on the safe side. If both, bending and torsion fatigue strengths have been investigated, and differ from the ratio, $\sqrt{3}$ the von Mises criterion should be excluded.

If only bending fatigue strength has been investigated, the torsional fatigue strength should be assessed conservatively. If the bending fatigue strength is concluded to be x% above the fatigue strength of the non-rolled material, the torsional fatigue strength should not be assumed to be more than 2/3 of x% above that of the non-rolled material.

2.1. Use of existing results for similar crankshafts

The increase in fatigue strength, which is achieved applying cold rolling, may be utilized in another similar crankshaft if all of the following criteria are fulfilled:

- At least the same circumferential extension of cold rolling
- Angular extension of the fillet contour relative to fillet radius within $\pm 15\%$ in comparison to the tested crankshaft and located to cover the stress concentration during engine operation
- Similar base material, e.g. alloyed quenched and tempered
- Roller force to be calculated so as to achieve at least the same relative (to fillet radius) depth of treatment

Tensile residual stress

Fatigue strength

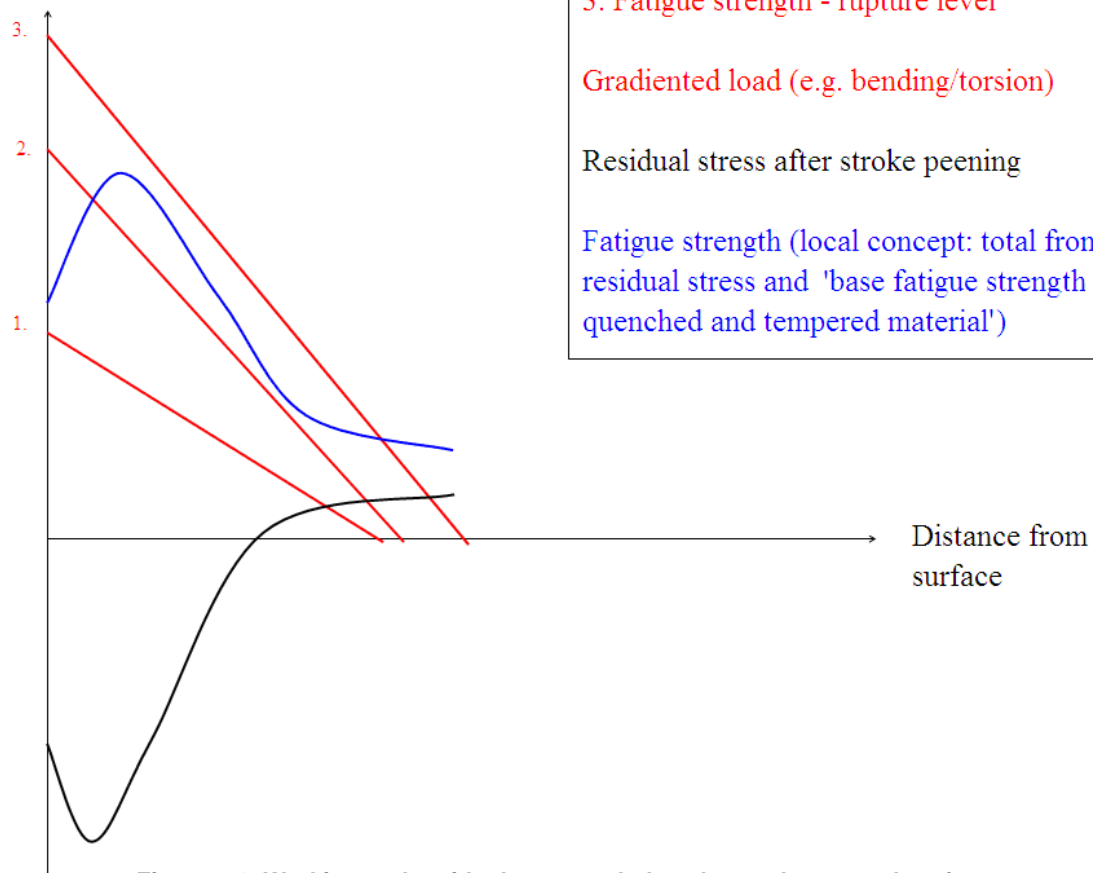


Figure 6.1. Working and residual stresses below the stroke-peened surface.
Straight lines 1...3 represent different possible load stress gradients.

APPENDIX VI

GUIDANCE FOR CALCULATION OF STRESS CONCENTRATION FACTORS IN THE OIL BORE OUTLETS OF CRANKSHAFTS THROUGH UTILISATION OF THE FINITE ELEMENT METHOD

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A. General

The objective of the analysis described in this document is to substitute the analytical calculation of the stress concentration factor (SCF) at the oil bore outlet with suitable finite element method (FEM) calculated figures. The former method is based on empirical formulae developed from strain gauge readings or photo-elasticity measurements of various round bars. Because use of these formulae beyond any of the validity ranges can lead to erroneous results in either direction, the FEM-based method is highly recommended.

The SCF calculated according to the rules set forth in this document is defined as the ratio of FEM-calculated stresses to nominal stresses calculated analytically. In use in connection with the present method in BCS-R M 53, principal stresses shall be calculated.

The analysis is to be conducted as linear elastic FE analysis, and unit loads of appropriate magnitude are to be applied for all load cases.

It is advisable to check the element accuracy of the FE solver in use, e.g. by modelling a simple geometry and comparing the FEM-obtained stresses with the analytical solution.

A boundary element method (BEM) approach may be used instead of FEM.

B. Model Requirements

The basic recommendations and assumptions for building of the FE-model are presented in Subsection 1. The final FE-model must meet one of the criteria in Subsection 3.

1. Element mesh recommendations

For the mesh quality criteria to be met, construction of the FE model for the evaluation of stress concentration factors according to the following recommendations is advised:

- The model consists of one complete crank, from the main bearing centre line to the opposite side's main bearing centre line.
- The following element types are used in the vicinity of the outlets:
 - 10-node tetrahedral elements
 - 8-node hexahedral elements
 - 20-node hexahedral elements
- The following mesh properties for the oil bore outlet are used:
 - Maximum element size $a = r / 4$ through the entire outlet fillet as well as in the bore direction (if 8-node hexahedral elements are used, even smaller elements are required for meeting of the quality criterion)
 - Recommended manner for element size in the fillet depth direction
 - First layer's thickness equal to element size of **a**
 - Second layer's thickness equal to element size of **2a**
 - Third -layer thickness equal to element size of **3a**
- In general, the rest of the crank should be suitable for numeric stability of the solver
- Drillings and holes for weight reduction have to be modelled

Submodeling may be used as long as the software requirements are fulfilled.

2. Material

BCS-R M53 does not consider material properties such as Young's modulus (E) and Poisson's ratio (ν). In the FE analysis, these material parameters are required, as primarily strain is calculated and stress is derived from strain through the use of Young's modulus and Poisson's ratio. Reliable values for material parameters have to be used, either as quoted in the literature or measured from representative material samples.

For steel the following is advised: $E = 2.05 \cdot 10^5$ MPa and $\nu = 0.3$.

3. Element mesh quality criteria

If the actual element mesh does not fulfil any of the following criteria in the area examined for SCF evaluation, a second calculation, with a finer mesh is to be performed.

3.1. Principal -stresses criterion

The quality of the mesh should be assured through checking of the stress component normal to the surface of the oil bore outlet radius. With principal stresses σ_1 , σ_2 and σ_3 the following criterion must be met:

$$\min(|\sigma_1|, |\sigma_2|, |\sigma_3|) < 0.03 \cdot \max(|\sigma_1|, |\sigma_2|, |\sigma_3|)$$

3.2. Averaged/unaveraged -stresses criterion

The averaged/unaveraged –stresses criterion is based on observation of the discontinuity of stress results over elements at the fillet for the calculation of the SCF:

- Unaveraged nodal stress results calculated from each element connected to a node i should differ less than 5 % from the 100 % averaged nodal stress results at this node i at the location examined.

C. Load cases and assessment of stress

For substitution of the analytically determined SCF in BCS- R M53, calculation shall be performed for the following load cases.

1. Torsion

The structure is loaded in pure torsion. The surface warp at the end faces of the model is suppressed.

Torque is applied to the central node, on the crankshaft axis. This node acts as the master node with six degrees of freedom, and is connected rigidly to all nodes of the end face.

The boundary and load conditions are valid for both in-line- and V- type engines.

For all nodes in an oil bore outlet, the principal stresses are obtained and the maximum value is taken for subsequent calculation of the SCF:

$$\gamma_T = \frac{\max(|\sigma_1|, |\sigma_2|, |\sigma_3|)}{\tau_N}$$

where the nominal torsion stress τ_N referred to the crankpin is evaluated per Section 2 item D.2.2.2 with

$$\text{torque } T: \tau_N = \frac{T}{W_P}$$

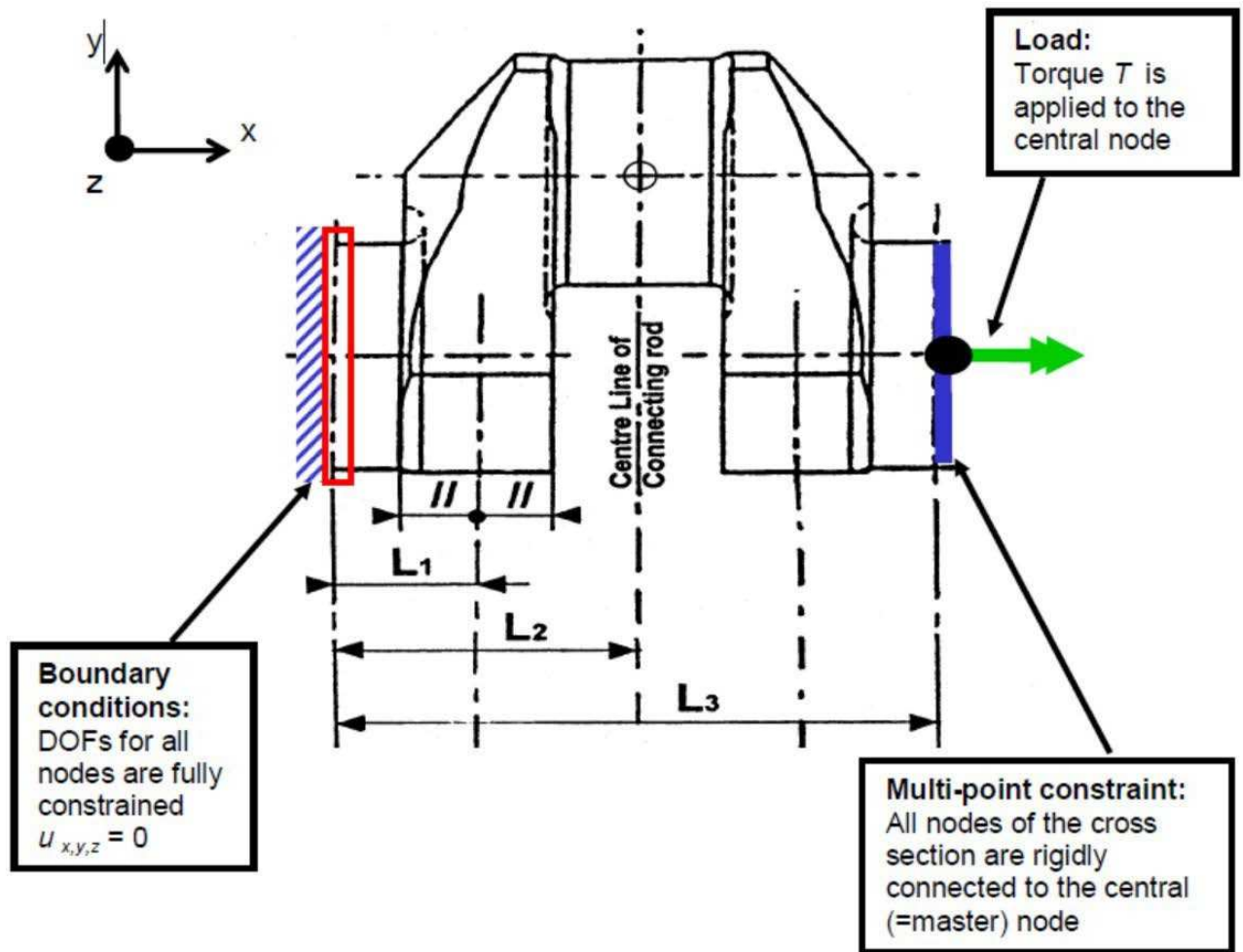


Figure 3.1 Boundary and load conditions for the torsion load case

2. Bending

The structure is loaded in pure bending. The surface warp at the end faces of the model is suppressed.

The bending moment is applied to the central node on the crankshaft axis. This node acts as the master node, with six degrees of freedom, and is connected rigidly to all nodes of the end face.

The boundary and load conditions are valid for both in-line- and V- type engines.

For all nodes in the oil bore outlet, principal stresses are obtained and the maximum value is taken for subsequent calculation of the SCF:

$$\gamma_B = \frac{\max(|\sigma_1|, |\sigma_2|, |\sigma_3|)}{\sigma_N}$$

where the nominal bending stress σ_N referred to the crankpin is calculated per Section 2 item D.2.1.2.2 with bending moment M :

$$\sigma_N = \frac{M}{W_e}$$

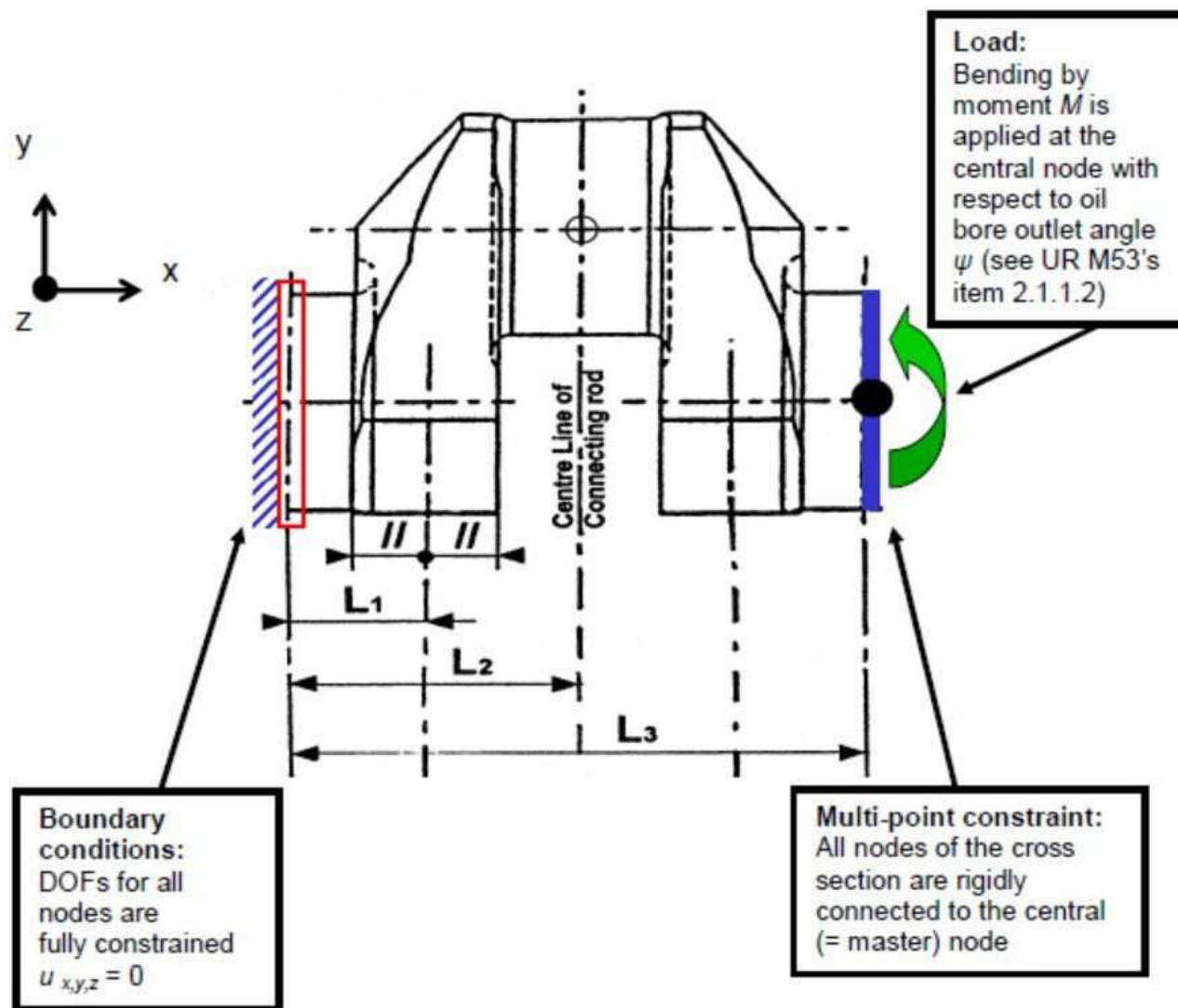


Figure 3.2. Boundary and load conditions for the pure bending load case

SECTION 3**THERMAL TURBOMACHINERY / STEAM TURBINES**

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A. General**1. Application**

The requirements of these rules apply to propulsion and auxiliary steam turbines. **BCS** reserves the right to authorize deviations from the Rules in the case of low-power turbines.

2. Definitions

2.1 The rated power of a turbine is the maximum power output at which the turbine is designed to run continuously at its rated speed.

2.2 The rated speed is the speed at which the turbine is designed to run its rated power.

2.3 The over speed limit is the maximum intermittent speed allowed for a turbine in service. It is not to exceed the rated speed by more than 15% and is to be the maximum permissible setting of the over speed governor.

3. Documents for Approval

3.1 For every steam turbine installation, the documents listed below are to be submitted to **BCS** in triplicate for approval:

- Assembly and sectional drawings of the turbines,
- Detail drawings of rotors, casings, blades, guide blades, valves, bed frames and main condenser,
- Schematic diagram of control and safety devices,
- Details of operating characteristics; rated power and corresponding rated rotational speed, and the values of pressure and temperature at each stage and critical speeds,
- Proof of a sufficient safety margin is required in the components subject to the severest loads. For temperatures up to approximately 400°C,

the relevant strength characteristic is the yield point at elevated temperatures; for higher temperatures it is the long-term creep strength for 100,000 hours at service temperature.

- Details of the welding conditions applicable to welded components,
- On request, strength calculation of rotors, discs and blades and calculations relating to blade vibration,
- Heat flow diagrams for each turbine installation and a set of operating instructions for at least each turbine type are to be submitted.

3.2 For small auxiliary turbines with a steam inlet temperature of up to 250°C it is generally sufficient to submit sectional drawings of the turbines.

B. Materials**1. Approved Materials****1.1 Rotating components**

1.1.1 Turbine rotors, discs and shafts are to be manufactured from forged steel.

The rotors of small turbines may also be cast in special-grade steel. Turbine blades, shrouds, binding and damping wires are to be made of corrosion-resistant materials.

1.2 Stationary components

1.2.1 The casings of high-pressure turbines and the bodies of manoeuvring, quick-closing and throttle valves are to be made of high-temperature steel or cast steel. Depending upon pressure and temperature, the casings of intermediate and low-pressure turbines may also be made of nodular or grey cast iron.

1.2.2 Diaphragms (guide vanes) are to be manufactured from steel, cast steel, nodular or grey cast iron depending on the temperature and load.

Welded construction may also be approved for steel or cast steel components.

1.2.3 Grey cast iron is not to be used for temperatures exceeding 260°C.

Nodular cast iron may be used up to a steam temperature of 300°C.

C. Design and Construction Principles

1. Foundations

1.1 The foundations of geared turbine installations are to be so designed and constructed that only minor relative movement can occur between the turbine and the gearing which can be compensated by suitable couplings.

1.2 For the design of foundation also Guideline for the Seating of Propulsion Plants and Auxiliary Machinery and Section 2, K.1 have to be considered.

2. Jointing of Mating Surfaces

The mating flanges of casings must form a tight joint without the use of any interposed material.

3. Bearing Lubrication

3.1 The lubrication of bearings must not be impaired by adjacent hot parts or by steam.

3.2 For the lubricating oil system, see Section 16, H.

4. Piping Connections

Pipes are to be connected to the turbine in such a way that no unacceptably high forces or moments can be transmitted to the turbine.

5. Drains

Turbines and the associated piping systems are to be equipped with adequate means of drainage.

6. Hot Surfaces

Hot surfaces likely to come into contact with crew during

operation are to be suitably guarded or insulated. Hot surfaces likely to exceed 220°C, and which are likely to come into contact with any leakage, under pressure or otherwise, of fuel oil, lubricating oil or other flammable liquid, are to be suitably insulated.

7. Turning Gear

7.1 Main propulsion turbines are to be equipped with turning gear for both directions of rotation. The rotors of auxiliary turbines must at least be capable of being turned by hand.

7.2 For vessels fitted with remote propulsion control, the turning gear status is to be indicated at each remote propulsion control station.

7.3 An interlock is to be fitted to prevent operation of the turbine when turning gear is engaged.

8. Measurement of Rotor Clearances

After assembly of each turbine in the manufacturer's works, the rotor position and the clearances are to be determined. The clearances are to be specified in the operating instructions.

9. Vibrations

The range of service speeds of turbine plant must not give rise to unacceptable bending vibrations or to vibrations affecting the entire installation. (The assessment may be based on ISO 10816-3 "Mechanical vibration-Evaluation of machine vibration by measurements on non-rotating parts" or an equivalent standard.)

10. Astern Running, Emergency Operation

10.1 Astern Power for Main Propulsion

10.1.1 The main propulsion machinery must possess sufficient power for running astern. The astern power is considered to be sufficient if, given free running astern, it is able to attain astern revolutions equivalent to at least 70% of the rated ahead revolutions for a period of at least 30 minutes.

10.1.2 For main propulsion machinery with reverse gearing, controllable pitch propellers or an electrical transmission system, astern running must not cause any overloading of the propulsion machinery.

10.1.3 During astern running, the main condenser and the ahead turbines are not to be excessively overheated.

10.2 Arrangements for Emergency Operation

10.2.1 In single screw ships fitted with cross compound steam turbines, the arrangements are to be such as to enable safe operation when the steam supply to any one of the turbines is isolated. For this emergency operation purpose the steam may be led directly to the lower pressure turbine and either the high or medium pressure part may exhaust directly to the condenser. Adequate arrangements and controls are to be provided for these operating conditions so that the pressure and temperature of the steam will not exceed those which the turbines and condenser are designed for, thus enabling a long term safe operation under emergency conditions.

10.2.2 The necessary pipes and valves for these arrangements are to be readily available and properly marked. A fit up test of all combinations of pipes and valves is to be presented to **BCS** prior to the first sea trials.

10.2.3 The permissible operating conditions (power/speeds) when operating without one of the turbines (all combinations) are to be specified and accessibly documented on board.

10.2.4 The operation of the turbines under emergency conditions is to be assessed by calculations for the potential influence on shaft alignment and gear teeth loading conditions. Corresponding documentation shall be submitted to **BCS** for appraisal.

11. Manoeuvring and Safety Equipment

11.1 Manoeuvring and Control Equipment

11.1.1 The simultaneous admission of steam to the

ahead and astern turbines is to be prevented by interlocks. Brief overlapping of the ahead and astern valves during manoeuvring can be allowed.

11.1.2 Fluids for operating hydraulic manoeuvring equipment, quick-closing and control systems must be suitable for all service temperatures and of low flammability.

11.1.3 Turbines for main propulsion machinery equipped with controllable pitch propellers, disengaging couplings or an electrical transmission system are to be fitted with a speed governor which, in the event of a sudden loss of load, prevents the revolutions from increasing to the trip speed.

11.1.4 The speed increase of turbines driving electric generators - except those for electrical propeller drive - resulting from a change from full load to no-load may not exceed 5% on the resumption of steady running conditions. The transient speed increase resulting from a sudden change from full load to no-load conditions may not exceed 10% and must be separated by a sufficient margin from the trip speed.

11.2 Safety Devices

11.2.1 Main propulsion turbines must be equipped with quick-closing devices which automatically shut off the steam supply in case of:

11.2.1.1 Over speed. Excess speeds of more than 15% above the rated value are to be prevented;

11.2.1.2 Unacceptable axial displacement of the rotor;

11.2.1.3 An unacceptable increase in the condenser pressure;

11.2.1.4 An unacceptable increase in the condenser water level; and

11.2.1.5 An unacceptable drop in the lubricating oil pressure.

11.2.2 In cases 11.2.1.1 and 11.2.1.2, the quick-closing devices must be actuated by the turbine shafts.

11.2.3 It must also be possible to trip the quick-closing device manually at the turbine and from the control platform.

11.2.4 Re-setting of the quick-closing device may be effected only at the turbine or from the control platform with the control valve in the closed position.

11.2.5 It is recommended that an alarm system should be fitted which responds to excessive vibration velocities. (The assessment may be based on ISO 10816-3 "Mechanical vibration-Evaluation of machine vibration by measurements on non-rotating parts" or an equivalent standard.)

11.2.6 An interlock is to be provided to ensure that the main turbine cannot be started up when the turning gear is engaged.

11.2.7 Steam bleeder and pass-in lines are to be fitted with automatic devices which prevent steam from flowing into the turbine when the main steam admission valve is closed.

11.2.8 Turbines driving auxiliary machines must at least be equipped with quick-closing devices for contingencies 11.2.1.1 and 11.2.1.4. An excessive rise in the exhaust steam pressure must actuate the quick-closing device.

11.2.9 It shall be possible to start up any turbine only when the quick-closing device is ready for operation.

11.3 Other Rules

Depending on the degree of automation involved, the extent and design of the equipment is also subject to the Rules in Chapter 4-1 - Automation.

12. Control and Monitoring Equipment

12.1 Arrangement

The control and monitoring equipment for each main propulsion unit is to be located on the control platform.

12.2 Scope and Design of Equipment

Depending on the degree of automation involved, the scope and design of the equipment is also subject to the Rules in Chapter 4-1 - Automation.

12.3 Control and Indicating Instruments

When the turning gear is engaged, this fact must be indicated visually at the control platform.

Turbine and pipeline drainage valves are either to operate automatically or are to be combined into groups which can be operated from the control platform.

12.4 Equipment for Auxiliary Turbines

Turbines driving auxiliary machines are to be provided with the necessary equipment on the basis of paragraphs 12.2 and 12.3.

13. Condensers

13.1 Design

13.1.1 The condenser is to be so designed that the inlet steam speed not to prohibitive stressing of the condenser tubes result. Excessive sagging of the tubes and vibration are to be avoided, e.g. by the incorporation of tube supporting plates.

13.1.2 The water chambers and steam space must be provided with openings for inspection and cleaning. Anti-corrosion protection is to be provided on the water side.

13.1.3 In the case of single-plane turbine installations, suitable measures must be taken to prevent condensate from flowing back into the low pressure turbine.

13.2. Cooling Water Supply

The supply of cooling water to the condenser is subject to the Rules contained in Section 16, I.

D. Tests**1. Material Testing**

1.1 The following parts are subject to testing in accordance with the **BCS** Material Rules:

- Rotating parts such as rotors, discs, shafts, shrink rings, blades, toothed coupling and other dynamically loaded components as well as valve spindles and cones;
- Stationary parts such as casings, guide blades, nozzles and nozzle chests, guide vanes, turbine casing bolts, bed frames and bearing pedestals;
- Condenser tubes and tube plates.

1.2 In the case of small auxiliary turbines with a steam inlet temperature of up to 250°C, the extent of the tests may be limited to the disc and shaft materials.

2. Testing of Turbine Rotors**2.1 Thermal stability test**

Rotors forged in one piece and welded rotors are to be tested for axial stability by submitting them to a thermal stability test.

2.2 Balancing

2.2.1 Finished rotors, complete with blades and associated rotating parts and ready for assembly, are to be dynamically balanced in the presence of the Surveyor (The assessment may be based on ISO 21940-11 standard “Mechanical vibration-Rotor balancing” or an equivalent standard.).

2.2.2 The stabilizing test temperature is to be not less than 28 °C above the maximum steam temperature to which the rotor will be exposed, and not more than the tempering temperature of the rotor material.

2.3 Cold overspeed test

Turbine rotors are to be tested at a speed at least 15% above the rated speed for not less than 3 minutes. **BCS** may accept mathematical proof of the stresses in the rotating parts at over speed as a substitute for the over speed test itself provided that the design is such that reliable calculations are possible and the rotor has been non-destructively tested to ascertain its freedom from defects.

3. Pressure and Tightness Tests

3.1 All finished casing components are to be subjected to hydrostatic testing in the presence of the Surveyor.

The test pressure p_p is calculated as follows:

$$p_p = 1.5 p_{e,perm} \quad \text{where } p_{e,perm} \leq 80 [\text{bar}]$$

$$p_p = p_{e,perm} + 40 \text{ bar} \quad \text{where } p_{e,perm} > 80 [\text{bar}]$$

$$p_{e,perm} [\text{bar}] \text{ Maximum allowable working pressure.}$$

For the bodies of quick-closing, manoeuvring and control valves, the test pressure is 1.5 times the maximum allowable working pressure of the boiler (approval pressure). The sealing efficiency of these valves when closed is to be tested at $1.1 p_{e,perm}$.

3.2 Casing parts on the exhaust side of low pressure turbines subject during operation to the condenser pressure are to be tested at $p_p = 1.0 \text{ bar}$.

3.3 Condensers are to be subjected to separate hydrostatic testing on both the steam and the water side. The test pressure p_p shall be:

$$p_p = 1.0 [\text{bar}] \quad \text{on the steam side}$$

$$p_p = 1.5 p_{e,perm} \quad \text{on the water side}$$

E. Trials**1. Factory Trials**

Where steam turbines are subjected to a trial run at the factory, the satisfactory functioning of the manoeuvring, safety and control equipment is to be verified during the trial run, and such verification shall in any case take place not later than the commissioning of the plant aboard ship.

2. Shipboard Trials

2.1 Main turbines are to be subjected to a dock trial and thereafter, during a trial voyage, to the following tests:

- Operation at rated rpm for at least 6 hours;
- Reversing manoeuvres; and

- During the dock or sea trials, astern revolutions equal to at least 70% of the rated ahead rpm for about 20 minutes.

During astern and subsequent forward operation, the steam pressures and temperatures and the relative expansion must not assume magnitudes liable to endanger the operational safety of the plant.

2.2 Turbines driving electric generators or auxiliary machines are to be run for at least 4 hours at their rated power and for 30 minutes at 110% rated power.

2.2 **BCS** reserves the right to call for additional tests in individual cases.

SECTION 4**TURBOMACHINERY / GAS TURBINES AND EXHAUST GAS TURBOCHARGERS**

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Exhaust Gas Turbochargers

A. General

1. Scope

1.1 These requirements are applicable for turbochargers with regard to design approval, type testing and certification and their matching on engines. Turbochargers are to be type approved, either separately or as a part of an engine. The requirements are written for exhaust gas driven turbochargers, but apply in principle also for engine driven chargers.

1.2 The requirements escalate with the size of the turbochargers. The parameter for size is the engine power (at MCR) supplied by a group of cylinders served by the actual turbocharger, (e.g. for a V-engine with one turbocharger for each bank the size is half of the total engine power).

1.3 Turbochargers are categorised in three groups depending on served power by cylinder groups with:

- Category A: ≤ 1000 kW
- Category B: > 1000 kW and ≤ 2500 kW
- Category C: > 2500 kW

2. Definitions

2.1 Turbocharger is designed to charge the diesel engine cylinders with air at a higher pressure and hence higher density than air at atmospheric pressure. The term turbocharger also refers to superchargers, turbo blowers, scavenge blowers.

2.2 The Maximum Operating Speed is the maximum permissible speed for which the turbocharger is designed to run continuously at the maximum permissible operating temperature (speed at 110% diesel engine output). The operational speed corresponds to the speed at 100% diesel engine output at MCR (Maximum Continuous Rating) condition.

3. Type Approval

In general turbochargers are type approved. A type Certificate valid for 5 years will be issued in accordance with 3.1.

3.1 Documentation to be submitted

For every turbocharger type, the documents listed below are to be submitted to **BCS** in triplicate for approval:

Category A:

On request

- Containment test report.
- Cross sectional drawing with principal dimensions and names of components.
- Test program.

Category B and C:

- Cross sectional drawing with principal dimensions and materials of housing components for containment evaluation.
- Documentation of containment in the event of disc fracture, see C.7.1.
- Operational data and limitations as:
 - Maximum permissible operating speed (rpm)
 - Alarm level for over-speed
 - Maximum permissible exhaust gas temperature before turbine
 - Alarm level for exhaust gas temperature before turbine
 - Minimum lubrication oil inlet pressure
 - Lubrication oil inlet pressure low alarm set point
 - Maximum lubrication oil outlet temperature
 - Lubrication oil outlet temperature high alarm set point
 - Maximum permissible vibration levels, i.e. self- and externally generated vibration

(Alarm levels may be equal to permissible limits but shall not be reached when operating the engine at 110% power or at any approved intermittent overload beyond the 110%.)

- Arrangement of lubrication system, all variants within a range.

- Type test reports.

- Test program.

Category C:

- Drawings of the housing and rotating parts including details of blade fixing.

- Material specifications (chemical composition and mechanical properties) of all parts mentioned above.

- Welding details and welding procedure of above mentioned parts, if applicable.

- Documentation* of safe torque transmission when the disc is connected to the shaft by an interference fit, see C.7.4.

- Information on expected lifespan, considering creep, low cycle fatigue and high cycle fatigue.

- Operation and maintenance manuals*.

** Applicable to two sizes in a generic range of turbochargers.*

Additional information is to be submitted to **BCS** with documents:

- Details (name and address) of the subcontractors for rotating parts and casings.

- Details (name and address) of the licensees, if applicable, who are authorized by the licensor to produce and deliver turbochargers of a certain type.

4. Certification

4.1 The manufacturer shall adhere to a quality system designed to ensure that the designer's specifications are met, and that manufacturing is in accordance with the approved drawings.

4.2 For category C, this shall be verified by means of periodic product audits of an Alternative Certification Scheme (ACS) by **BCS**.

4.3 These audits shall focus on:

- Chemical composition of material for the rotating parts.

- Mechanical properties of the material of a representative specimen for the rotating parts and the casing.

- UT and crack detection of rotating parts.

- Dimensional inspection of rotating parts.

- Rotor balancing.

- Hydraulic testing of cooling spaces to 4 bars or 1.5 times maximum working pressure, whichever is higher.

- Overspeed test of all compressor wheels for a duration of 3 minutes at either 20% above alarm level speed at room temperature or 10% above alarm level speed at 45°C inlet temperature when tested in the actual housing with the corresponding pressure ratio. The overspeed test may be waived for forged wheels that are individually controlled by an approved non-destructive method.

4.4 Turbochargers shall be delivered with:

- For category C, a society certificate, which at a minimum cites the applicable type approval and the ACS, when ACS applies.

- For category B, a work's certificate, which at a minimum cites the applicable type approval, which includes production assessment.

4.5 The same applies to replacement of rotating parts and casing.

4.6 Alternatively to the above periodic product audits, individual certification of a turbocharger and its parts may be made at the discretion of **BCS**. However, such individual certification of category C turbocharger and its parts shall also be based on test requirements specified in the above mentioned bullet points.

B. Design and Installation**1. General**

Turbochargers are to be designed to operate at least under the ambient conditions given in Section 1, C. The component lifetime and the alarm level for speed shall be based on 45°C air inlet temperature.

2. Basic Design Considerations

2.1 Basis of acceptance and subsequent certification of a turbocharger is the drawing approval and the documented type test as well as the verification of the containment integrity.

2.2 The turbocharger casings are to be of a specification suitable for stresses and temperatures to which they are designed to be exposed. Cast iron may only be considered for operating temperatures not exceeding 232°C. Ductile cast iron designed for high temperature service is acceptable subject to review of mechanical and metallurgical properties at design temperatures. Cast steel may be considered for operating temperatures not exceeding 427°C. All castings are to be properly heat-treated to remove internal stresses. Deviations from the standard heat-treatment have to be approved separately by **BCS**.

2.3 Casings are to be provided with suitable seals. Drains are to be fitted in places where water or oil may collect.

2.4 Rotors, bearings, discs, impellers and blades are to be designed in accordance with sound engineering principles. Design criteria along with engineering analyses substantiating the suitability of the design for the rated power and speed are to be submitted for review.

2.5 The turbocharger rotors also need to be designed according to the speed criteria for natural burst. In general the burst speed of the turbine shall be lower than the burst speed of the compressor in order to avoid an excessive turbine over speed after compressor burst due to loss of energy absorption in the compressor.

3. Air Inlet

The air inlet of the turbocharger is to be fitted with a filter in order to minimize the entrance of harmful foreign material or water.

4. Hot Surfaces

4.1 According to SOLAS Rules and Regulations, Chapter II-2, Part B - Prevention of fire and explosion, Regulation 4, Paragraph 2.3, parts with surface temperatures above 220°C are to be properly insulated in order to minimize the risk of fire if flammable oils, lubrication oils, or fuel come into contact with these surfaces.

4.2 Pipe connections have to be located or shielded with collars in such a way that either spraying or dripping leak oil may not come into contact with hot surfaces of more than 220°C.

4.3 Hot components in range of passageways or within the working area of turbochargers shall be insulated or protected so that touching does not cause burns.

5. Bearing Lubrication

5.1 Bearing lubrication may not be impaired by exhaust gases or by adjacent hot components.

5.2 Leakage oil and oil vapors are to be evacuated in such a way that they do not come into contact with parts at temperatures equal or above their self-ignition temperature.

5.3 For turbochargers which share a common lubrication system with the diesel engine and which have got an electrical lubrication oil pump supply, it is recommended to install an emergency lubrication oil tank.

5.4 A gas flow from turbocharger to adjacent components containing explosive gases, e.g. crankshaft casing shall be prevented by an adequate ventilating system.

6. Pipe and Duct Connections

Pipe or duct connections to the turbocharger casing are to be made in such a way as to prevent the transmission of excessive loads or moments to the turbochargers.

7. Alarms & Monitoring

7.1 For all turbochargers of Categories B and C, indications and alarms as listed in the table are required.

7.2 Indications may be provided at either local or remote locations.

C. Tests

1. Material Tests

1.1 General

1.1.1 Material testing is required for casings, shaft, compressor and turbine wheel, including the blades. The materials used for the components of exhaust gas turbochargers shall be suitable for the intended purpose and shall satisfy the minimum requirements of the approved manufacturer's specification.

1.1.2 All materials shall be manufactured by sufficiently proven techniques according to state of the art, whereby it is ensured that the required properties are achieved. Where new technologies are applied, a preliminary proof of their suitability is to be submitted to **BCS**. According to the decision of **BCS**, this may be done in terms of special tests for procedures and/or by presentation of the work's own test results as well as by expertise of independent testing bodies.

Pos.	Monitored Parameters	Category of Turbochargers				Notes
		B		C		
		Alarm	Indication	Alarm	Indication	
1	Speed	High ⁽⁴⁾	X ⁽⁴⁾	High ⁽⁴⁾	X ⁽⁴⁾	
2	Exhaust gas at each turbocharger inlet, temperature	High ⁽¹⁾	X ⁽¹⁾	high	X	High temp. alarms for each cylinder at engine is acceptable ⁽²⁾
3	Lub. oil at turbocharger outlet, temperature			high	X	If not forced system, oil temperature near bearings
4	Lub. oil at turbocharger inlet, pressure	low	X	low	X	Only for forced lubrication systems ⁽³⁾

(1) For Category B turbochargers, the exhaust gas temperature may be alternatively monitored at the turbocharger outlet, provided that the alarm level is set to a safe level for the turbine and that correlation between inlet and outlet temperatures is substantiated.

(2) Alarm and indication of the exhaust gas temperature at turbocharger inlet may be waived if alarm and indication for individual exhaust gas temperature is provided for each cylinder and the alarm level is set to a value safe for the turbocharger.

(3) Separate sensors are to be provided if the lubrication oil system of the turbocharger is not integrated with the lubrication oil system of the diesel engine or if it is separated by a throttle or pressure reduction valve from the diesel engine lubrication oil system.

(4) On turbocharging systems where turbochargers are activated sequentially, speed monitoring is not required for the turbocharger(s) being activated last in the sequence, provided all turbochargers share the same intake air filter and they are not fitted with waste gates.

1.2 Condition of supply and heat treatment

Materials are to be supplied in the prescribed heat-treated condition. Where the final heat treatment is to be performed by the supplier, the actual condition in which the material is supplied shall be clearly stated in the relevant Certificate. The final verification of material properties for components needs to be adapted and coordinated according to production procedure.

Deviations from the heat treatment procedures have to be approved by **BCS** separately.

1.3 Chemical composition and mechanical properties

Materials and products have to satisfy the requirements relating to chemical composition and mechanical properties specified in the **BCS** Material Rules or, applicable, in the relevant manufacturer's specifications approved in connection with the design in each case.

1.4 Non-destructive testing

Non-destructive testing shall be applied for the wheels, blades and welded joints of rotating parts. Another equal production control may be accepted for welded joints. The testing shall be performed by the manufacturer and the results together with details of the test method are to be evaluated according to recognized quality criteria and documented in a Certificate.

1.5 Material certificates

1.5.1 Material Certificates shall contain at least the following information:

- Quantity, type of product, dimensions where applicable, types of material, supply condition and weight
- Name of supplier together with order and job numbers, if applicable
- Construction number, where known
- Manufacturing process,
- Heat numbers and chemical composition,

- Supply condition with details of heat treatment,
- Identifying marks,
- Result of mechanical property tests carried out on material at ambient temperature.

1.5.2 Depending on the produced component of turbocharger material test certificates are to be issued by **BCS** respectively the manufacturer. The Certificates are indicated in Table 4. 1.

Table 4.1 Material certificates

Turbocharger components	Type of Certificate
Shaft	BCS Certificate (acc. to DIN EN 10204 - 3.1 C)
Rotors (compressor and turbine)	BCS Certificate (acc. to DIN EN 10204 - 3.1 C)
Blades	BCS Certificate (acc. to DIN EN 10204 - 3.1 C)
Casing	Manufacturer Inspection Certificate (acc. to DIN EN 10204 - 3.1)

1.5.3 Test certificates are to be issued in accordance with **BCS** Material rules. The materials to conform to specifications approved in connection with the approval of the type in each case.

1.5.4 If the manufacturer is approved according to D.2. as manufacturer of mass produced exhaust gas turbochargers fitted on diesel engines having a cylinder bore ≤ 300 mm, the material properties of these parts may be covered by Manufacturer Inspection Certificates and need not to be verified by a Surveyor.

2. Containment Test

2.1 The turbocharger has to fulfill containment requirements in case of rotor burst. This requires that at rotor burst no part may penetrate the casing of the turbocharger or escape through the air intake. For documentation purposes (test/calculation), it shall be assumed that the discs disintegrate in the worst possible way.

For category B and C, containment shall be documented by testing. Fulfilment of this requirement can be awarded to a generic range of turbochargers based on testing of one specific unit. Testing of a large unit is preferred as this is considered conservative for all smaller units in the generic range. In any case, it must be documented (e.g. by calculation) that the selected test unit really is representative for the whole generic range.

The following requirements are applicable for a type approval of turbochargers.

The minimum speeds for the containment test are defined as follows:

- Compressor: ≥ 120 % of its maximum permissible speed
- Turbine: ≥ 140 % of its maximum permissible speed or the natural burst speed (whichever is lower)

The containment test has to be performed at working temperature. The theoretical (design) natural burst speeds of compressor and turbine have to be submitted for information.

2.2 A numerical proof of sufficient containment integrity of the casing based on calculations by means of a simulation model may be accepted provided that

- The numerical simulation model has been tested and its applicability/accuracy has been proven by direct comparison between calculation results and practical containment test for a reference application (reference containment test). This proof has to be provided once by the manufacturer, who wants to apply for acceptance of numerical simulation,
- The corresponding numerical simulation for the containment is performed for the same speeds, as specified for the containment test (see above),
- The design of the turbocharger regarding the geometry and kinematics is similar to that of

one turbocharger which has passed the containment test. In general totally new designs will call for new containment tests,

- Material properties for high-speed deformations are to be applied in the numeric simulation. The correlation between normal properties and the properties at the pertinent deformation speed are to be substantiated.

2.3 In general a **BCS** Surveyor must be involved for the containment test. The documentation of the physical containment test as well as the report of the simulation results must be submitted to **BCS** within scope of the approval procedure.

2.4 Disc-shaft shrinkage fit

2.4.1 Applicable to Category C

2.4.2 In cases where the disc is connected to the shaft with interference fit, calculations shall substantiate safe torque transmission during all relevant operating conditions such as maximum speed, maximum torque and maximum temperature gradient combined with minimum shrinkage amount.

3. Type Testing

3.1 Applicable to Categories B and C

3.2 The type test for a generic range of turbochargers may be carried out either on an engine (for which the turbocharger is foreseen) or in a test rig.

3.3 Turbochargers are to be subjected to at least 500 load cycles at the limits of operation. This test may be waived if the turbocharger together with the engine is subjected to this kind of low cycle testing, see Section 2, E.3.

3.4 The suitability of the turbocharger for such kind of operation is to be preliminarily stated by the manufacturer.

3.5 The rotor vibration characteristics shall be measured and recorded in order to identify possible sub-synchronous vibrations and resonances.

3.6 The type test shall be completed by a hot running test at maximum permissible speed combined with maximum permissible temperature for at least one hour. After this test, the turbocharger shall be opened for examination, with focus on possible rubbing and the bearing conditions.

3.7 The extent of the surveyor's presence during the various parts of the type tests is left to the discretion of **BCS**.

4. Spare Parts

The rotating assembly parts (rotor, wheels and blades) as well as turbocharger casings have to be replaced by spare parts which are manufactured by **BCS** manufacturers according to the previously approved drawings and material specifications. The manufacturer must be recognized by the holder of the original type approval.

D. Shop Approvals

1. Materials and Production

The manufacturers of the material as well as the production procedures for the rotating parts and casings have to be approved by **BCS**.

2. Produced Exhaust Gas Turbochargers

2.1 Manufacturers of turbochargers who operate a quality management system and are manufacturing exhaust gas turbochargers fitted on **BCS** approved diesel engines having a cylinder bore of ≤ 300 mm may apply for the shop approval by **BCS**.

2.2 Upon satisfactory shop approval, the material tests according to C.1. for these parts may be covered by a Manufacturer Inspection Certificate and need not to be verified by a Surveyor.

2.3 In addition a bench test according to C.6 may be carried out on a sample basis and need not to be verified by a **BCS** Surveyor.

2.4 The shop approval is valid for 3 years with annual follow up audits.

2.5 No **BCS** certificate will be issued for produced turbochargers. Produced turbochargers will be mentioned with the serial number in the final Certificate intended for the diesel engine.

3. Manufacturing of Exhaust Gas Turbochargers Under License Agreement

3.1 Manufacturers who are manufacturing exhaust gas turbochargers under a license agreement must have shop recognition of **BCS**.

3.2 The shop approval can be issued in addition to a valid license agreement if the following requirements are fulfilled:

- The manufactured turbochargers have a valid **BCS** approval of the type for the licensor.
- The drawings and the material specification as well as the working procedures comply with the drawings and specifications approved in connection with the turbocharger approval of the type for the licensor.

3.3 Upon satisfactory assessment in combination with a bench test carried out on a sample basis with **BCS** Surveyor's attendance, the drawing approval and tests according to C.7. and C.8. are not required. The scope of the testing for materials and components has to be fulfilled unchanged according to C.2 to C.6.

3.4 The shop recognition is valid for three years with annual follow up audits and can be granted, if required in combination with an approval as manufacturer of mass-produced turbochargers.

3.5 The approval becomes invalid if the license agreement expires. The licensor is obliged to inform **BCS** about the date of expiry.

E. Gas Turbines

The documents for approval for main and auxiliary gas turbines have to be submitted to **BCS**, see A.3.1.

1. Governor and Over Speed Protective Devices

1.1 Main gas turbines are to be provided with over speed protective devices to prevent the turbine speed from exceeding more than 15% of the maximum continuous speed.

1.2 Where a main gas turbine incorporates a reverse gear, electric transmission, controllable pitch propeller or other free-coupling arrangement, a speed governor independent of the over speed protective device is to be fitted and is to be capable of controlling the speed of the unloaded gas turbine without bringing the over speed protective device into action.

2. Miscellaneous Automatic Safety Devices

2.1 Details of the manufacturer's proposed automatic safety devices to safeguard against hazardous conditions arising in the event of malfunctions in the gas turbine installation are to be submitted to the Classification Society together with the failure mode and effect analysis.

2.2 Main gas turbines are to be equipped with a quick closing device (shut-down device) which automatically shuts off the fuel supply to the turbines at least in case of:

- Over speed,
- Unacceptable lubricating oil pressure drop,
- Loss of flame during operation,
- Excessive vibration,
- Excessive axial displacement of each rotor (Except for gas turbines with rolling bearings),
- Excessive high temperature of exhaust gas,

- Unacceptable lubricating oil pressure drop of reduction gear,

- Excessive high vacuum pressure at the compressor inlet.

2.3 The following turbine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the main gas turbine:

- Lubricating oil supply,
- Oil fuel supply (or automatic control of oil fuel viscosity as alternative),
- Exhaust gas

2.4 Automatic or interlocked means are to be provided for clearing all parts of the main gas turbine of the accumulation of liquid fuel or for purging gaseous fuel, before ignition commences on starting or recommences after failure to start.

2.5 Hand trip gear for shutting off the fuel in an emergency is to be provided at the manoeuvring station.

2.6 Starting devices are to be so arranged that firing operation is discontinued and main fuel valve is closed within pre-determined time, when ignition is failed.

3. Alarming Devices

3.1 Alarming devices listed in Table 4.2 are to be provided.

3.2 Suitable alarms are to be operated by the activation of shutdown devices.

Table 4.2 List of alarm and shutdown

Monitoring parameter	Alarm	Shutdown
Turbine speed	H	S
Lubricating oil pressure	L*	S
Lubricating oil pressure of reduction gear	L*	S
Differential pressure across lubricating oil filter	H	
Lubricating oil temperature	H	
Oil fuel supply pressure	L	
Oil fuel temperature	H	
Cooling medium temperature	H	
Bearing temperature	H	
Flame and ignition Failure	T	S
Automatic starting Failure	T	
Vibration	H*	S
Axial displacement of rotor	H	S
Exhaust gas temperature	H*	S
Vacuum pressure at the compressor inlet	H*	S
Loss of control system	T	
<i>H = Alarm for high value</i> <i>L = Alarm for low value</i> <i>T = Alarm activated</i> <i>S = Shut down</i> <i>* Alarms are to be activated at the suitable setting points prior to arriving the critical condition for the activation of shutdown devices.</i>		

SECTION 5

MAIN SHAFTING

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A. General

approved by **BCS** are classified and itemized as follows:

1. Scope

1.1 The following rules apply to the standard and established types of shafting for main and auxiliary propulsion system and their associated components such as couplings, clutches, shafts and other power transmitting components for propulsion purposes as well as for lateral thrusters. Novel designs require the **BCS's** special approval.

1.2 All kind of propulsion shafts and their associated components are to be superb designed and constructed so that they can hold out the maximum permissible stresses arising from every kind condition of the continuous, the transient and the peak operation.

1.3 In the case of ships with ice classes, the strengthening factors given in Section 19 are to be complied with . **BCS** reserves the right to call for propeller shaft dimensions in excess of those specified in this Section if the propeller arrangement results in increased bending stresses.

1.4 The introduced definitions apply to the formulas in this section:

- “**Tail shaft**” is the part of the shaft of a ship's propeller extending through the stern tube.
- “**Stern tube shaft**” or “**tube shaft**” is the part of the propulsion shaft passing through the stern tube from the forward end of the propeller end bearing to the in-board shaft seal.
- “**Propeller shaft**” covers the tail shaft and tube shaft.
- “**Line shaft**” or “**intermediate shaft**” is the part of the propulsion shaft in-board of the vessel.
- “**Thrust shaft**” is the part of the propulsion shaft transmitting thrust to the thrust bearing.

2. Documents for Approval

The documents, plans and particulars which are

2.1 Documents for propulsion shafting

- General drawings of the entire shafting arrangement from the main engine coupling to the propeller,
- Detail drawings of the propulsion shaft (thrust, line, tube and tail shaft, as applicable),
- Detailed drawing and arrangement of the couplings (integral, demountable, keyed, or shrink-fit, coupling bolts **(1)** and keys),
- Engineering analyses and fitting instructions for shrink-fit couplings,
- Detailed drawing and arrangement of the shaft bearings, the shaft seals and the shaft lubricating system,
- Detail drawings and arrangement of the stern tube, the stern tube seals and the cast resin mount,
- Rated power of main engine, reduction ratio of gear and shaft rpm,
- Power take-off to shaft generators, propulsion boosters, or similar equipment, (rated 100 kW and over, as applicable),
- Materials,

2.1.1 The drawings must contain all the data necessary for approval. Where necessary, design calculations for components and descriptions of the plant are to be submitted.

2.1.2 For the arrangement of the shaft bearings, an alignment calculation, including alignment instructions, has to be submitted for approval (see C.6.5 and D.2) With consent of the **BCS** for shafting with intermediate shafts $d < 200$ mm the alignment calculation may be waived.

(1) *Specific details regarding the interference fit of the coupling bolts are to be submitted.*

2.1.3 The submitted documentation must contain all the data necessary to enable the stresses to be evaluated.

2.2 Documents for clutches

- Construction details of torque transmitting components, housing along with their materials and dimensions,
- Rated power and engine speed,
- Engineering analysis,
- Clutch operating data.

2.3 Documents for flexible couplings

- Construction details of torque transmitting components, housing along with their materials and dimensions,
- Rated power and engine speed,
- Engineering analysis,
- Static and dynamic torsional stiffness and damping characteristics,
- Allowable vibratory torque for continuous and transient operation,
- Allowable power loss (overheating),
- Allowable misalignment for continuous operation.

2.4 Documents for cardan shafts

- Dimensions of all torque transmitting components and their materials,
- Rated power, rated torque, and input speed from engine,
- Engineering analysis,
- Operating data.

2.5 Design calculations

- Propulsion shaft alignment calculations where propulsion shaft is sensitive to alignment, (See the requirements in C.2 and D.2),
- Torsional vibration analyses,
- Axial and lateral (whirling) vibration calculations where there are barred speed ranges within the engine operating speed range.

B. Approved Materials

1. General

1.1 Propulsion shafts (tail, tube, intermediate and thrust shafts) together with flange, couplings, coupling bolts, clutches and keys are to be made of forged steel or rolled bars, as convenient, in accordance with Chapter 2 - Material, Section 5, or other specifications as may be specially approved with a specific design. Where appropriate, the couplings and their components may be made of cast steel. Rolled round steel may be used for plain, flangeless shafts. Where the materials other than those mentioned here are proposed, full details of chemical composition, heat treatment and mechanical properties, as convenient, are to be submitted for approval.

1.2 Shaft liners may be of bronze, corrosion resistant stainless steel or other approved alloys and are to be free from porosity and other defects. Continuous liners are to be in one piece or, if made of two or more lengths, the joining of the separate pieces is to be done by an approved method of welding through not less than two thirds the thickness of the liner or by an approved rubber seal arrangement.

1.3 In general, the minimum specified ultimate tensile strength of steels used for propulsion shafting

(shafts, flange couplings, bolts/fitted bolts) shall be between 400 N/mm² and 800 N/mm².

1.4 Carbon steel material having a percentage elongation more than 16 is permitted to be used in any shafting component. However, the materials having an elongation of less than 10% are not accepted to be used in the non-fitted alloy steel coupling bolts even they are manufactured to a recognized Standard.

Alloy steels having a percentage elongation less than 16 may be applied subject to **BCS** approval.

1.5 For dynamically loaded parts of the shafting, designed in accordance to the formulas in C and D explicitly for the shafts themselves as well as for connecting / fitted bolts for flanged connections in general quenched and tempered steels should be used with a tensile strength of more than 500 N/mm².

1.6 Where shafts may experience vibratory stresses close to the permissible stresses for transient operation, the materials are to have a specified minimum ultimate tensile strength (R_M) of 500 N/mm². Otherwise materials having a specified minimum ultimate tensile strength (R_M) of 400 N/mm² may be used.

For use in the formulae (2) of item C.2.1 and (1), (2), (3), (4) of Section 6, C.1.1, R_M is limited as follows:

- For carbon and carbon manganese steels, a minimum specified tensile strength not exceeding 600 N/mm² for use in the formulae (1), (2), (3), (4) of Section 6, C.1.1 and not exceeding 760 N/mm² in the formulae (2) of item C.2.1.
- For alloy steels, a minimum specified tensile strength not exceeding 800 N/mm².
- For propeller shafts in general a minimum specified tensile strength not exceeding 600 N/mm² (for carbon, carbon manganese and alloy steels).

1.7 Where materials with greater specified or actual tensile strengths than the limitations given above are used, reduced shaft dimensions or higher permissible vibration stresses are not acceptable when derived from formulae (1) and (2) of item C.2 and (1),

(2) of Section 6, C.1.1 unless **BCS** verifies that the materials exhibit similar fatigue life as conventional steels (Refer to item B.2).

1.8 Where in special cases wrought copper alloys resistant to seawater are to be used for the shafting, the consent of **BCS** shall be obtained.

2. Special Approval of Alloy Steel Used For Intermediate Shaft Material

2.1 Application

These requirements are applied to the approval of alloy steel which has a minimum specified tensile strength greater than 800 N/mm², but less than 950 N/mm² intended for use as intermediate shaft material.

2.2 Torsional fatigue test

A torsional fatigue test is to be performed to verify that the material exhibits similar fatigue life as conventional steels. The torsional fatigue strength of said material is to be equal to or greater than the permissible torsional vibration stress τ_C given by the formulae (1), (2), (3), (4) of Section 6, C.1.1. The test is to be carried out with notched and unnotched specimens respectively. For calculation of the stress concentration factor of the notched specimen, fatigue strength reduction factor β should be evaluated in consideration of the severest torsional stress concentration in the design criteria.

2.2.1 Test conditions

Test conditions are to be in accordance with Table 5.1. Mean surface roughness is to be $<0.2\mu\text{m Ra}$ with the absence of localised machining marks verified by visual examination at low magnification (x20) as required by Section 8.4 of ISO 1352.

Test procedures are to be in accordance with Section 10 of ISO 1352.

2.2.2 Acceptance criteria

Measured high-cycle torsional fatigue strength τ_{C1} and low-cycle torsional fatigue strength τ_{C2} are to be equal to or greater than the values given by the following

formulae:

$$\tau_{C1} \geq \tau_{C,\lambda=0} = \frac{R_M + 160}{6} \cdot C_K \cdot C_D$$

$$\tau_{C2} \geq 1.7 \cdot \frac{1}{\sqrt{c_K}} \tau_{C1}$$

where

C_K = Factor for the particular shaft design features, see Section 6, Table 6.1

scf = Stress concentration factor, see Section 6, Table 6.1 (For unnotched specimen, 1.0.)

C_D = Size factor, see Section 6, A.4

R_M = Specified minimum tensile strength in N/mm² of the shaft material

Table 5.1 Test Condition

Loading Type	Torsion
Stress ratio	R=-1
Load waveform	Constant-amplitude sinusoidal
Evaluation	S-N curve
Number of cycles for test termination	1 x 10 ⁷ cycles

2.3 Cleanliness requirements

The steels are to have a degree of cleanliness as shown in Table 5.2 when tested according to ISO 4967 method A. Representative samples are to be obtained from each heat of forged or rolled products.

The steels are generally to comply with the minimum requirements of Part A, Chapter 2, Section 5, Table 5.3 with particular attention given to minimising the concentrations of sulphur, phosphorus and oxygen in order to achieve the cleanliness requirements. The specific steel composition is required to be approved by **BCS**.

2.4 Inspection

The ultrasonic testing required by Part A, Chapter 2, Section 5, items A and B are to be carried out prior to

acceptance. The acceptance criteria are to be in accordance with BCS- G 68 or a recognized national or international standard.

Table 5.2 Cleanliness requirements

Inclusion group	Series	Limiting chart diagram index /
Type A	Fine	1
	Thick	1
Type B	Fine	1.5
	Thick	1
Type C	Fine	1
	Thick	1
Type D	Fine	1
	Thick	1
Type DS	-	1

C. Design Quality

1. Goal

1.1 The following requirements apply to propulsion shafts such as intermediate and propeller shafts of traditional straight forged design and which are driven by rotating machines such as diesel engines, turbines or electric motors.

1.2 For shafts that are integral to equipment, such as for gear boxes (see Section 7, Gears and Couplings), podded drives, electrical motors and/or generators, thrusters, turbines and which in general incorporate particular design features, additional criteria in relation to acceptable dimensions have to be taken into account. For the shafts in such equipment, the following requirements may only be applied for shafts subject mainly to torsion and having traditional design features. Other limitations, such as design for stiffness, high temperatures etc. are to be considered additionally.

1.3 Explicitly it will be emphasized that the following applications are not covered by the requirements in this Section:

- Additional strengthening for shafts in ships classed for navigation in ice (see Section 19).
- Gearing shafts (see Section 7, Gears and Couplings).
- Electric motor and generator rotor shafts.
- Turbine rotor shafts (See Sections 3 and 4).
- Diesel engine crankshafts (see Section 2).

1.4 Additionally, all parts of the shafting are to be designed to comply with the requirements relating to torsional vibrations, as mentioned briefly in D.3 and in detail in Section 6.

1.5 In general, the dimensions of the shafting shall be based on the total rated installed power. Changes in diameter are to be effected by tapering or ample radiusing. Radii must be at least equal to the change in diameter. For intermediate and thrust shafts, the radius at forged flanges is to be at least 8% of the calculated minimum diameter for a full shaft at the relevant location. For the aft propeller shaft flange, the radius is to be at least 12.5% of the calculated minimum diameter for a full shaft at the relevant location.

Filletts are to have a smooth finish and should not be recessed in way of nuts and bolt heads.

For intermediate, thrust and propeller shaft couplings, the fillet may be formed of multiradii in such a way that the stress concentration factor will not be greater than that for a circular fillet with radius 8 % of the actual shaft diameter.

1.6 Where the geometry of a part is such that it cannot be dimensioned in accordance with these formulae, special evidence of the mechanical strength of the part concerned is to be furnished to **BCS**.

1.7 Any alternative calculation has to include all relevant loads on the complete dynamic shafting system under all permissible operating conditions. Consideration has to be given to the dimensions and arrangements of all shaft connections. Moreover, an

alternative calculation has to take into account design criteria for continuous and transient operating loads (dimensioning for fatigue strength) and for peak operating loads (dimensioning for yield strength). The fatigue strength analysis may be carried out separately for different load assumptions, for example:

- Low cycle fatigue criterion (typically $<10^4$), i.e. the primary cycles represented by zero to full load and back to zero, including reversing torque if applicable. This is addressed by formula (1)
- High cycle fatigue criterion (typically $>>10^7$), i.e. torsional vibration stresses permitted for continuous operation as well as reverse bending stresses. The limits for torsional vibration stresses are given in D.3 and Section 6. The influence of reverse bending stresses is addressed by the safety margins inherent in formula (1).
- The accumulated fatigue due to torsional vibration when passing through a barred speed range or any other transient condition with associated stresses beyond those permitted for continuous operation is addressed by the criterion for transient stresses in D.3 and Section 6.

2. Shaft Dimensioning

2.1 The minimum shaft diameter is to be calculated by applying formula (1).

$$d_a \geq d \geq F k \sqrt[3]{\frac{C_w P_w / n}{1 - \left(\frac{d_i}{d_a}\right)^4}} \quad (1)$$

d = Minimum required outer diameter of shaft, [mm]

d_a = Actual outer shaft diameter, [mm]

d_i = Actual inner diameter of shaft bore, where present. If the bore in the shaft is $\leq 0.4 d_a$ the expression, [mm]

$$1 - \left(\frac{d_i}{d_a} \right)^4 = 1.0 \quad \text{may be applied}$$

P_w = Rated power of propulsion motor, gearbox and bearing losses must not be subtracted. [kW]

n = Shaft speed at rated power [min^{-1}]

C_w = Material factor, [-]

$$= \frac{560}{R_m + 160} \quad (2)$$

R_m = Actual specified minimum tensile strength of the shaft material (see B), [N/mm^2]

F = Design factor for the straight sections of propulsion shaft for installation type [-]

Intermediate and thrust shafts

- = 95 for turbine drives, electric drives and diesel drives through slip couplings (hydraulic or electric)
- = 100 for all other diesel drives,

Propeller shafts (tail and tube)

- = 100 for all other diesel drives,

k = Factor for the type of shaft, [-]
See Section 6, Table 6.1

3. Shaft Tapers and Propeller Nut Threads

3.1 Keyways are in general not to be used in installations with a barred speed range.

3.2 Keyways in the shaft taper for the propeller should be so designed that the forward end of the groove makes a gradual transition to the full shaft section. In addition, the forward end of the keyway should be spoon-shaped. The edges of the keyway at the surface of the shaft taper for the propeller may not be sharp. The forward end of the keyway must lie well within the seating of the propeller boss. Threaded

holes to accommodate the securing screws for propeller keys should either be in accordance with an international standard (i.e. DIN 6885) or be located only in the aft half of the keyway (see Fig. 5.1).

3.3 In general, tapers for securing flange couplings which are jointed with adjusting springs should have a conicity of between 1:12 and 1:20. See Section 8 for details of propeller shaft tapers on the propeller side.

3.4 The outside diameter of the threaded end for the propeller retaining nut should not be less than 60% of the calculated major taper diameter (A). (See Fig. 5.2)

4. Securing the Propeller Shaft

4.1 Sealing

4.1.1 Propeller shafts running in oil or grease lubrication are to be fitted with seals of proven efficiency and approved by **BCS** at the stern tube ends (see Fig. 5.3 and see also the requirements applicable to the external sealing of the stern tube in the context of the propeller shaft survey prescribed in the Rules of Classification and Surveys, Section 3, Surveys - General Requirements).

4.1.2 The securing at stern tube, shaft line or propeller (e.g. chrome steel liner) but to guarantee a permanent tightness. **BCS** reserves to demand corresponding verifications

4.1.3 For protection of the sealing, a rope guard should be provided. (See Fig. 5.3)

4.1.4 The propeller boss seating is to be effectively protected against the ingress of seawater. The seal at the propeller can be dispensed with if the propeller shaft is made of corrosion-resistant material. (See Fig. 5.3)

4.1.5 In the case of classification standard **IWS**, the seal must be fitted with a device by means of which the play of the bearing can be measured when the vessel is afloat.

4.2. Shaft liners

4.2.1 Propeller shafts which are not made of

corrosion-resistant material and which run in seawater are to be protected against contact with seawater by seawater-resistant metal liners or other liners approved by **BCS** and by proven seals at the propeller. (See Fig. 5.3)

4.2.2 Metal liners in accordance with 4.2.1, which run in seawater, are to be made in a single piece. With the expressed consent of **BCS** the liner may consist of two or more parts, provided that the abutting edges of the parts are additionally sealed and protected after fitting by a method approved by **BCS** to guarantee water-tightness. Such a possibility are special coatings. Such joints will be subject to special tests to prove their effectiveness.

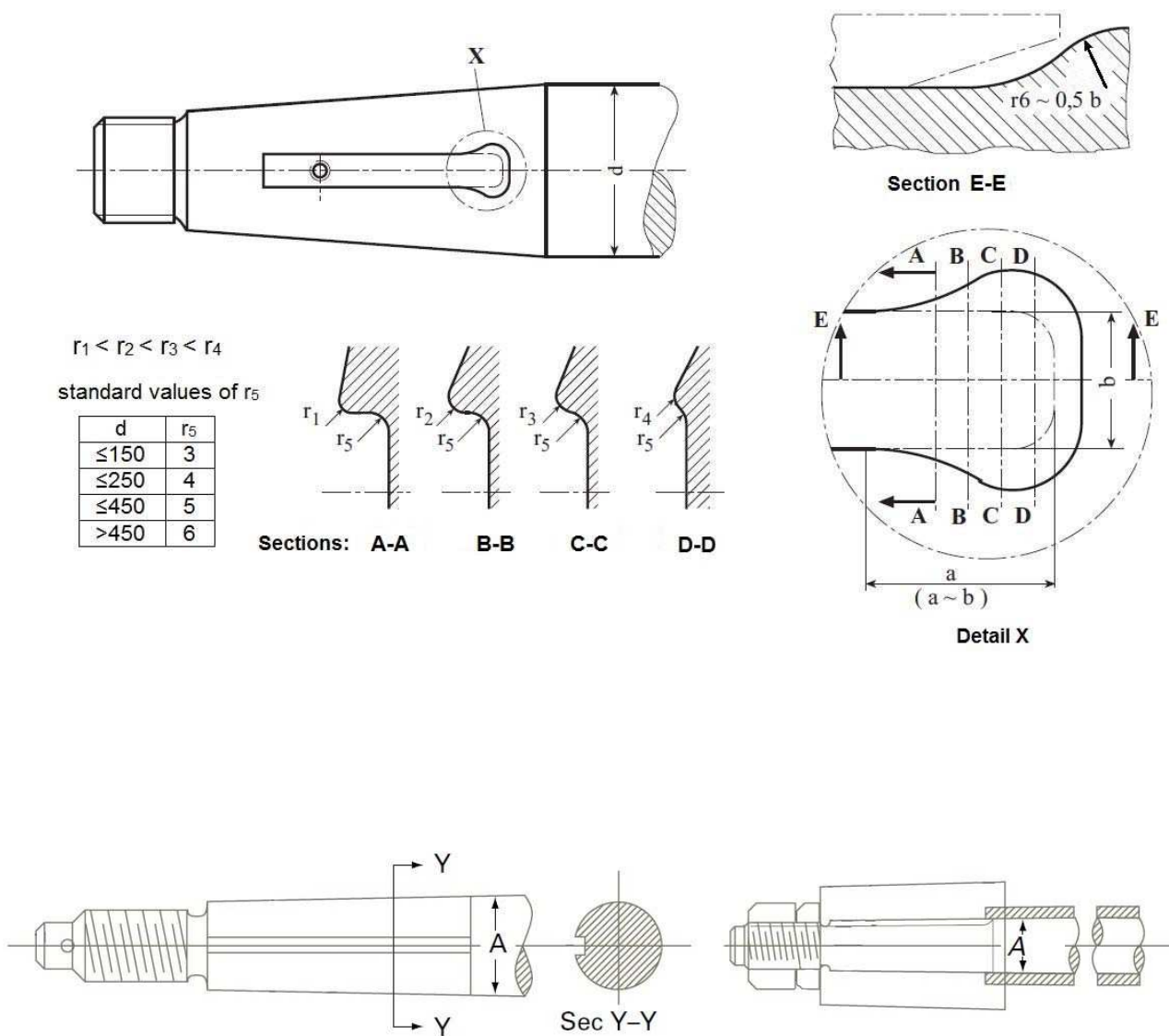


Figure 5.2 Typical details of propeller shaft ends

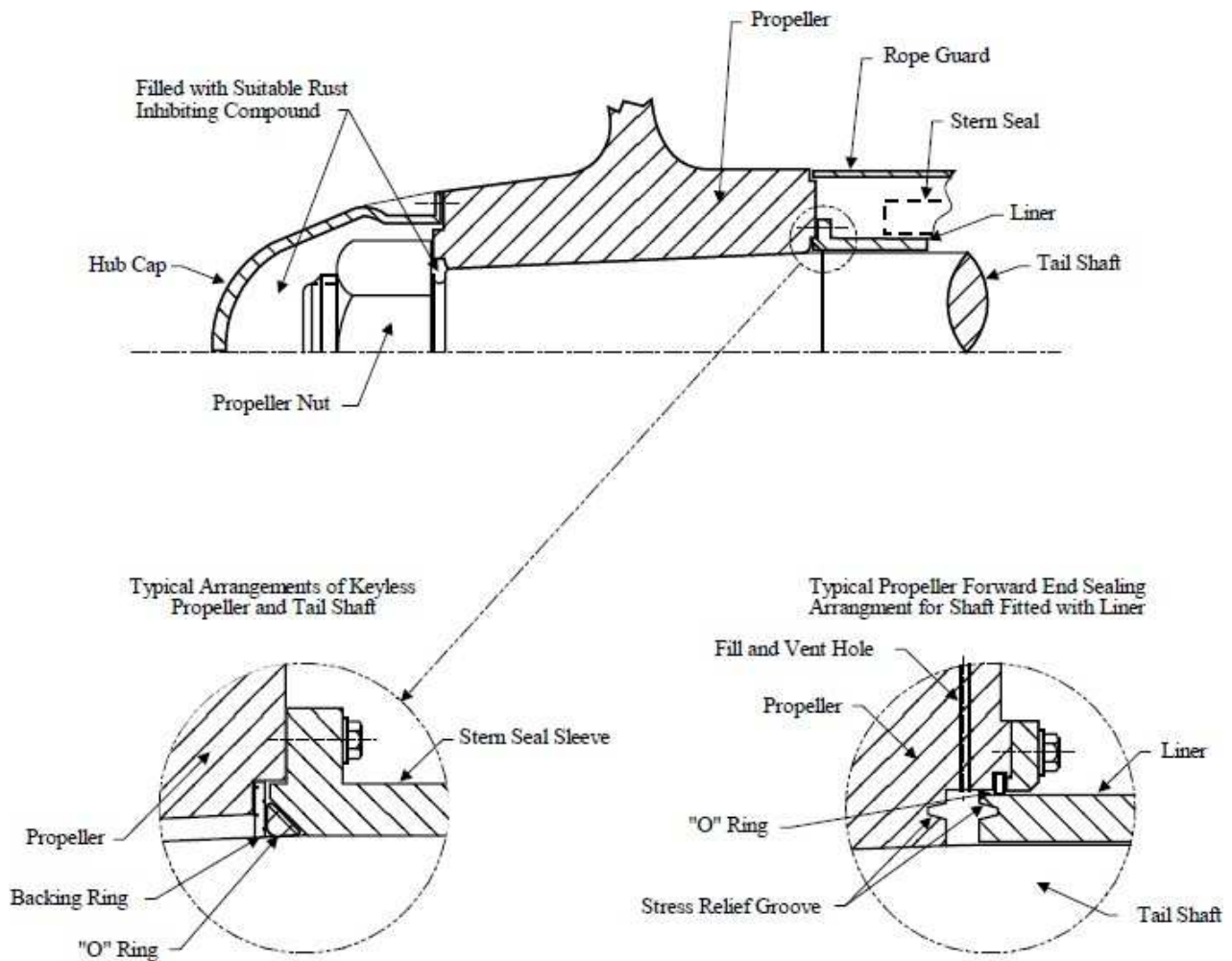


Figure 5.3 Typical Arrangements and Details of Fitting of Tail Shaft and Propeller

4.2.3 Minimum wall thickness of shaft liners

Minimum wall thickness of the bronze liners to be fitted to tail shafts in accordance with 4.2.1 is to be determined using the following formula:

$$s = 0.03.d + 7.5 \quad [\text{mm}] \quad (3)$$

Where

d = Shaft diameter under the liner [mm].

s = Minimum wall thickness at bearing [mm].

In case of the continuous liner, the wall thickness between the bearings may be reduced to 0.75.s.

5. Couplings

The design of coupling bolts in the shaftline other than that covered by this Section are to be considered and approved by BCS individually.

5.1 The thickness of coupling flanges on intermediate and thrust shafts and on the inboard end of the propeller shaft must be equal to at least 20% of the Rule diameter of the shaft at the relevant location or the thickness of the coupling bolt diameter calculated for the material having the same tensile strength as the corresponding shaft, whichever is greater. The tensile strength of shaft material should not be assumed more than as defined in B-1.6.

Special consideration will be given by **BCS** for flanges having non-parallel faces, but in no case is the thickness of the flange to be less than the coupling bolt diameter.

Where propellers are attached to a forged flange on the propeller shaft, the flange should have a thickness of at least 25% of the calculated minimum diameter of the solid shaft at that relevant location and condition. These flanges may not be thinner than the Rule diameter of the fitted bolts if these are based on the same tensile strength as that of the shaft material.

In the formulae (4), (5), (6), (7) and (8), the following symbols are used:

A = Effective area of shrink-fit seating, [mm²]

C_A = Coefficient for shrink-fitted joints, depending on the kind of driving unit [-]:

= 1.0 for geared oil engine and turbine drives,

= 1.2 for geared direct oil engine drives,

C = Conicity of shaft ends [-]:

= $\frac{\text{difference between the diameters at taper ends}}{\text{length of taper}}$

d = Shaft diameter in area of clamp-type coupling, [mm]

d_s = Diameter of fitted bolts, [mm]

d_k = Inner throat diameter of necked-down bolts, [mm]

D = Diameter of pitch circle of bolts, [mm]

E = Modules of elasticity, [N/mm²]

f = Coefficient for shrink-fitted joints, [-]

Q = Peripheral force at the mean joint diameter of a shrink fit, [N]

n = Shaft speed, [min⁻¹]

p = Contact pressure of shrink fits, [N/mm²]

P_w = Interface rated power transmitted by shaft, [kW]

s_{fl} = Flange thickness in area of bolt pitch circle, [mm]

S = Safety factor against slipping of shrink fits in the shafting, [-]

= 3.0 for between engine and gearbox,

= 2.5 for all other applications,

T = Propeller thrust, [N]

z = Number of fitted or plain bolts, [-]

R_{m,b} = Tensile strength of fitted or plain bolt material, [N/mm²]

μ_o = Coefficient of static friction, [-]

= 0.15 for hydraulic shrink fits,

= 0.18 for dry shrink fits,

θ = Half conicity of shaft ends, [-]
= C/2

5.2 The bolts used to connect flange couplings are normally to be designed as fitted bolts. The minimum diameter d_s of fitted bolts at the coupling flange faces is to be determined by applying the formula:

$$d_s = 16 \sqrt{\frac{10^6 P_W}{n \cdot z \cdot D \cdot R_{mb}}} \quad (4)$$

For intermediate, thrust and propeller shaft couplings having all fitted coupling bolts, the coupling bolt diameter, calculated according to formulae (4) is not to be less than that given by the following formula:

$$d_s = 0.65 \sqrt{\frac{d^3 \cdot (R_m + 160)}{z \cdot D \cdot R_{m,b}}} \quad (5)$$

where

d = Rule diameter (mm), i.e., minimum required diameter of intermediate shaft made of material with tensile strength R_m , taking into account ice strengthening requirements where applicable

while: $R_m \leq R_{m,b} \leq 1.7 \cdot R_m$, but not higher than 1000 N/mm².

See also B,1.3.

5.3 Where, in special circumstances, the use of fitted bolts is not feasible, **BCS** may agree to the use of an equivalent frictional resistance transmission.

5.4 The minimum thread root diameter d_k of the connecting bolts used for clamp-type couplings is to be determined using the formula:

$$d_s = 12 \sqrt{\frac{10^6 P_w}{n \cdot z \cdot D \cdot R_{m,b}}} \quad (6)$$

5.5 The shaft of necked-down bolts can be designed to have a diameter more than 0.9 times the thread root diameter. If, besides the torque, the bolted connection is also required to transmit considerable additional forces, the size of the bolts must be increased accordingly.

5.6 Shrink fitted couplings

Where shafts are connected by keyless shrink fitted couplings (flange or sleeve type), the dimensioning of these shrink fits shall be chosen in a way that the maximum von Mises equivalent stress in all parts will not exceed 80 % of the yield strength of the specific materials during operation and 95 % during mounting and dismounting.

For the calculation of the safety margin of the connection against slippage, the maximum clearance will be applied. This clearance has to be derived as the difference between the lowest respectively highest diameters for the bore and the shaft according to the manufacturing drawings. The contact pressure p [N/mm²] in the shrunk-on joint to achieve the required safety margin may be determined by applying formulae (7) and (8).

$$p = \frac{\sqrt{\theta^2 \cdot T^2 + f \cdot (c^2 \cdot Q^2 + T^2)} \pm \theta \cdot T}{A \cdot f} \quad (7)$$

Note:

- Sign following the root applies to conical shrunk joints without an axial stop to absorb astern thrust
- Sign following the root if the conical shrunk joint has an axial stop to absorb astern thrust.

T has to be introduced as positive value if the propeller thrust increases the surface pressure at the taper. Change of direction of propeller thrust is to be neglected as far as power and thrust are essentially less.

T has to be introduced as negative value if the propeller thrust reduces the surface pressure at the taper, e.g. for tractor propellers.

$$f = \left| \frac{\mu}{S} \right| - \theta^2 \quad (8)$$

For direct coupled propulsion plants with a barred speed range it has to be confirmed by separate calculation that the vibratory torque in the main resonance is transmitted safely. For this proof the safety against slipping for the transmission of torque shall be at least $S = 2.0$ (instead of $S = 2.5$), the coefficient “ c_A ” may be set to 1.0. For this additional proof the respective influence of the thrust may be disregarded.

6. Shaft Bearings

6.1 Arrangement of shaft bearings

Drawings showing the shaft bearings and stern tube bearings must be submitted for approval separately, if the design details are not visible on the shafting arrangement drawings. The permissible bearing loads must be indicated. The lowest permissible shaft speed also has to be considered.

Shaft bearings both inside and outside the stern tube are to be so arranged that, when the plant is hot and irrespective of the condition of loading of the ship, each bearing is subjected to positive reaction forces.

By appropriate spacing of the bearings and by the

alignment of the shafting in relation to the coupling flange at the engine or gearing, care is to be taken to ensure that no undue shear forces or bending moments are exerted on the crankshaft or gear shafts when the plant is at operational design temperature. By spacing the bearings sufficiently far apart, steps are also to be taken to ensure that the reaction forces of line or gear shaft bearings are not appreciably affected should the alignment of one or more bearings be altered by hull deflections or by displacement or wear of the bearings themselves.

Guide values for the maximum permissible distance between bearings ℓ_{\max} [mm] can be determined using formula (9):

$$\ell_{\max} = K_1 \cdot \sqrt{d} \quad (9)$$

d = Diameter of shaft between bearings, [mm]

K_1 = 450 for oil-lubricated white metal bearings,
 = 280 for grey cast iron, grease-lubricated stern tube bearings,
 = 280 – 350 for water-lubricated rubber bearings in stern tubes and shaft brackets (upper values for special designs only),

Where the shaft speed exceeds 350 min^{-1} it is recommended that the maximum bearing spacing in accordance with formula (10) be observed in order to avoid excessive loads due to bending vibrations.

In limiting cases it is advisable to check the reaction forces of the bearing by calculating the alignment of the shafting. It is also required that a bending stress analysis should be made for the shafting system.

$$\ell_{\max} = K_2 \cdot \sqrt{\frac{d}{n}} \quad (10)$$

n = Shaft speed, [min^{-1}]

K_2 = 8400 for oil-lubricated white metal bearings,
 = 5200 for grease-lubricated, grey cast iron bearings and for rubber bearings inside stern tubes and tail shaft brackets.

In general, the distance between bearings should not be less than 60% of the maximum permissible distance as

calculated using formula (9) or (10) respectively.

6.2 Stern tube bearings

6.2.1 Inside the stern tube the propeller shaft should normally be supported by two bearing points. In short stern tubes, the forward bearing may be dispensed with, in which case at least one free-standing journal bearing should be provided.

6.2.2 Where the propeller shaft inside the stern tube runs in oil-lubricated white metal bearings; or in synthetic rubber or reinforced resin or plastic materials approved for use in oil-lubricated stern tube bearings, the lengths of the after and forward bearings should be approximately $2 \cdot d_a$ and $0.8 \cdot d_a$ respectively.

The length of the after stern tube bearing may be reduced to $1.5 \cdot d_a$ where the contact load, which is calculated from the static load and allowing for the weight of the propeller is less than 0.8 MPa in the case of shafts supported on white metal bearings and 0.6 MPa in the case of bearings made of synthetic materials.

6.2.2.1 Oil lubricated white metal bearings

The length of white-metal-lined, oil-lubricated propeller-end bearings fitted with an approved oil-seal gland is to be not less than two times the required tail shaft diameter. The length of the bearing may be reduced, provided the nominal bearing pressure is not more than 0.80 N/mm^2 , as determined by static bearing reaction calculation taking into account shaft and propeller weight which is deemed to be exerted solely on the aft bearing, divided by the projected area of the bearing surface. The minimum length, however, is not to be less than 1.5 times the actual diameter.

6.2.2.2 Oil lubricated synthetic material bearings

The length of synthetic rubber, reinforced resin or plastic oil-lubricated propeller end bearings fitted with an approved oil-seal gland is to be not less than two times the required tail shaft diameter. The length of bearing may be reduced, provided the nominal bearing

pressure is not more than 0.60 N/mm², as determined by static bearing reaction calculation taking into account shaft and propeller weight which is deemed to be exerted solely on the aft bearing, divided by the projected area of the bearing surface. The minimum length, however, is not to be less than 1.5 times the actual diameter. Where the material has demonstrated satisfactory testing and operating experience, consideration may be given to increased bearing pressure.

Synthetic materials for application as oil lubricated stern tube bearings are to be Type Approved.

6.2.2.3 Oil lubricated cast iron or bronze bearings

The length of oil-lubricated cast iron or bronze bearings which are fitted with an approved oil-seal gland is to be not less than four times the required tail shaft diameter.

6.2.2.4 Stern tube bearing oil lubricating system sampling arrangement

An arrangement for readily obtaining accurate oil samples is to be provided. The sampling point is to be taken from the lowest point in the oil lubricating system, as far as practicable. Also, the arrangements are to be such as to permit the effective removal of contaminants from the oil lubricating system.

6.2.3 Water lubricated bearings

Where the propeller shafts inside the stern tube runs in bearings approved for use in water-lubricated stern tube bearings, the length of the after bearing is to be not less than $4 \cdot d_a$ and at that of the forward bearing is to be not less $1.5 \cdot d_a$.

For a bearing of synthetic material, consideration may be given to a bearing length not less than 2.0 times the rule diameter of the shaft in way of the bearing, provided the bearing design and material is substantiated by experiments to the satisfaction of **BCS**.

Synthetic materials for application as water lubricated stern tube bearings are to be Type Approved.

Note: In a closed fresh water system lubricated stern tube, the sample is to be drawn from the same agreed position in the system which should be positively identified. The sample should be representative of the water circulating within the stern tube (also refer to BCS - G 143 Recommended procedure for the determination of contents of metals and other contaminants in a closed fresh water system lubricated stern tube).

6.2.4 Grease lubricated bearings

The length of a grease lubricated bearing is to be not less than 4.0 times the rule diameter of the shaft in way of the bearing.

6.2.5 Where propeller shafts are to run in anti-friction bearings inside the stern tube, these should wherever possible take the form of cylindrical roller bearings with cambered rollers or races and with increased bearing clearance. The camber must be large enough to accommodate a 0.1% inclination of the shaft relative to the bearing axis without adverse effects.

For application of roller bearings care must be taken that the minimum load requirements as specified by the manufacturer are fulfilled (axial adjustment recommended).

6.3 Intermediate bearings

6.3.1 Plain bearings

For intermediate bearings shorter bearing lengths or higher specific loads as defined in 6.2.1 may be agreed with **BCS**.

6.3.2 Roller bearings

For the case of application of roller bearings for shaft lines the design is to be adequate for the specific requirements.

For shaft lines significant deflections and inclinations have to be taken into account. Those shall not have adverse consequences.

For application of roller bearings the required minimum loads as specified by the manufacturer are to be observed.

The minimum L_{10a} (acc. ISO 281) lifetime has to be suitable with regard to the specified overhaul intervals.

6.4 Bearing lubrication

6.4.1 Lubrication and matching of materials for the plain or roller bearing of the shafting system should satisfy the operational demands of seagoing vessel.

6.4.2 Lubricating oil or grease must be introduced into the stern tube in such a way as to ensure a reliable supply of oil or grease to the forward and after stern tube bearings.

With grease lubrication, the forward and after bearings are each to be provided with a grease connection. Wherever possible, a grease pump driven by the shaft is to be used to secure a continuous supply of grease.

6.4.3 Where the shaft runs in oil within the stern tube, a header tank is to be fitted at a sufficient height above the ship's load line. Facilities are to be provided for checking the level of oil in the tank at any time.

6.4.4 The temperature of the after stern tube bearing is to be indicated. Alternatively, with propeller shafts less than 400 mm in diameter the stern tube oil temperature may be indicated. In this case the temperature sensor is to be located in the vicinity of the after stern tube bearing.

6.4.5 In the case of ships with automated machinery, Rules for Automation has to be complied with.

6.4.6 The length of the bearing, next to and supporting the propeller, is to be not less than four times the required tail-shaft diameter. However, for bearings of rubber, reinforced resins, or plastic materials, the length of the bearing, next to and supporting the propeller, may be less than four times, but not less than two times the required tail shaft diameter, provided the bearing design is being substantiated by experimental tests to the satisfaction of **BCS** surveyor.

6.5 Stern tube connections

Oil-lubricated stern tubes are to be fitted with filling, testing and drainage connections as well as with a vent pipe. Where the propeller shaft runs in seawater, a flushing line is to be fitted in front of the forward stern tube bearing in place of the filling connection.

6.6 Condition monitoring of tube shaft

6.6.1 Where the propeller shaft runs within the stern tube in oil the possibility exists to prolong the intervals between shaft withdrawals. For this purpose the following design measures have to be provided:

- A device for measurement of the temperature of the aft stern tube bearing (and regular documentation of measured values), compare 6.3.4
- A possibility to determine the oil consumption within the stern tube (and regular documentation)
- An arrangement to measure the wear down of the aft bearing
- A system to take representative oil samples at the rear end of the stern tube under running conditions for analysis of oil quality (aging effects and content of H_2O , iron, copper, tin, silicon, bearing metal, etc.) and suitable receptacles to send samples to accredited laboratories. (The samples shall be taken at least every six months.)

- A written description of the right procedure to take the oil samples
- A test device to evaluate the water content in the lubricating oil on board (to be used once a month)
- If roller bearings are provided, additional vibration measurements have to be carried out regularly and to be documented. The scope of the measurements and of the documentation has to be agreed with **BCS** specifically for the plant.

6.6.2 The requirements for the initial survey of this system as well as for the checks at the occasion of annual and Class Renewal surveys are defined in the **BCS** Classification and Survey Rules.

6.6.3 If the requirements according to 6.6.1 and 6.6.2 are fulfilled, the Class Notation **CM-PS** (Condition Monitoring – Planned Maintenance System) may be assigned

6.7 Cast resin mounting

The mounting of stern tubes and stern tube bearings made of cast resin and also the seating of plummer blocks on cast resin parts is to be carried out by approved companies in the presence of a **BCS** surveyor.

Only **BCS** approved cast resins may be used for seatings.

Installation instructions of the cast resin manufacturer are to be observed.

6.8 Shaft locking devices

A locking device according to the Section 1, D.12.3 has to be provided at each shaft line of multiple shaft systems.

The locking device must be designed to keep the locked shaft from rotating while the ship is operating with the remaining shafts at reduced power. This reduced power

must ensure a ship speed that maintains the full manoeuvring capability of the ship, in general not less than 8 knots.

If the locking device is not designed for the full power and ship speed of the remaining shafts, the corresponding operational restriction must be shown to the operator by adequate signs.

6.9 Propeller shaft brackets and elastic stern tube couplings

For construction of propeller shaft brackets and elastic stern tube couplings, see Chapter 1 - Hull, Section 10, C and D respectively.

D. Alignment and Vibration

1. General

In addition to the design requirements addressed above, considerations are to be given to additional stresses in the shafting system given rise to by shaft alignment in relation to location and spacing of the shaft bearings, and by axial, lateral and torsional vibrations.

2. Fundamentals of Shaft Alignment

It has to be verified by alignment calculation that the requirements for shaft, -gearbox- and engine bearings are fulfilled in all relevant working conditions of the drive line. At this all essential static, dynamic and thermal effects have to be taken into account.

The calculation reports to be submitted shall include the complete scope of used input data and have to disclose the resulting shaft deflection, bending stress and bearing loads and must document the compliance of the specific maker requirements.

An instruction for the alignment procedure has to be issued describing the execution on board and listing the permissible gap and sag values for open flange connections or jack-up loads for measuring the bearing loads.

The final alignment on board has to be checked by suitable measurement methods in afloat condition in presence of the **BCS** Surveyor.

In general, shaft alignment calculations, as well as a shaft alignment procedure, are to be submitted for reference. However, calculations for the following alignment-sensitive types of installations are to be submitted for review:

- Propulsion shafting of diameter greater than 300 mm.
- Propulsion shafting with reduction gears where the bull gear is driven by two or more ahead pinions.
- Propulsion shafting with power take-off or with booster power arrangements.
- Propulsion shafting for which the tail shaft bearings are to be slope-bored.

The alignment calculations are to include bearing reactions, shear forces and bending moments along the shafting, slope boring details (if applicable) and detailed description of alignment procedure.

The alignment calculations are to be performed for theoretically aligned cold and hot conditions of the shaft with specified alignment tolerances.

Calculations are to be performed for the maximum allowable alignment tolerances and are to show that:

- Bearing loads under all operating conditions are within the acceptable limits specified by the bearing manufacturer.
- Bearing reactions are always positive (i.e., supporting the shaft).
- Shear forces and bending moments on the shaft are within acceptable limits in association with other stresses in the shaft.
- Forces and moments on propulsion equipment are within the limits specified by the machinery manufacturers.

If the calculated relative misalignment slope between the shaft and the tail shaft bearing is greater than $0.3 \cdot 10^{-3}$ [rad], then consideration is to be given to reducing the relative misalignment slope by means of slope-boring or bearing inclination.

3. Torsional Vibrations

For torsional vibration calculations, see Sec.6.

4. Axial Vibrations

The designer or the builder is to evaluate the shafting system to ensure that axial vibration characteristics in association with diesel engine or propeller blade-rate frequency forces will not result in deleterious effects throughout the engine operating speed range, with consideration also given to the possibility of the coupling of torsional and axial vibration, unless experience with similar shafting system installations makes it unnecessary. The axial vibrations may be controlled by axial vibration detuners to change the natural frequency of the system or by axial vibration dampers to limit the amplitude of axial vibrations to an acceptable level.

When on the basis of axial vibration calculations the designer or builder proposed to provide barred speed ranges within the engine operating speed range, the calculations are to be submitted for information. The barred speed ranges due to axial vibrations are to be verified and established by measurement.

5. Lateral Vibrations

The designer or the builder is to evaluate the shafting system to ensure that the amplitudes of lateral (whirling) vibration are of acceptable magnitude throughout the engine operating speed range, unless experience with similar shafting system installations makes it unnecessary.

When on the basis of lateral vibration calculations, the designer or builder proposed to provide barred speed ranges within the engine operating speed range, the calculations are to be submitted for information. The barred speed ranges due to lateral vibration are to be verified and established by measurement.

E. Inspection, Testing And Certification

1. General

1.1 All component parts including shafts, couplings, coupling bolts, clutches and keys of the propulsion shafting system which assist in transmitting the torque from the ship's propulsion plant are subject to the **BCS** Rules Chapter 2 - Material, Section 5, and must be tested in the presence of the Surveyor. This requirement also covers metal propeller shaft liners. Where propeller shafts running in seawater are protected against seawater penetration not by a metal liner but by plastic coatings, the coating technique used must be approved by **BCS**.

1.2 The ratio of length to diameter of the material sample rods should be equal to 4.

1.3 Coupling bolts manufactured and marked to a recognized Standard will not require material testing.

2. Non-destructive Tests and Inspections

Shafting and couplings are to be surface examined by the Surveyor.

The methods indicated in these requirements concerning the magnetic particle test and ultrasonic tests are limited to the application of forged components made of ferritic steel grades. For forged components made of austenitic or austenitic-ferritic steel grades the methods and acceptance criteria for the ultrasonic and penetrant tests shall be agreed upon with **BCS** individually. This may be performed based on standards or specifications from the manufacturer or the orderer.

The tests are to be performed in accordance with the **BCS** Rules Chapter 2 - Material, Section 1. Unless otherwise agreed it may also be performed according to ISO 16810, EN 10228 -3, SEP 1923, EN 10228 -3 and /or other equivalent and recognized standards, manufacturer or orderer specifications.

Forgings for all shafts are to be ultrasonically examined to the satisfaction of the attending Surveyor according

to Chapter 2, Material, Section 5. Conformity with the Chapter 2 - Material or equivalent, will be considered to meet this requirement. Tail shafts in the finished machine condition are to be subjected to magnetic particle, dye penetrant or other nondestructive examinations. They are to be free of linear discontinuities greater than 3.2 mm, except that in the following locations the shafts are to be free of all linear discontinuities:

For the tapered tail shafts, the forward one-third length of the taper, including the forward end of any keyway and an equal length of the parallel part of the shaft immediately forward of the taper are to be surface examined by **BCS** Surveyor.

For the flanged tail shafts, the Surveyor inspections are intensively focused on the flange fillet area.

3. Pressure Tests

3.1 Shaft liners

Prior to fitting but as far as possible in the finish-machined condition, shaft liners are to be subjected to a hydraulic tightness test at 2 bar pressure.

3.2 Stern Tubes

Prior to fitting but as far as possible in the finish-machined condition, cast stern tubes and cast stern tube parts are to be subjected to a hydraulic tightness test at 2 bar pressure. A further tightness test is to be carried out after fitting.

For stern tubes fabricated from welded steel plates, it is sufficient to test for tightness during the pressure tests applied to the hull spaces traversed by the stern tube.

F. Special Requirements for Fibre Laminate Shafts

1. Theoretical strength calculation

The strength calculation must at least cover the following failure mode in conjunction with the given

corresponding load cases:

- Statical failure

Dimensioning to be performed against nominal torque with a safety factor of 3.

- Failure due to fatigue (high cycle)

As far as the shaft is not exposed to bending stresses fatigue analysis may be carried out for nominal torque plus 30 % torsional vibration torque.

- Buckling failure mode

Dimensioning may be estimated for a load of 3 times the nominal torque and in accordance to the formulas in 2.

For the strength analysis the nominal strength of the material has to be reduced by the factor 0,7 in order to compensate random influence factors such as geometrical and production inaccuracies as well as environmental factors (moisture, temperature).

The calculation of the stress may be performed on the basis of accepted analytical methods such as CLT (Classical Laminate Theory) or FEM models. With these stresses as input a set of failure modi in relation to fibre and interfibre failure must be checked. This set of failure modi must be coherent, i.e. a complete and accepted theory.

2. Buckling failure

For shafts made of anisotropic materials, such as winded shafts of fibre laminate, buckling strength can be checked for the critical torque by the following formula:

$$M_{crit} = C_s \cdot \frac{\pi^3}{6000} \cdot \frac{r_m^{5/4} \cdot t^{9/4} \cdot E_x^{3/8}}{0,5} \cdot \left(\frac{E_y}{1 - \nu_{xy} \cdot \nu_{yz}} \right)^{5/8} [Nm]$$

C_s = Factor depending on boundary conditions of support

= 0,800 for free ends

= 0,925 ends simply supported

E_x = Modulus of elasticity in x-direction [N/mm²]

E_y = Modulus of elasticity in transverse direction [N/mm²]

ℓ = Unsupported length of shaft [mm]

r_m , = Average radius of the shaft with bore [mm]
= 0,25($d_a + d_i$)

t = Thickness of shaft

= ($d_a - d_i$) · 0,5 [mm]

ν_{xy} = Poisson's ratio of the laminate in longitudinal direction

ν_{yz} = Poisson's ratio of the laminate in peripheral direction

The design criteria is:

$$3,5 \cdot M_t \leq M_{t,crit}$$

M_t = Nominal torque at maximum continuous rating [Nm]

3. Experimental strength investigation

Experimental strength investigation has to be provided on request. Specifically:

- Testing of samples, if necessary for verification of material data
- Prototype testing/process checking for verification of the theoretical analysis in presence of a **BCS** Surveyor
- After a year or 3000 operating hours, whichever is reached earlier, a visual examination and optionally a crack or delamination check of the fibre laminate components is to be carried out by a **BCS** Surveyor.

4. Final documentation

After finalising manufacturing of the components an updated documentation in the form of a list of all definitive valid analyses and documents is to be submitted to **BCS**. The documentation must refer to the status quo and take into account all alterations or optimisations introduced during designing and manufacturing process as well as the achieved and measured properties.

5. If fire protection requirements are relevant for the composite shafting, specifically in the cases of penetration of fire protection bulkheads and/or redundant propulsion, appropriate provisions shall be taken to ensure the required properties in consent with **BCS**.

SECTION 6

TORSIONAL VIBRATIONS

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A. General

1. Scope

This section applies to propulsion plants with the main propulsion engines having a power of not less than 75 kW when diesels are used and of not less than 100 kW when using turbo or electric drives, and to diesel generators as well as to internal combustion engines (ICE) driven auxiliary machineries having a primary engine power of not less than 100 kW.

Torsional vibration calculations is to be overcome both for the basic variant and for other variants and conditions possible in the operation of the installation as follows:

- Maximum power take-off and idling speed (with the propeller blades at zero position) for installations comprising controllable pitch propeller (CPP) or azimuth thrusters,
- Individual and simultaneous operation of main engines with a common reduction gear,
- Reverse gear,
- Connection of additional power consumers if their moments of inertia are commensurate with the inertia moments with of the working cylinder,
- Running with one cylinder misfiring, for installations containing flexible couplings and reduction gear, to be assumed not firing is the cylinder the disconnection of which accounts to the top degree for the increase of stresses and alternating torques,
- Damper jammed or removed where single main engine installations are concerned,
- Any flexible coupling blocked due to breakage of its elastic components (where single main engine drive is concerned)

2. Definitions

For the purposes of these requirements, torsional

vibration loads are the additional loads due to torsional vibrations. They result from the alternating torque which is superimposed on the mean torque.

3. Documents for approval

No calculations shall be submitted if it is proved that the installation is similar to that approved earlier or that its mass moments of inertia and its torsional stiffness between masses do not differ from the basic ones by ± 10 and $\pm 5\%$ respectively. Calculations might be limited to determination of the natural frequencies if, at this stage of the calculation, it is established that the differences in the mass inertia moments and torsional stiffness between masses do not result in a change of the natural frequency of any one of the modes under consideration by more than 5%.

Design drawings, plans and particulars of rotating or harmonic moving system, partially or complete, are to be submitted to **BCS** in triplicate for approval. The documents are required to contain the details of all the installation components:

- Particulars of engine, propeller, damper, flexible coupling, reduction gear, generator, etc.
- Layout of all installation operation conditions possible,
- Torsional vibration analysis for propulsion shafting systems for all modes of operation including the condition of one-cylinder misfiring,
- Natural frequency tables for all basic modes of vibration having a resonance up to 12th order inclusive within a range of between 0 and 120% of the rated revolution speed with relative amplitudes of masses and moments, and with scales of stresses (or torques) for all sections of the system,
- Resonance amplitudes of the first mass of the system for each order of all vibration modes

- Resonance stresses (or torques) in all system components (such as shafts, reduction gear, couplings, generators, compression-key joints) for each order of all vibration modes,
- Estimated temperature variation of the rubber components of flexible couplings as compared to relevant permissible values of the manufacturer for each order of all vibration modes,
- The alternating torsional stress amplitude is understood as $(\tau_{\max} - \tau_{\min})/2$ as it can be measured on the shaft in a relevant condition over a repetitive rotation,
- Conclusions based on the results of calculation.

4. Symbols and Terms

C_D = Size (or scale) factor [-],

$$= 0.35 + 0.93 \cdot d^{-0.2}$$

C_K = Form factor for intermediate and propeller shafts depending on details of design and construction of the applied mechanical joints in the shaft line. The value for C_K is given in

Table 6.1 depending on the design [-],

C_W = Material factor [-],
 $= (R_m + 160) / 18$

d_0 = Shaft diameter [mm],

D = Crankpin diameter [mm],

D_G = Journal diameter [mm],

D_{BG} = Diameter of bore in journal [mm],

M_T = Nominal alternating torque which is calculated by Formulae (7) [Nm],

$M_{T\max}$ = Maximum value of the torque [Nm],

$M_{T\min}$ = Minimum value of the torque [Nm],

n = Speed under consideration. For tugs, trawlers and other ships which main engines run continuously under conditions of maximum torque at speeds below the rated speed throughout the speed range, $n=n_0$ shall be adopted and Formulae (9) and (10) shall be used. For the main diesel generators of ships with electric propulsion plants, all the specified values of n_0 shall, by turn, be adopted as n , and in each of the ranges $0.9 < \lambda < 1.05$, Formulae (11) and (12) shall be used for partial loads [min^{-1}],

n_0 = Rated (nominal) speed [min^{-1}],

R_m = Tensile strength of shaft material [N/mm^2], see Section 5, B.1.6

W_P = Polar moment of resistance related to cross-sectional area of the section under consideration and determined by the formulae (6) [mm^3].

λ = Speed ratio = n/n_0 [-]

τ_N = Nominal alternating torsional stress referred to the section under consideration to be determined by the formulae (8) [N/mm^2],

τ_2 = Transient permissible stresses for speed range to be rapidly passed through [N/mm^2].

B. Calculations of Torsional Vibration

1. A torsional vibration analysis covering the torsional vibration stresses to be expected in the main shafting system including its branches is to be submitted to **BCS** for examination. The following data shall be included in the analysis.

Input data:

- Equivalent torsional vibration system: Moments of inertia and inertialess torsional elasticities/stiffnesses for the complete system

- Prime mover: Engine type, rated power, rated speed, cycle number per revolution, design (in-line or V-type), number of cylinders, firing order, cylinder diameter, stroke, stroke to connecting rod ratio, oscillating mass of one crank gear, excitation spectrum of engine in the form of tangential coefficients (for new or unconventional types of engines)
- Vibration dampers: Type, damping coefficient, moments of inertia, dynamics stiffness,
- Elastic couplings: Type, damping coefficient, moments of inertia, dynamics stiffness
- Reduction / Power Take Off (PTO) gears: Type, moment of inertia for wheels and pinions, individual gear's ratios per mesh, effective stiffness
- Shafting: Shaft diameter of crankshafts, intermediate shafts, gear shafts, thrust shafts and propeller shafts,
- Propeller: Type, diameter, number of blades, pitch and expanded area ratio, moment of inertia in air moment of inertia of entrained water (for zero and full pitch for controllable pitch propeller, CPP)

Output data / Results:

- Natural frequencies : With their relevant vibration forms (modes)
- Forced vibratory loads (torques or stresses) : Calculated torques/stresses during torsional vibration movement in all essential elements of the system with particular reference to clearly defined resonance speeds for the whole operating speed range. The results shall include the synthesized values (vectorial sum over all harmonics) for the torques/stresses.

2. The calculations are to be performed both for normal operation (uniform pressure distribution over all cylinders or small deviations in the pressure distribution, e.g. $\pm 5\%$) and misfiring operation (one

cylinder without ignition, compression of the cylinder still existing).

3. Where the installation allows various operation modes, the torsional vibration characteristics are to be investigated for all possible modes, e.g. in installations fitted with controllable pitch propellers for zero and full pitch, with power take off gear integrated in the main gear or at the forward crankshaft end for loaded and idling conditions of the generator unit, with clutches for engaged and disengaged branches.

4. The calculation of torsional vibrations shall also take account of the stresses/torques resulting from the superimposition of several harmonics in so far as this has a bearing on the assessment of the system.

5. If modifications are introduced into the system which have a substantial effect on the torsional vibrational characteristics, the calculation of the torsional vibrations is to be adapted and re-submitted to **BCS** for approval.

6. Where an electrical machine (e.g. static converter controlled motors) can generate periodic excitation leading to relevant torsional vibration stresses in the system as a whole, this is to be taken into account in the calculation of the forced torsional vibration. The manufacturer of the electrical machine is responsible for defining the excitation spectrum in a suitable manner for performing forced torsional vibration calculations.

C. Permissible Stresses for Torsional Vibration

1. Shafting

1.1 In no part of the shafting may the alternating torsional vibration stresses exceed the following values of τ_1 for continuous operation or of τ_2 under transient conditions. Figures 6.1 and 6.2 indicate the τ_1 and τ_2 limits as a reference for intermediate and propeller shafts of common design and for the location deemed to be most severely stressed ($c_k=0.45$ or $c_k=0.55$ for propeller shafts, $c_k=0.8$ and $c_k=1.0$ for intermediate shafts). The limits which depend on the design and the

location considered and may in particular cases lie outside the indicated ranges according to Figures 6.1 and 6.2. They are to be determined in accordance with equations (1) ÷ (4) and Table 6.1.

Speed ranges in the $\lambda \leq 0.8$ area, in which the permissible values of τ_1 for continuous operation are exceeded shall be crossed through quickly (barred speed ranges for continuous operation), provided that the limit for transient operation τ_2 is not exceeded.

For speed ratio values $\lambda < 0.9$ at continuous operation;

$$\tau_1 = \pm c_{\psi} \cdot c_K \cdot (3_D \cdot 2\lambda^2) \quad [\text{N/mm}^2] \quad (1)$$

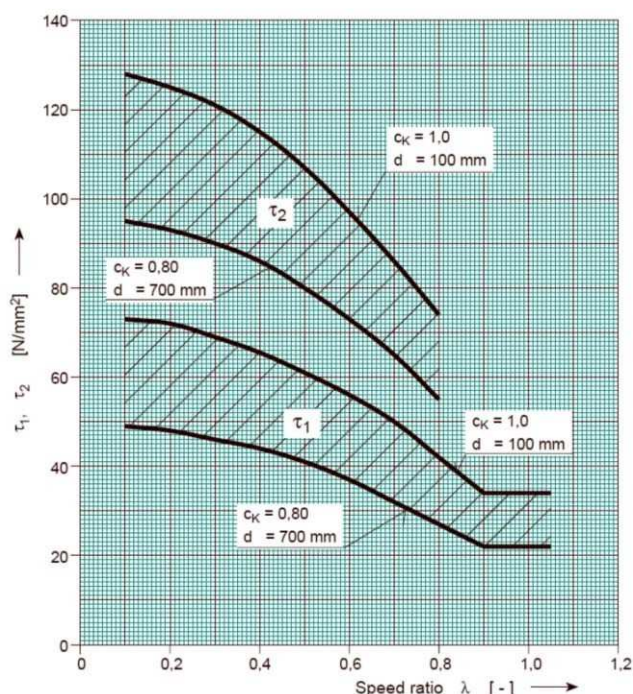


Figure 6.1 Permissible torsional vibration stress for intermediate shafts

For speed ratio values $0.9 < \lambda < 1.05$ at continuous operation:

$$\tau_1 = \pm 1.38 \cdot c_W \cdot c_K \cdot c_D \quad [\text{N/mm}^2] \quad (2)$$

The total stresses at transient operations due to torsional vibration within speed ranges prohibited for continuous running, but which may only be rapidly passed through, shall not exceed the following formulas for intermediate, thrust, propeller shafts and the shafts of the generators driven by the main engine:

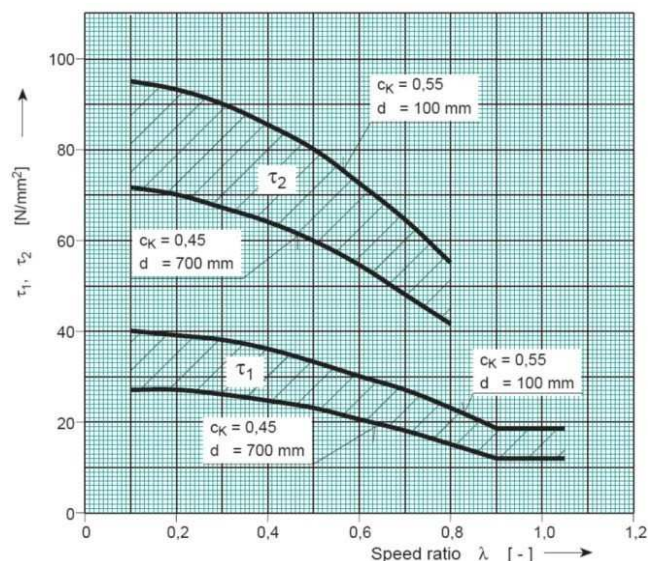


Figure 6.2 Permissible torsional vibration stress for propeller shafts

$$\tau_2 = \pm 1.7 \frac{6 \cdot \tau_1}{\sqrt{c_K \cdot c_W}} \quad [\text{N/mm}^2] \quad (3)$$

Alternatively, depending on the material and design the following formula may be used instead of (3):

$$\tau_2 = \pm 1.7 \frac{\tau_1}{\sqrt{c_K}} \quad [\text{N/mm}^2] \quad (4)$$

$$c_W = \frac{R_m + 160}{18} \quad (5)$$

1.2 In the speed range $0.9 \leq \lambda \leq 1.05$ the alternating torques in the shafting system may not exceed 75 % of the mean full-load torque transmitted by the shafting . With the consent of **BCS** , 90 % of the mean torque may be permitted provided that the torque is only transmitted by the frictional connections only or the integrally forged flanges.

1.3 For the shafts of generators driven by the auxiliary engines, transient stress shall be calculated by formula (14).

1.4 For propeller shafts, the material factor c_W is not to be taken as greater than 42.2 ($R_m = 600 \text{ N/mm}^2$).

1.5 For the controllable pitch propeller systems, the permissible values of τ_2 within a barred speed range may be exceeded provided that the system is operated at a low pitch and the additional alternating shear stresses remain below the τ_2 value for $\lambda = 0.6$ calculated by formula (3).

Applying this alternative, which is subject to special approval, requires an adequate design case by case. Especially a fast crossing of barred speed range has to be guaranteed additionally by adequate measures. In such cases an adequate dimensioning of all connections in the shaft system for dynamic torque at resonance speed has to be proven individually.

1.6 Where the scantlings of coupling bolts and straight shafting differ from the minimum required by the Rules, special consideration will be given.

2. Crankshafts

2.1 Crankshafts applied for engines for ships classed by **BCS** shall be approved on the basis of the Section 2, D. The manufacturer of the engine also applies for approval of a maximal additional (vibratory) shear stress , which is referred to the crank with the highest load due to mean torque and bending forces . Normally this approved additional shear stress may be applied for first evaluation of the calculated vibratory stresses in the crankshaft via the torsional vibration model. Common values are between 30 and 70 N/mm² for medium and high speed engines and between 25 and 40 N/mm² for two stroke engines, but special confirmation of the value considered for judgement by **BCS** is necessary.

For further details see also Section 2, D.

2.2 When the generally approved limit for the vibratory stresses for the crankshaft of the engine as defined under 2.1 is exceeded, special considerations may be applied to define a higher limit for the special investigated case. For this detailed system calculations (combined axial / torsional model) and application of the actual calculated data within the model in accordance with Section 2, D, as quoted under 2.1 are necessary.

Such special considerations, especially the application of combined axial and torsional vibration calculations, may only be considered for direct coupled two stroke engine plants. For such evaluations, in no case the acceptability factor in accordance with the Section 2, D shall be less than 1,15 over the whole speed range.

2.3 Torsional vibration dampers which are aiming to reduce the stresses in the crankshaft shall be suitable for use for diesel engines. **BCS** reserve the right to call for proof of this, compare also F.

Torsional vibration dampers shall be capable of being checked for their performance ability in the assembled condition or shall be capable of being dismantled with reasonable ease for checking purposes. This requirement does not apply for small medium or high speed engines, so far the exchange of the damper is a part of the regular service of the engine and a fixed exchange interval is part of the engine's crankshaft approval.

2.4 For main engine crankshafts of all the ships except for ice class, and the crankshafts of engines driving generators and other auxiliary machinery for essential services within the speed ratio values $0.9 < \lambda < 1.05$, the total stresses due to torsional vibration under conditions of continuous operation shall not exceed the values determined by the following formulas:

Polar moment of resistance related to the cross-sectional area bored journal, W_P

$$W_P = \frac{\pi}{16} \left(\frac{D^4 - D_G^4}{D_G} \right) \quad [\text{mm}^3] \quad (6)$$

Nominal alternating torque, M_T

$$M_T = \pm \frac{1}{2} (M_{T_{\max}} - M_{T_{\min}}) \quad [\text{Nm}] \quad (7)$$

Nominal alternating torsional stress, τ_N

$$\tau_N = \pm \frac{1000 \cdot M_T}{W_P} \quad [\text{N/mm}^2] \quad (8)$$

Table 6.1 Form factors for intermediate and propeller shafts

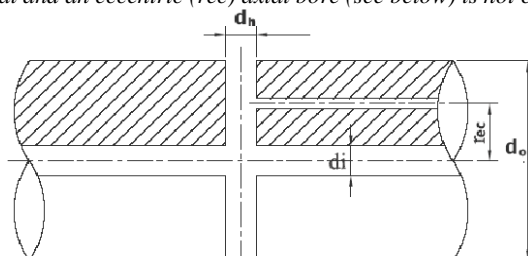
c_K [-]	k [-]	Shaft Type / Design
Intermediate shafts with		
1.00	1.00	Integral coupling flange and straight sections (1)
1.00	1.00	Shrink fit couplings (2)
0.60	1.10	Keyway, tapered connection (not valid with barred speed ranges) (3) (4)
0.45	1.10	Keyway, cylindrical connection (3) (4)
0.50	1.10	Radial holes of standard design (for example OD shaft of CP plants) (5)
0.30 (7)	1.20	with longitudinal slots of standard design (for example OD shaft of CP plants) (6)
Thrust shafts external to engine		
0.85	1.10	transmitting thrust, additionally to the torque, by means of a collar (bending)
0.85	1.10	in way of axial bearing where a roller bearing is used as a thrust bearing
Propeller shafts		
0.80	1.15	between forward end of the aft most bearing and forward stern tube
0.55	1.22	with flange mounted or keyless taper fitted propellers (8)
0.55	1.26	with key fitted propellers (in general not to be used for plants with barred speed ranges) (8)

Note:

Transitions of diameters are to be designed with either a smooth taper or a blending radius. For guidance, a blending radius equal to the change in diameter is recommended.

Footnotes

- (1) Fillet radius is not to be less than $0.08d_0$.
- (2) k and c_K refer to the plain shaft section only. Where shafts may experience vibratory stresses close to the permissible stresses for continuous operation, an increase in diameter to the shrink fit diameter is to be provided, e.g. a diameter increase of 1 to 2 % and a blending radius as described in the table note.
- (3) At a distance of not less than $0.2d_0$ from the end of the keyway the shaft diameter may be reduced to the diameter calculated with $k=1.0$.
- (4) Keyways are in general not to be used in installations with a barred speed range.
- (5) Diameter of radial bore (d_h) not to exceed $0.3d_0$.
The intersection between a radial and an eccentric (rec) axial bore (see below) is not covered here.



- (6) Subject to limitations as slot length (l)/outside diameter < 0.8 and inner diameter (d_i)/outside diameter < 0.7 and slot width (e)/outside diameter > 0.15 . The end rounding of the slot is not to be less than $(e)/2$. An edge rounding should preferably be avoided as this increases the stress concentration slightly.
The k and c_K values are valid for 1, 2 and 3 slots, i.e. with slots at 360 respectively 180 and respectively 120 degrees apart.
- (7) $c_K = 0.3$ is an approximation within the limitations in (6). More accurate estimate of the stress concentration factor (scf) may be determined from 2.6 or by direct application of FE calculation. In which case:
 $c_K = 1.45/\text{scf}$
Note that the scf is defined as the ratio between the maximum local principal stress and $\sqrt{3}$ times the nominal torsional stress (determined for the bored shaft without slots).
- (8) Applicable to the portion of the propeller shaft between the forward edge of the aftermost shaft bearing and the forward face of the propeller hub (or shaft flange), but not less than 2.5 times the required diameter.

Explanation of k and c_K

The factors k (for low cycle fatigue) and c_K (for high cycle fatigue) take into account the influence of:

- The stress concentration factors (scf) relative to the stress concentration for a flange with fillet radius of $0.08d_0$ (geometric stress concentration of approximately 1.45).

$$c_K = \frac{1.45}{\text{scf}} \quad k = \left[\frac{\text{scf}}{1.45} \right]^x$$

where the exponent x considers low cycle notch sensitivity.

- The notch sensitivity. The chosen values are mainly representative for soft steels ($\sigma_B < 600$), while the influence of steep stress gradients in combination with high strength steels may be underestimated.

- The size factor c_D being a function of diameter only does not purely represent a statistical size influence, but rather a combination of this statistical influence and the notch sensitivity.
The actual values for k and c_K are rounded off.

Permissible torsional stress as an alternative

$$\tau_1 = \pm \tau_N \quad [\text{N/mm}^2] \quad (9)$$

or

$$\tau_1 = \pm 0.76 \cdot c_w \cdot c_D \quad [\text{N/mm}^2] \quad (10)$$

For speed ratio values $\lambda < 0.9$ at continuous operation:

$$\tau_1 = \pm \frac{\tau_N \cdot (3 - 2\lambda^2)}{1.38} \quad [\text{N/mm}^2] \quad (11)$$

For speed ratio values $0.9 < \lambda < 1.05$ at continuous operation:

$$\tau_1 = \pm 0.55 \cdot c_w \cdot c_D \cdot (3 - 2\lambda^2) \quad [\text{N/mm}^2] \quad (12)$$

2.5 The total stress due to torsional vibration within the speed ranges prohibited for continuous operation, but which may only be rapidly passed through, shall not exceed the values determined by the following formulas:

For the crankshafts of main engines

$$\tau_2 = 2 \cdot \tau_1 \quad [\text{N/mm}^2] \quad (13)$$

For the crankshafts of engines driving generators or other auxiliary machinery for essential services

$$\tau_2 = 5 \cdot \tau_1 \quad [\text{N/mm}^2] \quad (14)$$

2.6 Stress concentration factors of slots

The stress concentration factor (scf) at the end of slots can be determined by means of the following empirical formula

$$\text{scf} = \alpha_{t(\text{hole})} + 0.8 \cdot \frac{(l - e) / d_0}{\sqrt{\left(1 - \frac{e}{d_0}\right) \cdot \frac{e}{d_0}}}$$

This formula applies to:

- Slots at 120; 180 or 360 degrees apart
- Slots with semicircular ends. A multi-radii slot end can reduce the local stresses, but this is not included in this empirical formula.

- Slots with no edge rounding (except chamfering), as any edge rounding increases the scf slightly.

$\alpha_{t(\text{hole})}$ represents the stress concentration of radial holes (e = hole diameter) and can be determined as :

$$\alpha_{t(\text{hole})} = 2.3 - 3 \cdot \frac{e}{d_0} + 15 \cdot \left| \frac{e}{d_0} \right| + 10 \cdot \left| \frac{e}{d_0} \right|^2 + \frac{\left(\frac{e}{d_0} \right)^2 \left(\frac{d}{d_0} \right)^2}{\left(\frac{d}{d_0} \right)}$$

or simplified to $\alpha_{t(\text{hole})} = 2.3$.

3. Gears

3.1 For the case of continuous operation or transient and rapid passage, the alternating torques in any reduction gear stage shall not exceed the permissible values established for the operating conditions by the manufacturer.

3.2 Where the values mentioned under C.3.1 are not available, the alternating torque in any reduction gear stage for the case of continuous operation shall satisfy the following conditions:

Within the service speed range $0.9 \leq \lambda \leq 1.05$:

$$M_{\text{alternating}} \leq 0.3 \cdot M_{\text{nominal}} \quad [\text{Nm}] \quad (15)$$

Within the service speed range lower than indicated ($\lambda < 0.9$), the permissible value of alternating torque will be specially considered by **BCS** in each case, but, in any case:

$$M_{\text{alternating}} \leq 1.3 \cdot M_{\text{nominal}} - M \quad [\text{Nm}] \quad (16)$$

M_{nominal} = Average torque in the stage under consideration at nominal speed, N.m

M = Average torque at the speed under consideration, N.m

For the case of rapid passage, the alternating torque value is subject to special consideration by **BCS** in each case.

3.3 In the service speed range $0.9 \leq \lambda \leq 1.05$, any alternating torque higher than 30% of the mean nominal

torque should not occur in any loaded gear's mesh. Otherwise, the reference values for the permissible bending stresses at the tooth root and for the tooth flank (Hertzian) pressures are to be reduced accordingly. In general, the value for the maximum mean torque transmitted by the gear stage has to be applied for evaluation purposes as the mean nominal torque.

If the gearing is demonstrably designed for a higher power, then, in agreement with **BCS**, 30 % of the design torque of the concerned gear's mesh concerned may be applied as the load limit.

3.4 The alternating torques in the gear at resonant speeds outside the operational speed range (i.e. when starting up or stopping the engine or within a barred speed range) shall not exceed twice the nominal mean torque for which the gear has been designed.

3.5 Load reversal due to alternating torques is normally permitted only while passing through the lower speed range up to $\lambda \leq 0.35$.

In the special cases such a speed range of $\lambda \leq 0.35$, when the gear hammering is unavoidable, a barred speed range in accordance with E.1 is to be specified.

This requirement does not apply to gear stages which run without load (e.g. the idling stage of a reversing gear or the idling gears of an unloaded shaft-driven generator). These are covered by the provisions in accordance to C.3.6.

3.6 In installations where parts of the gear train run without load, the torsional vibration torque in continuous operation shall not exceed 20 % of the nominal torque in order to avoid unacceptable stresses due to gear hammering. This applies not only to gear stages but also to parts which are particularly subject to torsional vibrations (e.g. multiple-disc clutch mountings). The loaded parts of the gear system are also subject to the provisions of C.3.3.

Higher alternating torques may be approved by **BCS** if proof is submitted to **BCS** that design measures have been taken and the design takes into account these higher loadings see C.3.3.

3.7 In cases where the proposed transmission torque loading on the gear teeth is less than the maximum allowable, special consideration will be given to the acceptance of additional vibratory loading on the gears.

3.8 Where calculations indicate the possibility of torque reversal, the operating speed range is to be determined on the basis of observations during sea trials.

4. Flexible couplings

4.1 Flexible couplings must be designed to withstand the torsional vibration loads which occur in the operation of the ship. In this context, the total load resulting, in accordance with B.4., from the superimposition of several orders is to be taken into account (see also Section 7).

4.2 Flexible couplings must be capable of transmitting for a reasonable time the increased alternating torques which occurs under abnormal operating conditions in accordance with B.2. A reasonable time is, in general, the time consumed until the misfiring operation is detected and the propulsion plant is transferred to a safe operating condition.

Speed ranges within which, under abnormal operating conditions, the continuous operation is not allowed must be indicated in accordance with E.2.

4.3 For the case of continuous operation or transient and rapid passage, the alternating torque in a coupling, relevant stresses in and temperatures of the flexible component material due to torsional vibration shall not exceed the permissible values established for the operating conditions by the manufacturer.

4.4 Where the values mentioned under C.4.3 are not available, the torque, stress and temperature values permissible for continuous operation or transient and rapid passage shall be determined by the procedures approved by **BCS**.

4.5 Where calculations indicate that the limits

recommended by the manufacturer may be exceeded under misfiring conditions, a suitable means is to be provided for detecting and indicating misfiring. Under these circumstances power and/or speed restrictions may be required. Where machinery is non-essential, disconnection of the branch containing the coupling would be an acceptable action in the event of misfiring.

5. Shaft-driven generators

5.1 In installations with generators directly and rigidly coupled to the engine (free crankshaft end) it is necessary to ensure that the accelerations do not exceed the values prescribed by the manufacturer in any part of the generator.

The applicable criterion in such cases is the tangential acceleration, which is the product of the angular acceleration and the effective radius. The angular acceleration is determined by means of forced torsional vibrations calculations and is to be regarded as the synthesized value of all major orders. However, for simplified consideration of excited resonant speeds, the value of the individual harmonics may be used instead for assessment.

5.2 The torsional vibration amplitude (angle) of shaft-driven generators shall normally not exceed an electrical value of $\pm 5^\circ$. The electrical vibration amplitude is obtained by multiplying the mechanical vibration amplitude by the number of pole pairs. Whether **BCS** is able to permit higher values depends on the configuration of the ship's electrical system.

6. Connected Units

6.1 If further units (e.g. power turbines or compressors) are coupled to the main propulsion system with or without the ability to declutch, due attention is to be paid to these units when investigated the torsional vibration loadings.

In the assessment of their dynamic loads, the limits as defined by the respective manufacturers are to be considered in addition to the criteria mentioned in C.1. If these limits are exceeded, the units concerned are to be disengaged or prohibited ranges of operation in

accordance with E.1 are to be declared. Disengaging of such units shall generally not lead to substantial overloading of the main system in terms of exceeding the τ_2 limit for shafting systems, the maximum torque for flexible couplings and so on.

6.2 In especially critical cases, the calculations of forced torsional vibrations, including those for disturbed operation (uncoupled set), as stated in B.1 are to be submitted to **BCS**.

In such cases **BCS** reserves the right to stipulate the performance of confirmatory measurements (compare . D.) including such as related to disturbed operation.

D. Torsional Vibration Measurements

1. Where calculations indicate that the limits for torsional vibration within the range of working speeds are exceeded, measurements, using an appropriate technique, may be taken from the machinery installation for the purpose of approval of torsional vibration characteristics, or determining the need for restricted speed ranges, and the confirmation of their limits.

2. Stresses shall be determined proceeding from the greatest vibration or stress amplitudes measured in the respective section of the torsiogram or oscillogram.

3. Where calculations and/or measurements have indicated the possibility of any excessive vibratory stress, torque or angular amplitude in the event of a malfunction, vibration or performance monitoring, directly or indirectly, may be required.

4. Where restricted speed ranges under normal operating conditions are imposed, notice boards are to be fitted at the control stations stating that the engine is not to be run continuously between the speed limits obtained as above, and the engine tachometers are to be marked accordingly.

5. During the ship's sea trials, the torsional vibrations of the propulsion plant are to be measured over the whole operating range. Measuring investigations should cover the normal as well as the misfiring condition. Speed ranges, which have been

declared as barred speed ranges in accordance with E.1 for misfiring operation must not be investigated by measurements, as far as these ranges are finally declared as “barred” on the base of reliable and approved calculations and adequately documented.

6. Measurements are required by **BCS** for all plants with a nominal torque exceeding 40 kNm. For other plants not meeting this condition, **BCS** reserves the right to ask for measurements depending on the calculation results. The requirement for measurements is communicated to the yard / engine supplier with the approval letter for the torsional vibration calculation.

7. Where measurements of identical propulsion plants (especially sister vessels) are available, further torsional vibration measurements for repeat ships may, with the consent of **BCS**, be dispensed with.

8. Free resonance vibration frequencies obtained as a result of measurement shall not differ from the design values by more than 5%. Otherwise, the calculations are to be corrected accordingly.

9. When estimating the total stresses due to vibration of several orders, the approved parameters are to be undergone the harmonic analysis.

10. Where existing propulsion plants are modified, **BCS** reserves the right to require a renewed investigation of the torsional vibration characteristics.

E. Prohibited Ranges of Operation

1. Operating ranges, which because of the magnitude of the torsional vibration stresses and/or torques, may only be passed through quickly (transient operation), are to be indicated as prohibited ranges of operation by red marks on the tachometer or in some other suitable manner at the operating station.

In normal operation the speed range $\lambda \geq 0.8$ is to be kept free of prohibited ranges of operation.

In specifying prohibited ranges of operation, it has to be observed that the navigating and manoeuvring functions

are not severely restricted. The width of the barred speed range is to be selected in a way that the stresses in the shafting do not exceed the permissible τ_1 limit for continuous operation with an adequate allowance considering the inaccuracies of the tachometers and the speed setting devices. For geared plants the barred speed ranges, if any, mostly refer to the gear meshes and elastic couplings and are to be determined in the same way with reference to the permissible vibratory torques or permissible power loss for these components (see corresponding paragraphs C.4 and C.5)

2. Measures necessary to avoid overloading the propulsion plant under abnormal operating conditions are to be displayed on an instruction plates to be affixed to all operating stations from which the plant can be controlled.

3. Where the shaft stresses or torques in any components or temperature of the rubber components of flexible coupling arising due to the torsional vibration, exceed the relevant permissible values for continuous running, the restricted speed ranges are assigned.

4. No restricted ranges are permitted for the following speeds:

- In a range of $\lambda \geq 0.7$ for ice-class ships,
- In a range of $\lambda \geq 0.8$ for all ship except for ice-class,
- In the range of $0.9 \leq \lambda \leq 1.05$ for diesel generators and other auxiliary diesel machineries in essential services

Where the main diesel generators of ships with electric propulsion plants are concerned, all the fixed speed values corresponding to the specified conditions of partial loading shall alternatively be adopted for n_0 .

5. If all the other methods of decreasing the stresses (or torques) due to the torsional vibration are proven to be ineffective, a vibration damper or a vibration absorber (detuners) or an antivibrator may be mounted where the values of permissible torsion stress are exceed or undesirable as mentioned in C.

The use of dampers or absorbers to limit vibratory stress due to resonances which occur within the range between $0.85 \leq \lambda \leq 1.05$ are to be considered. If fitted, these should be of a type which makes adequate provision for dissipation of heat. Where necessary, performance monitoring may be required

6. Restricted speed ranges in one-cylinder misfiring conditions on ships with single engine propulsion are to enable safe navigation whereby sufficient propulsion power is available to maintain control of the ship.

7. There are normally to be no restricted speed ranges imposed above a speed ratio of $\lambda = 0.8$ under normal operating conditions.

F. Auxiliary Machineries

1. General

For the ship's safety and operation, essential auxiliary machineries such as diesel generators and bow thrusters must be designed in a way that the operating speed range is free of unacceptable stresses due to torsional vibrations in accordance with item C.

2. Generators

2.1 For diesel generator sets with a mechanical output of 110 kW or above, torsional vibration calculations must be submitted to **BCS** for approval. The investigations must include natural frequencies as well as forced vibration calculations. The speed range 90 % to 105 % of the nominal speed shall be investigated under full load conditions (nominal excitation).

The generating set shall show torsional vibration levels which are compatible with the allowable limits for the alternator, shafts, coupling and damper.

2.2 For rigidly coupled generators (without elastic coupling) the vibratory torque in the input part of the generator's shaft must not exceed 250% of the nominal torque. For the purposes of this requirement, nominal torque is the torque which can be calculated by applying the actual data of the diesel engine (nominal output / nominal speed).

Compliance of the limit of 250% for the nominal torque within a nominal speed range of 90% to 105% shall be proven. The calculation for this speed range should be carried out by utilising the excitation corresponding to the nominal torque as defined above.

Exceeding the limit of 250% for the nominal torque may be considered in exceptional cases, provided that the generator's manufacturer has designed the generator for a higher dynamical torque. But also in such cases a highest value of 300 % of the actual nominal torque of the gen-set as defined above must not be exceeded.

2.3 The coupling selection for the generating set shall take into account the stresses and torques imposed on it by the torsional vibration of the system.

3. Bow Thrusters

3.1 For bow thrusters as well as for further essential auxiliary machinery driven by a diesel engine with a mechanical output higher than 150 kW, natural as well as forced torsional vibration calculations shall be submitted to **BCS** for approval. The torsional vibration calculations must be focused onto the actual load profile of the set.

3.2 For bow thrusters as well as for further essential auxiliary machinery driven by electrical motor the supplier must check that relevant excitation forces (i.e. propeller blade frequency or similar) may not lead to unacceptable torsional vibration loadings within the set. In special cases **BCS** may require the submission of corresponding calculations.

SECTION 7

GEARS, COUPLINGS

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A. General**1. Scope**

1.1 These requirements apply to all types of couplings used for either main propulsion or essential auxiliary services and enclosed gears, internal and external involute spur and planetary i.e. helical cylindrical gears having parallel axis as well as bevel gears which accumulate a large number of load cycles (several millions), whose gear set is intended to transmit a maximum continuous power equal to, or greater than:

- 220 kW for gears intended for main propulsion
- 110 kW for gears intended for essential auxiliary services

BCS reserves right to apply these requirements to the enclosed gears, whose gear set is intended to transmit a maximum continuous power less than those specified above.

1.2 Application of these requirements to the auxiliary machinery couplings mentioned in 1.1 may generally be restricted to a general approval of the particular coupling type by **BCS**. Regarding the design of elastic couplings for use in generator sets, reference is made to G.2.6.

1.3 For the dimensional design of gears and couplings for ships with ice classes, see Section 19.

1.4 Formulae in this section are not valid when any of the following conditions exist:

- Spur or helical gears with transverse contact ratios less than 1.0;
- Spur or helical gears with transverse contact ratios greater than 2.5;
- Interference between tooth tips and root fillets;
- Teeth are pointed;

- Backlash is zero.

The rating formulae in ISO 6336 are not applicable to other types of gear tooth deterioration such as plastic yielding, scuffing, case crushing, welding and wear, and are not applicable under vibratory conditions where there may be an unpredictable profile breakdown. The bending strength formulae are applicable to fractures at the tooth fillet, but are not applicable to fractures on the tooth working surfaces, failure of the gear rim, or failures of the gear blank through web and hub.

2. Documents for Approval

The documents to be submitted for approval shall include in triplicate:

2.1 Assembly drawings,

2.2 Detailed drawings of torque transmitting components including material characteristics,

2.3 Documentation of the related system for engaging and disengaging (for all new type of clutches),

2.4 General dimensions and characteristics about gears to be indicated on technical drawings: Assembly and sectional drawings together with the necessary detail drawings and part lists are to be submitted to the **BCS** in triplicate for approval. The drawings must contain the following data necessary to enable the load calculations to be checked,

2.4.1 Tip diameter and tolerance,

2.4.2 Facewidth,

2.4.3 Angle of the back cone (and, if applicable, inner cone),

2.4.4 Bore diameter and tolerance (or diameter and tolerance for the part of the shaft used for setting on the cutting machine),

2.4.5 Locating face(s),

2.4.6 Surface finish of the tooth flank and, if applicable, of the root surface and of the fillets (according to ISO 1302).

2.5 Information to be given in a table : The following information should preferably be given in the upper right-hand corner of the drawing :

2.5.1 Module of diametral pitch (normal, in the case of helical gears),

2.5.2 Number of teeth (for a sector : total number of teeth of the gear from which the sector is taken),

2.5.3 Basic rack (give the number of the corresponding national standard or the pressure angle of 20°. If the basic rack differs from the standard rack, its characteristics should be specified, preferably by a figure),

2.5.4 Value of helix angle,

2.5.5 Helix direction (for double helix teeth, the helix direction should be shown by a symbol in accordance with ISO 2203),

2.5.6 Reference diameter,

2.5.7 Reference cone angle,

2.5.8 Cone distance,

2.5.9 Addendum modification coefficient (to be expressed in unit module)

2.5.10 Tooth thickness: basic value and upper and lower deviations (the basic value may be given in three different ways : Wildhaber measurement, measurement of constant chord, or measurement over pins or balls. For the first method, the number of teeth over which the measurement is to be carried out should be stated, and, for the third method, the diameter of the pins or balls),

2.5.11 All useful information on tolerances (see ISO 1328)

2.5.12 Centre distance of gear pair and tolerance,

2.5.13 Number of teeth and drawing number of the mating gear.

2.6 Technical data for gears:

2.6.1 Transmitted rated power for each gear,

2.6.2 Rotational speed, input in each gear drive at rated power,

2.6.3 Bearing length and diameter,

2.6.4 Length of gap between helices, if any,

2.6.5 Distance between inner ends of bearings,

2.6.6 Geometric form layout of tooth or cross-sectional view of tooth or calculated data,

2.6.7 Facewidths, net and total,

2.6.8 Width of tooth at highest stressed section,

2.6.9 Helix angle at reference and at pitch diameter,

2.6.10 Helix deviation,

2.6.11 Normal pressure angle,

2.6.12 Transverse pressure angle at reference cylinder,

2.6.13 Transverse pressure angle at working pitch cylinder,

2.6.14 Reference cone angle for gears,

2.6.15 Tip angle for gears,

2.6.16 Cone distance for gears,

2.6.17 Middle cone distance for gears,

2.6.18 Normal module,

2.6.19 Transverse module,

2.6.20	Bending moment arm for tooth root bending stress for application of load at the point of single tooth pair contact,	2.6.41	Grade of accuracy,
2.6.21	Working pitch diameter of gears,	2.6.42	Tooth hardness range, including core hardness and total depth of hardness, surface to core,
2.6.22	Tip diameter of gears,	2.6.43	Mean peak-to-valley roughness of tooth root fillets
2.6.23	Root diameters of gears,	2.6.44	Mass of rotating parts,
2.6.24	Reference diameters,	2.6.45	Balancing data,
2.6.25	Addendum,	2.6.46	Spline data,
2.6.26	Addendum modification coefficient of gears,	2.6.47	Shrink allowance for rims and hubs,
2.6.27	Dedendum,	2.6.48	Type of coupling between prime mover and reduction gears,
2.6.28	Transverse diametral pitch,	2.6.49	Type and viscosity of lubricating oil recommended by manufacturer,
2.6.29	Normal base pitch,	2.7	Technical data for couplings:
2.6.30	Number of gear teeth,	2.7.1	Construction details of torque transmitting components, housing, along with their dimensions and materials,
2.6.31	Virtual number of spur teeth for gears,	2.7.2	Rated power and rotational speed,
2.6.32	Centre distance between mating gears,	2.7.3	Engineering analyses,
2.6.33	Length of contact in plane of rotation,	2.7.4	Allowable power loss (overheating),
2.6.34	Root fillet radius of gears in the critical section,	2.7.5	Allowable misalignment for continuous operation,
2.6.35	Axial lead modification or lead mismatch, if any, for reference,	2.7.6	Rubber Shore Hardness,
2.6.36	Method of cutting and finishing gear teeth,	2.7.7	Nominal torque T_{KN}
2.6.37	Tooth thickness modification coefficient (midface),	2.7.8	Permissible torque TK_{max1} for normal transient conditions like starts/stops, passing through resonances, electrical or mechanical engagements, ice impacts, etc.
2.6.38	Sketch of basic rack tooth form,		
2.6.39	Root radius, addendum, dedendum of basic rack,		
2.6.40	Degree of finish of tooth flank,		

2.7.9 Permissible torque TK_{max2} for abnormal impact loads like short circuits, emergency stops, etc.

2.7.10 Permissible vibratory torque $\pm T_{KW}$ for continuous operation

2.7.11 Permissible power loss P_{KV} due to heat dissipation

2.7.12 Permissible rotational speed n_{max}

2.7.13 Dynamic torsional stiffness C_{Tdyn} , radial stiffness C_{rdyn}

2.7.14 Relative damping ψ respectively damping characteristics

2.7.15 Permissible axial, radial and angular displacement

2.7.16 Permanent permissible twist.

2.8 Technical data for clutches:

2.8.1 Construction details of torque transmitting components, housing along with their materials and dimensions,

2.8.2 Rated power and rotational speed,

2.8.3 Engineering analyses,

2.8.4 Maximum and minimum working pressure for hydraulic or pneumatic systems [bar]

2.8.5 Static and dynamic friction torque [kNm]

2.8.6 Time diagram for clutching procedure

2.8.7 Operating manual with definition of the permissible switching frequency

2.8.8 For special cases calculation of heat balance, if requested by **BCS**

2.9 Design calculations covering the life estimation for bearings and also including the tooth coupling and the spline connections.

2.10 Test reports

B. Materials

1. Approved Materials

1.1 Shafts, pinions, wheels and wheel rims of gears in the main propulsion plant should preferably be made of forged steel. Rolled steel bar may also be used for plain, flangeless shafts. Gear wheel bodies may be made of grey cast iron **(1)** or nodular cast iron or may be fabricated from welded steel plate with steel or cast steel hubs.

1.2 Couplings in the main propulsion plant must be made of steel, cast steel or nodular cast iron with a mostly ferritic matrix. Grey cast iron or suitable cast aluminium alloys may also be permitted for lightly stressed external components of couplings and rotors and casings of hydraulic slip couplings.

1.3 The gears of essential auxiliary machinery according to Section 1, H. are subject to the same requirements as those specified in 1.1 as regards the materials used. For the gears intended for the auxiliary machinery other than that of the mentioned ones in Section 1, H. alternate materials may also be permitted.

1.4 Flexible coupling bodies for important auxiliary machinery according to Section 1, H. may generally be made of grey cast iron, and for the outer coupling bodies a suitable aluminium alloy may also be used. However, for generator sets use should only be made of coupling bodies preferably made of nodular cast iron with a mostly ferritic matrix, of steel or of cast steel, to ensure that the coupling are well able to withstand the shock torques occasioned by short circuits. **BCS** reserves the right to impose similar requirements on the couplings of particular auxiliary drive units.

(1) *The peripheral speed of cast iron gear wheels shall generally not exceed 60 m/s, that of cast iron coupling clamps or bowls, 40 m/s.*

2. Testing of Materials

2.1 All gear and coupling components which are involved in the transmission of torque and which are considered for the main propulsion plant must be tested in accordance with the **BCS** 's Rules for Materials . The same applies to the materials used for gear components with a major torque transmission function of gears and couplings in generator drives . Suitable proof should be submitted for the materials used for the major components of the couplings and gears of all other functionally important auxiliary machines in accordance with Section 1, H. This documentation may substitute for the form of a **BCS** Material Test Certificate or for an acceptance test certificate issued by the steelmaker.

C. Calculation of The Load-Bearing Capacity of Gear Teeth

Note: The revisions of subsection C indicated with vertical line are to be uniformly implemented from 1st July 2015 to any Marine Gear subject to approval and to any Type Approved Marine gear from the date of the first renewal after 1st July 2015. For a Marine gear approved prior to 1st July 2015 where no failure has occurred, and no changes in design / scantlings of the gear meshes or materials or declared load capacity data has taken place the requirements of the revisions of subsection C indicated with vertical line may be waived.

1. General

1.1 The sufficient load-bearing capacity of the gear-tooth system of main and auxiliary gears in ship propulsion systems is to be demonstrated by load-bearing capacity calculations according to the international standards of ISO. ISO 6336, ISO 9083 and DIN 3990 cover the spur gear tooth systems. ISO 10300 or DIN 3991 contains the standards and remarks for bevel gears. Table 7.1 describes the minimum safety margins for flank and root stress according to the utilizing places of gears in ships.

1.2 For gears in the main propulsion plant proof of the sufficient mechanical strength of the roots and flanks of gear teeth in accordance with the

formulae contained in this Section is linked to the requirement that the accuracy of the teeth should ensure sufficiently smooth gear operation combined with satisfactory exploitation of the dynamic loading capacity of the teeth.

For this purpose, the magnitude of the individual pitch error f_p and of the total profile error F_t for peripheral speeds at the pitch circle up to 25 m/s should generally conform to at least quality 5 as defined in DIN 3962 or 4 to ISO 1328, and in the case of higher peripheral speeds generally to at least quality 4 as defined in DIN 3962 or 3 to ISO 1328.

The total error of the tooth trace $f_{H\beta}$ should conform at least to quality 5 to DIN 3962, while the parallelism of axis should at least meet the requirements of quality 5 according to DIN 3964 or 4 according to ISO 1328.

Prior to running-in, the surface roughness R_z of the tooth flanks of gears made by milling or by shaping should generally not exceed 10 μm . In the case of gears where the tooth profile is achieved by e.g. grinding or lapping, the surface roughness should generally not exceed 4 μm . The tooth root radius ρ_{a0} on the tool reference profile should be at least $0.25 \cdot m_n$.

BCS reserves the right to call for proof of the manufacturing accuracy of the gear -cutting machines used and for testing of the method used to harden the gear teeth.

1.3. The input data required to carry out load-bearing capacity evaluations are summarized in Table 7.2.

2. Symbols, Terms and Summary of Input Data

2.1 Symbols and terms used

Indices	0 tool
	1 pinion
	2 wheel
	M in the mid of face width
	n normal plane
	t transverse plane

Parameters	d_f = Root diameter, [mm]
a = Centre distance between mating gears [mm]	d_{f1}, d_{f2} = Root diameter of pinion, wheel (refer to Figure 7.1) [mm]
b = Common facewidth, [mm]	d_{w1}, d_{w2} = Working pitch diameter of pinion, wheel, [mm]
b_1, b_2 = Facewidth of pinion, wheel, [mm]	F_{bt} = Nominal tangential load on base cylinder in the transverse section, [N]
b_{eH} = Effective facewidth (for bevel gears), [mm]	F_t = Nominal transverse tangential load at reference cylinder, [N]
BZ_0 = Measure for shift of datum line (i.e. BZ at tool, [mm])	$F_{\beta x}$ = Initial equivalent misalignment, [μ m]
d = Standard pitch diameter, (without subscript, at reference cylinder), [mm]	f_{pe} = Normal pitch error, [μ m]
d_1, d_2 = Reference diameter of pinion, wheel [mm]	f_f = Profile form error, [μ m]
d_a = Tip diameter, [mm]	h = Tooth depth, [mm]
d_{a1}, d_{a2} = Tip diameter of pinion, wheel, (refer to Figure 7.1) [mm]	h_1, h_2 = Tooth depth of pinion, [mm]
d_{b1}, d_{b2} = Base diameter of pinion, wheel (refer to Figure 7.1) [mm]	h_{a0}^* = Addendum coefficient of tool, [-]

Table 7.1 Minimum safety margins for contact and root bending stress

Ref.	Application	Boundary conditions	S_H	S_F
1.1	Gearing in ship propulsion systems and generator drive systems	Modulus $m_n \leq 16$	1.3	1.8
1.2		Modulus $m_n > 16$	$0.024 m_n + 0.916$	$0.02 m_n + 1.48$
1.3		In the case of two mutually independent main propulsion systems up to an input torque of 8 kNm	1.2	1.55
2.1	Gears in auxiliary drive systems which are subjected to dynamic load		1.2	1.4
2.2	Gears in auxiliary drive systems used for dynamic positioning (class notation DP)		1.3	1.8
2.3	Gears in auxiliary drive systems which are subjected to static load	$N_L \leq 10^4$	1.0	1.0

Note: If the fatigue bending stress of the tooth roots is increased by special technique approved by BCS, e.g. by shot peening, for case-hardened toothing with modulus $m_n \leq 10$ the minimum safety margin S_F may be reduced up to 15% with the consent of BCS.

Table 7.2 List of input data for evaluating load-bearing capacity

Shipyard New building No.					Reg. No.				
Manufacturer					Type				
Application					Cylindrical gear	<input type="checkbox"/>			
					Bevel gear (1)	<input type="checkbox"/>			
Nominal rated power	P			kW	Ice class				
No. of revolutions	n_1			1/min	No. of planets				
Application factor	K_A			-	Internal dynamic factor	K_V			
Face-load distribution factors	$K_{H\beta}$				Load distribution factor	K_γ			
	$K_{H\beta-be}(1)$			-	Transverse load distribution factors	$K_{H\alpha}$			
	$K_{F\beta}$			-		$K_{F\alpha}$			
Geometry Data		Pinion	Wheel		Tool Data			Pinion	Wheel
Number of teeth	z			-	Addendum modification coefficient	$x / x_{hm}(1)$			-
Normal modul	$m_n / m_{nm}(1)$			mm	Thickness modification coefficient	$x_{sm}(1)$			-
Normal pressure angle	α_n			°	Coefficient of tool tip radius	ρ_{a0}^*			-
Centre distance	a			mm	Addendum coefficient of tool	h_{a0}^*			-
Shaft angle	$\Sigma(1)$			°	Dedendum coefficient of tool	h_{f0}^*			-
Relative effective facewidth	$b_{eh} / b(1)$			-	Utilized dedendum coefficient of tool	h_{FfP0}^*			-
Helix angle	β			°	Protuberance	p_r			mm
Mean helix angle	$\beta_m(1)$			°	Protuberance angle	α_{pr}			°
Facewidth	b			mm	Machining allowance	q			mm
Tip diameter	d_a			mm	Measure at tool	B_{z0}			mm
Root diameter	d_{fe}			mm	Backlash allowance / tolerance				-
Lubrication Data					Quality				
Kin.viscosity 40°C	ν_{40}			mm ² /s	Quality according to DIN	Q			-
Kin.viscosity 100°C	ν_{100}			mm ² /s	Mean peak to valley roughness of flank	R_{zH}			μm
Oil temperature	ϑ_{oil}			°C	Mean peak to valley roughness of root	R_{zF}			μm
FZG load stage				-	Initial equivalent misalignment	$F_{\beta x}$			μm
Material Data					Normal pitch error				
Material type					Profile form error				
Endurance limit for contact stress	$\sigma_{H\lim}$			N/mm ²	Date : Signature :				
Endurance limit for bending stress	$\sigma_{F\lim}$			N/mm ²					
Surface hardness				HV					
Core hardness				HV					
Heat treatment method				-					
(1) Declaration for bevel gear.									

h_{a01}, h_{a02} = Addendum of tool of pinion, wheel, [mm]	Q = Tooth quality, according to DIN, [-]
h_{a1}, h_{a2} = Addendum of pinion, wheel, [mm]	q = Machining allowance, [mm]
h_{f0}^* = Dedendum coefficient of tool, [-]	R_a = Arithmetic mean roughness, [μm]
h_{f1}, h_{f2} = Dedendum of pinion, wheel [mm]	R_m = Mean cone distance[mm]
h_{FfP0}^* = Utilized dedendum coefficient of tool, [-]	R_{zF} = Mean peak to valley roughness of root [μm]
K_A = Application factor, [-]	R_{zH} = Mean peak to valley roughness of flank [μm]
$K_{F\alpha}$ = Transverse load distribution factor (root stress), [-]	r_{eo} = Cutter radius[mm]
$K_{F\beta}$ = Face load distribution factor (root stress), [-]	S_F = Safety factor against the tooth breakage [-]
$K_{H\alpha}$ = Transverse load distribution factor (contact stress), [-]	S_H = Safety factor against the pittings, [-]
$K_{H\beta}$ = Face load distribution factor (contact stress), [-]	T = Torque, [Nm]
$K_{H\beta-be}$ = Bearing factor (bevel gears), [-]	T_1, T_2 = Nominal torque of pinion, wheel, [Nm]
K_v = Dynamic load factor, [-]	u = Gear ratio, [-]
K_γ = Load distribution factor. [-]	v = Tangential (linear) velocity at reference (pitch) diameter, [m/s]
m_n = Normal modul, [mm]	x = Addendum modification coefficient, [-]
m_{nm} = Mean normal modul (for bevel gear), [mm]	x_1, x_2 = Addendum modification coefficient of pinion, wheel, [-]
m_t = Transverse modul, [mm]	x_{hm} = Mean addendum modification coefficient (bevel gears) [-]
n = Number of revolutions, [rpm]	x_{sm} = Thickness modification coefficient (bevel gears) [-]
n_1, n_2 = Rotational speed of pinion, wheel, [rpm]	Y_F = Tooth form factor (root), [-]
N_L = Number of load cycles, [-]	Y_N = Live factor (root), [-]
P = Transmitted power by the gear set at Maximum Continuous Rate, [kW]	$Y_{\delta \text{ rel } T}$ = Relative notch sensitivity factor, [-]
pr = Protuberance at tool, [mm]	$Y_{R \text{ rel } T}$ = Relative surface condition factor, [-]

Y_s	=	Stress correction factor, [-]	β	=	Helix angle (without subscript, at reference cylinder), [°]
Y_{ST}	=	Stress correction factor for reference test gears, [-]	β_b	=	Helix angle at base cylinder, [°]
Y_X	=	Size factor for tooth root stress, [-]	β_m	=	Mean helix angle (bevel gears), [°]
Y_β	=	Helix angle factor for tooth root stress, [°]	ε_α	=	Transverse contact ratio, [-]
z	=	Number of teeth, [-]	ε_β	=	Overlap ratio, [-]
z_1, z_2	=	Number of teeth of pinion, wheel, [-]	ε_γ	=	Total contact ratio, [-]
z_n	=	Virtual number of teeth, [-]	ϑ_{oil}	=	Oil temperature, [°C]
z_{n1}, z_{n2}	=	Virtual number of teeth of pinion, wheel, [-]	ν_{40}	=	Kinematic viscosity of the oil at 40°C, [mm²/s]
Z_E	=	Elasticity factor, [-]	ν_{100}	=	Kinematic viscosity of the oil at 100°C, [mm²/s]
Z_H	=	Zone factor (contact stress), [-]	ρ_{a0}	=	Coefficient of tip radius of tool, [-]
Z_L	=	Lubricant factor, [-]	ρ_c	=	Radius of curvature at pitch surface, [mm]
Z_N	=	Live factor (contact stress), [-]	Σ	=	Shaft angle (bevel gears), [°]
Z_v	=	Speed factor, [-]	σ_F	=	Root bending stress, [N/mm²]
Z_R	=	Roughness factor, [-]	σ_{FE}	=	Root stress, [N/mm²]
Z_W	=	Work-hardening factor, [-]	σ_{FG}	=	Root stress limit, [N/mm²]
Z_X	=	Size factor (contact stress), [-]	σ_{F0}	=	Nominal tooth root stress, [N/mm²]
Z_β	=	Helix angle factor (contact stress), [-]	$\sigma_{F\ lim}$	=	Endurance limit for bending stress, [N/mm²]
Z_ε	=	Contact ratio factor (contact stress), [-]	σ_{FP}	=	Permissible tooth root stress, [N/mm²]
α_n	=	Normal pressure angle (without subscript, at reference cylinder), [°]	σ_H	=	Calculated contact stress, [N/mm²]
α_t	=	Transverse pressure angle at reference cylinder [°]	σ_{HG}	=	Modified contact stress limit, [N/mm²]
α_{wt}	=	Transverse pressure angle at working pitch cylinder [°]	$\sigma_{H\ lim}$	=	Endurance limit for contact stress, [N/mm²]
α_{pr}	=	Protuberance angle, [°]	σ_{HP}	=	Permissible contact stress, [N/mm²]
			σ_{H0}	=	Nominal contact stress, [N/mm²]

3. Geometrical Definitions

For internal gearing z_2 , a , d_2 , d_{a2} , d_{b2} , d_{w2} and u are negative. However, for external gears u is positive.

The pinion is defined as the gear with the smaller number of teeth. Therefore the absolute value of the gear ratio, defined as follows, is always greater or equal to the unity:

$$u = \frac{z_2}{z_1} = \frac{d_{w2}}{d_{w1}} = \frac{d_2}{d_1}$$

In the equation of surface durability, b is the common facewidth on the pitch diameter.

In the equation of tooth root bending stress, b_1 or b_2 are the facewidths at the respective tooth roots. In any case, b_1 and b_2 are not to be taken as greater than b by more than one normal module m_n on either side.

The common facewidth b may be used also in the equation of teeth root bending stress if significant crowning or end relief have been applied.

Additional geometrical definitions are given in the following expressions:

$$\tan(\alpha_t) = \tan(\alpha_n) \cdot \cos(\beta)$$

$$\tan(\beta_b) = \tan(\beta) \cdot \cos(\alpha_t)$$

$$d_{1,2} = \frac{z_{1,2} \cdot m_n}{\cos \beta}$$

$$d_{b1,2} = d_{1,2} \cos \alpha_t$$

$$\left. \begin{aligned} d_{w1} &= \frac{2a}{u+1} \\ d_{w2} &= \frac{2au}{u+1} \end{aligned} \right\} \text{ where } a = 0,5(d_{w1} + d_{w2})$$

$$z_{n1,2} = z_{1,2} / (\cos^2(\beta_b) \cdot \cos(\beta))$$

$$m_t = m_n / \cos(\beta)$$

$$\text{inv}(\alpha) = \tan(\alpha) - \pi\alpha/180 \quad (\text{where } \alpha \text{ is in degrees})$$

$$\text{inv}\alpha_{tw} = \text{inv}\alpha_t + 2 \tan \alpha_n \frac{x_1 + x_2}{z_1 + z_2}$$

$$\text{or } \cos \alpha_{tw} = \frac{m_t(z_1 + z_2)}{2a} \cos \alpha_t$$

$$\alpha_{wt} = \arccos \left(\frac{d_{b1} + d_{b2}}{2a} \right) \quad (\text{where } \alpha_{wt} \text{ is in degrees})$$

$$x_1 = \frac{h_{a0}}{m_n} - \frac{d_1 - d_{f1}}{2m_n}$$

$$x_2 = \frac{h_{a0}}{m_n} - \frac{d_2 - d_{f2}}{2m_n}$$

$$\varepsilon_\alpha = \frac{0.5(d_{a1}^2 - d_{b1}^2)^{0.5} \pm 0.5(d_{a2}^2 - d_{b2}^2)^{0.5} - a \cdot \sin \alpha_{tw}}{\pi \cdot m_t \cdot \cos \alpha_t}$$

(The positive sign is to be used for external gears; the negative sign for internal gears.)

$$\varepsilon_\beta = \frac{b \cdot \sin(\beta)}{\pi \cdot m_n}$$

(For double helix, b is to be taken as the width of one helix.)

$$\varepsilon_\gamma = \varepsilon_\alpha + \varepsilon_\beta$$

$$\rho \leq \frac{a \cdot u \cdot \sin(\alpha_{wt})}{\pi \cdot m_n}$$

$$v = \frac{\pi \cdot d_{1,2} \cdot n_{1,2}}{60 \cdot 10^3}$$

4. Nominal Tangential Load,

Nominal tangential load, F_t , tangential to the reference cylinder and perpendicular to the relevant axial plane, is calculated directly from the maximum continuous power transmitted by the gear set by means of the following equations:

$$T_{1,2} = \frac{30 \cdot 10^3 \cdot P}{\pi \cdot n_{1,2}}$$

$$F_t = \frac{1000 \cdot T}{\frac{d}{2}} = \frac{19,1 \cdot 10^6 \times P}{n \cdot d} = \frac{2000 \cdot T_{1,2}}{d_{1,2}}$$

5. General Influence Factors for Load Calculations

5.1 Application factor K_A

The application factor K_A takes into account the increase in rated torque caused by the superimposed dynamics and impact (transient) loads.

The application factor K_A for gears designed for infinite life is defined as the ratio of between the maximum repetitive cyclic torque applied to the gear set and the nominal rated torque.

The application factor, K_A , should be determined by measurements or by system analysis acceptable to **BCS**. Where a value determined in such a way cannot be supplied, the values for the application factor of K_A given in Table 7.3 approved by **BCS** can be considered for several main and auxiliary system arrangements.

Where the vessel, on which the reduction gear is being used, is receiving an Ice Class notation, the Application Factor or the Nominal Tangential Force should be adjusted to reflect the ice load associated with the requested Ice Class, i.e. applying the design approach in BCS- R I 3 when applicable.

5.2 Load distribution factor K_γ

The load distribution factor K_γ takes into account the deviations in load distribution e.g. in gears with dual or multiple load distribution or planetary gearing with more than three planet wheels.

The load distribution factor K_γ is defined as the ratio between the maximum load through an actual path and the evenly shared load. The factor mainly depends on accuracy and flexibility of the branches.

Table 7.3 Application factors

System type	K_A factor
Main propulsion gears	
Turbines and electric drive systems	1.1
Diesel engine with hydraulic or electromagnetic slip coupling	1.1
Diesel engine with high elasticity couplings	1.3
Diesel engine with other couplings	1.5
Generator drives	1.5
Auxiliary machinery under static load	0.6-1.0
Auxiliary system	
Thruster drives	1.1(20000h) (1)
Thruster drives with diesel engines	1.3 (20000h) (1)
Windlasses	0.6 (300h) (1) 2.0 (20h) (2)
Combined anchor and mooring winches	0.6 (1000h) (1) 2.0 (20h) (2)
(1) Estimated running hours for low cycle fatigue layout (2) Estimated maximum load for windlasses For other types of system the K_A is to be stipulated separately	

The load distribution factor K_γ should be determined by measurements or by system analysis acceptable to **BCS**. Where a value determined in such a way cannot be supplied; the following values apply for epicyclic or planetary gears:

- Up to 3 planetary gears $K_\gamma = 1.0$
- 4 planetary gears $K_\gamma = 1.2$
- 5 planetary gears $K_\gamma = 1.3$
- 6 planetary gears and over $K_\gamma = 1.6$

In gear which have no load distribution $K_\gamma=1$ is applied.

For all other cases K_γ is to be agreed with **BCS**.

5.3 Internal dynamic factor K_v

The internal dynamic factor K_v takes into account the internally generated dynamic loads due to vibrations of pinion and wheel against each other.

The internal dynamic factor K_v is defined as the ratio between the maximum load which dynamically acts on the tooth flanks and the maximum externally applied load ($F_t \cdot K_A \cdot K_Y$).

The factor mainly depends on transmission errors (depending on pitch and profile error), masses of pinion and wheel, gear mesh stiffness variation as the gear teeth pass through the meshing cycle, transmitted load including application factor, pitch line velocity, dynamic unbalance of gears and shaft, shaft and bearing stiffness, and damping characteristics of the gear system.

The internal dynamic factor K_v is to be advised by the manufacturer as supported by his measurements, analysis or experience data. The internal dynamic factor K_v can also be determined as follows:

This method may be applied only to cases where all the following conditions are satisfied:

- Running velocity in the subcritical range, (i.e.):

$$\frac{v \cdot z_1}{100} \sqrt{\frac{u^2}{1+u^2}} < 10 \text{ m/s}$$

- spur gears ($\beta = 0^\circ$) and helical gears with $\beta \leq 30^\circ$
- pinion with relatively low number of teeth, $z_1 < 50$
- solid disc wheels or heavy steel gear rim

This method may be applied to all types of gears if the formula below is satisfied, as well as to helical gears where $\beta > 30^\circ$

$$\frac{v \cdot z_1}{100} \sqrt{\frac{u^2}{1+u^2}} < 3 \text{ m/s}$$

For gears other than the above, reference is to be made to Method B outlined in the reference standard ISO 6336-1.

5.3.1 For spur gears and for helical gears with overlap ratio $\varepsilon_\beta \geq 1$

$$K_v = 1 + \left(\frac{K_1}{K_A E_t} + K_2 \right) \cdot \frac{v \cdot z_1}{100} \cdot K_3 \sqrt{\frac{u^2}{1+u^2}}$$

If $K_A F_t / b$ is less than 100 N/mm, this value is assumed to be equal to 100 N/mm.

Numerical values for the factor K_1 are to be as specified in the Table 7.4

Table 7.4 Values of the factor K_1 for the calculation of K_v

	K_1 ISO accuracy grades (1)					
	3	4	5	6	7	8
spur gears	2.1	3.9	7.5	14.9	26.8	39.1
helical gears	1.9	3.5	6.7	13.3	23.9	34.8
(1) ISO accuracy grades according to ISO 1328. In case of mating gears with different accuracy grades, the grade corresponding to the lower accuracy should be used.						

For all accuracy grades the factor K_2 is to be in accordance with the following:

- for spur gears, $K_2 = 0.0193$
- for helical gears, $K_2 = 0.0087$

Factor K_3 is to be in accordance with the following:

$$\text{— If } \frac{v \cdot z_1}{100} \cdot \sqrt{\frac{u^2}{1+u^2}} \leq 0.2 \quad \text{then } K_3 = 2$$

$$\text{— If } \frac{v \cdot z_1}{100} \cdot \sqrt{\frac{u^2}{1+u^2}} \geq 0.2$$

$$\text{then } K_3 = 2.071 - 0.357 \cdot \frac{v \cdot z_1}{100} \cdot \sqrt{\frac{u^2}{1+u^2}}$$

5.3.2 For helical gears with overlap ratio $\varepsilon_\beta < 1$ the value K_v is determined by linear interpolation between values determined for spur gears ($K_{v\alpha}$) and helical gears ($K_{v\beta}$) in accordance with:

$$K_v = K_{v\alpha} - \varepsilon_\beta(K_{v\alpha} - K_{v\beta})$$

Where:

$K_{v\alpha}$ is the K_v value for spur gears, in accordance with 5.3.1;

$K_{v\beta}$ is the K_v value for helical gears, in accordance with 5.3.1.

5.4 Face load distribution factors $K_{H\beta}$ and $K_{F\beta}$

The face load distribution factors, $K_{H\beta}$ for contact stress and $K_{F\beta}$ for tooth root bending stress, account for the effects of non-uniform distribution of load across the facewidth.

The face load distribution factor $K_{H\beta}$ for contact stress per unit facewidth is described as the ratio of maximum load to mean load.

The face load distribution factor $K_{F\beta}$ for tooth root bending stress at tooth root per unit facewidth is described as the ratio of maximum bending stress to mean bending stress. The mean bending stress at tooth root relates to the considered facewidth b_1 or b_2 .

Each face load distribution factor can be expressed as a function of other.

The face load distribution factors mainly depend on:

- Gear tooth manufacturing accuracy,
- Errors in mounting due to bore errors,
- Bearing clearances,
- Wheel and pinion shaft alignment errors,

- Elastic deflections of gear elements, shafts, bearings, housing and foundations which support the gear elements,
- Thermal expansion and distortion due to operating temperature,
- Compensating design elements (tooth crowning, end-relief, etc.).

In case of flank corrections which have been determined by recognized calculation methods, the $K_{H\beta}$ and $K_{F\beta}$ values can be preset. Hereby the special influence of ship operation on the load distribution has to be taken into account.

The face load distribution factors, $K_{H\beta}$ for contact stress, $K_{F\beta}$ for tooth root bending stress, are to be determined according to the method C outlined in the ISO 6336-1 standard.

Alternative methods acceptable to **BCS** may be also applied.

5.4.1 Face load distribution factor for contact stress $K_{H\beta}$

- Helical and spur gears

$$C_{KH\beta} = \frac{b \cdot F_{\beta y} \cdot C_\gamma}{2 \cdot F_t \cdot K_A \cdot K_\gamma \cdot K_v}$$

$$K_{H\beta} = 1 + C_{KH\beta} < 2 \quad \text{when} \quad C_{KH\beta} < 1$$

$$K_{H\beta} = \sqrt{4 \cdot C_{KH\beta}} \geq 2 \quad \text{when} \quad C_{KH\beta} \geq 1$$

Where:

$$F_{\beta y} = F_{\beta x} - y_\beta \quad \text{or} \quad F_{\beta y} = F_{\beta x} \cdot x_\beta$$

Calculated values of $K_{H\beta} \geq 2$ are to be reduced by improvement accuracy and helix deviation.

- Bevel gears

$$K_{H\beta} = 1.5 \cdot \frac{0.85}{B_0} \cdot K_{H\beta be}$$

The bearing factor, $K_{H\beta be}$, representing the influence of the bearing arrangement on the faceload distribution, is given by Table 7.5.

Table 7.4 Bearing factor $K_{H\beta be}$ for bevel gears

Mounting conditions of pinion and wheel	$K_{H\beta be}$
Both members straddle mounted	1.10
One member straddle mounted	1.25
Neither member straddle mounted	1.50

5.4.2 Face load distribution factor for tooth root bending stress $K_{F\beta}$

- In case the hardest contact is at the end of the facewidth $K_{F\beta}$ is given by the following equations:

$$K_{F\beta} = (K_{H\beta})^N$$

$$N = \frac{\left(\frac{b}{h}\right)^2}{1 + \left(\frac{b}{h}\right) + \left(\frac{b}{h}\right)^2} = \frac{1}{1 + \left(\frac{h}{b}\right) + \left(\frac{h}{b}\right)^2}$$

Where:

(b/h) = (facewidth/tooth depth), the lesser of (b_1/h_1) or (b_2/h_2) . For double helical gears, the facewidth of only one helix is to be used, i.e., $(b_\beta = b/2)$ is to be substituted for (b) in the equation for N . When $b/h < 3$ the value $b/h=3$ is to be used.

- In case of gears where the ends of the facewidth are lightly loaded or unloaded (end relief or crowning)

$$K_{F\beta} = K_{H\beta}$$

- Bevel gears

$$K_{F\beta} = \frac{K_{H\beta}}{K_{FO}}$$

for spiral bevel gears:

$$K_{FO} = 0.211 \cdot \left(\frac{r_{eo}}{R_m} \right)^q + 0.789$$

r_{eo} = Cutter radius [mm]

R_m = Mean cone distance [mm]

$$q = \frac{0.279}{\log[\sin(\beta_m)]}$$

for straight or zero bevel gears:

$$K_{FO} = 1$$

Limitations of K_{FO} :

$$K_{FO} = 1.00 \text{ if } K_{FO} < 1.00$$

$$K_{FO} = 1.15 \text{ if } K_{FO} > 1.15$$

5.5 Transverse load factors $K_{H\alpha}$ and $K_{F\alpha}$

The transverse load distribution factors $K_{H\alpha}$ for contact stress and $K_{F\alpha}$ for tooth root bending stress, account for the effects of pitch and profile errors on the transversal load distribution between two or more pairs of teeth in mesh.

In case of gears in main propulsion systems with a gear tooth system of a quality described in 1.2

$$K_{H\alpha} = K_{F\alpha} = 1.0$$

can be applied.

For other gears, the transverse load distribution factors are to be calculated in accordance with DIN/ISO standards defined in 1.1.

The face load distribution factors, $K_{H\alpha}$ and $K_{F\alpha}$ mainly depend on :

- Total mesh stiffness,
- Total tangential load F_t , K_A , K_v , $K_{H\beta}$
- Base pitch error,
- Tip relief,

- Running in allowances

The load distribution factors, $K_{H\alpha}$ and $K_{F\alpha}$ are to be advised by the manufacturer as supported by his measurements, analysis or experience data or are to be determined according to the Method B outlined in the ISO 6336-1 standard:

5.5.1 Estimating of $K_{H\alpha}$ and $K_{F\alpha}$

If $\varepsilon_v > 2$ then

$$K_{H\alpha} = K_{F\alpha} = 0.9 + 0.4 \sqrt{\frac{2(\varepsilon_v - 1)}{\varepsilon_v} \frac{C_v(f_{pbe} - y_a)b}{F_{tH}}}$$

If $\varepsilon_v \leq 2$ then

$$K_{H\alpha} = K_{F\alpha} = \frac{\varepsilon_v}{2} \left[0.9 + 0.4 \frac{C_v(f_{pbe} - y_a)b}{F_{tH}} \right]$$

for cylindrical gears:

$$F_{tH} = F_t \cdot K_A \cdot K_v \cdot K_{h\beta}$$

$$f_{pbe} = f_{pb} \cdot \cos(\alpha_t)$$

for bevel gears:

$$F_{mtH} = F_{mt} \cdot K_A \cdot K_v \cdot K_{h\beta}$$

For bevel gears, f_{pt} , ε_{vy} , F_{mtH} , F_{mt} and α_{vt} (equivalent) are to be substituted for f_{pbe} , ε_γ , F_{tH} , F_t and α_t in the above formulas.

5.5.2 Limitations of $K_{H\alpha}$

$$K_{H\alpha} < 1 \Rightarrow K_{H\alpha} = 1$$

for cylindrical gears:

$$K_{H\alpha} > \frac{\varepsilon_v}{\varepsilon_\alpha Z^2} \Rightarrow K_{H\alpha} = \frac{\varepsilon_v}{\varepsilon_\alpha Z^2}$$

for helical gears:

$$Z_\varepsilon = \sqrt{\frac{4 - \varepsilon_\alpha}{3} (1 - \varepsilon_\beta) + \frac{\varepsilon_\beta}{\varepsilon_\alpha}} \quad \text{if } \varepsilon_\beta < 1$$

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}} \quad \text{if } \varepsilon_\beta \geq 1$$

for spur gears:

$$Z_\varepsilon = \sqrt{\frac{4 - \varepsilon_\alpha}{3}}$$

for bevel gears:

$$K_{H\alpha} \xRightarrow{> Z_\varepsilon^{\varepsilon_{v\gamma}} \varepsilon_{v\alpha}} = K_{H\alpha} \xrightarrow{\frac{\varepsilon_v}{\varepsilon_\gamma} \frac{\varepsilon_v}{\varepsilon_\alpha} Z_\varepsilon^2} \text{LS} \quad \text{LS}$$

For the calculation of Z_{LS} , see 6.8. The calculation of Z_{LS} is also described in ISO 10300-2, Annex A, Load Sharing Factor, Z_{LS}

5.5.3 Limitations of $K_{F\alpha}$

$$K_{F\alpha} < 1 \Rightarrow K_{F\alpha} = 1$$

$$K_{F\alpha} > \frac{\varepsilon_\gamma}{\varepsilon_\alpha Y_\varepsilon} \Rightarrow K_{F\alpha} = \frac{\varepsilon_\gamma}{\varepsilon_\alpha Y_\varepsilon}$$

$$Y_\varepsilon = 0.25 + \frac{0.75}{\varepsilon_\alpha} \quad \text{if } \varepsilon = 0$$

$$Y_\varepsilon = 0.25 + \frac{0.75}{\varepsilon_\alpha} - \left(\frac{0.75}{\varepsilon_\alpha} - 0.375 \right) \varepsilon_\beta \quad \text{if } 0 < \varepsilon_\beta < 1$$

$$Y_\varepsilon = 0.625 \quad \text{if } \varepsilon_\beta \geq 1$$

or further alternative for Y_ε for cylindrical gears only

$$Y_\varepsilon = 0.25 + \frac{0.75 \cdot \cos^2(\beta_b)}{\varepsilon_\alpha}$$

For bevel gears, ε_{vy} , $\varepsilon_{v\beta}$ and $\varepsilon_{v\alpha}$ (equivalent) are to be substituted for ε_γ , ε_β and ε_α in the above formulas.

6. Surface Durability (Pitting)

6.1 Scope and general remarks

The criterion for surface durability is based on the Hertzian pressure on the operating pitch point or at the inner point of single pair contact. The contact stress σ_H

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6.2 Contact stress

$$\sigma_H = \sigma_{H01,2} \sqrt{K_A K_V K_H K_{H\beta} K_{H\alpha}} \leq \sigma_{HP} \quad (1)$$

where; σ_{H01} and σ_{H02} denote the basic value of contact stress for pinion and wheel, significantly.

For cylindrical gears:

$$\sigma_{H01} = Z_B Z_H Z_E Z_{\epsilon} Z_{\beta} \sqrt{\frac{1+u}{u} \frac{F_t}{b \cdot d_1}} \quad \text{for pinion}$$

$$\sigma_{H02} = Z_D Z_H Z_E Z_{\epsilon} Z_{\beta} \sqrt{\frac{1+u}{u} \frac{F_t}{b \cdot d_1}} \quad \text{for wheel}$$

Gear ratio u for external gears is positive and for internal gears, u is negative.

For bevel gears:

$$\sigma_{H01} = Z_{MB} Z_H Z_E Z_{LS} Z_K Z_{\beta} \sqrt{\frac{1+u_v}{u_v} \frac{F_{mt}}{\ell_{bm} \cdot d_{v1}}} \quad \text{for pinion}$$

where;

d_{m1} = Mean pitch diameter of pinion of bevel gear,

d_{v1} = Reference diameter of pinion of virtual (equivalent) cylindrical gears,

F_t = Nominal transverse tangential load at reference cylinder for pinion and wheel,

F_{mt} = Nominal transverse tangential load,

ℓ_{bm} = Length of middle line contact,

u = Gear ratio of bevel gear,

u_v = Gear ratio of virtual (equivalent) cylindrical gear,

Z_B = Single pair tooth contact factor for pinion,

Z_D = Single pair tooth contact factor for wheel,

Z_E = Elasticity factor,

Z_H = Zone factor,

Z_K = Bevel gear factor (flank),

Z_{LS} = Load sharing (distribution) factor,

Z_{MB} = Mid-zone factor,

Z_{ϵ} = Contact ratio factor (pitting),

Z_{β} = Helix angle factor.

6.3 Permissible contact stress

The permissible contact stress, σ_{HP} is to be evaluated separately for pinion and wheel. The permissible contact stress, σ_{HP} shall include a safety margin S_H as given in Table 7.1 against the modified contact stress σ_{HG} . The modified contact stress σ_{HG} is determined from the material dependent endurance limit for bending stress $\sigma_{H \lim}$ as show in Table 7.6 (2) allowing for the stress correction factors $Z_N, Z_L, Z_V, Z_R, Z_W, Z_X$.

$$\sigma_{HP} = \frac{\sigma_{HG}}{S_H} \quad (2)$$

$$\sigma_{HG} = \sigma_{H \lim} Z_N Z_L Z_V Z_R Z_W Z_X$$

where;

$\sigma_{H \lim}$ = Endurance limit for contact stress

S_H = Safety factor for contact stress

Z_L = Lubrication factor

Z_N = Life factor for contact stress

Z_R = Roughness factor

Z_V = Velocity factor

Z_W = Hardness ratio factor

Z_X = Size factor for contact stress

(2) With consent of BCS for case hardened steel with or over proven quality higher endurance strength may be permitted.

Table 7.5 Endurance limits for contact stress $\sigma_{H \text{ lim}}$

Material	$\sigma_{H \text{ lim}}$ N/mm ²
Case hardened carburized CrNiMo steel	
- of ordinary grade	1500
- of specially approved high quality grade	1650
Other case hardened (carburized) steels	1500
Gas nitrided steels: hardened, tempered and gas nitrided, Surface hardness: 700-850 HV10	1250
Through hardened steels: hardened, tempered and gas nitrided, Surface hardness: 500-650 HV10	1000
Through hardened steels: hardened, tempered or normalized and nitro-carburized, Surface hardness: 450-650 HV10	950
Flame or induction hardened steels, Surface hardness: 520-620 HV10	0.65·HV10+830
Alloyed through hardening steels, Surface hardness: 195-360 HV10	1.32·HV10+372
Through hardened carbon steels, Surface hardness: 135-210 HV10	1.05·HV10+335
Alloyed cast steels, Surface hardness: 198-358 HV10	1.30 HV10+295
Cast carbon steels, Surface hardness: 135-210 HV10	0.87·HV10+290

6.4 Single pair tooth contact factors, Z_B , Z_D and mid-zone factor Z_{MB}

The single pair tooth contact factors, Z_B for pinion and Z_D for wheel, account for the influence of the tooth flank curvature of contact stresses at the inner point of single pair contact in relation to Z_H .

The factors transform the contact stresses determined at the pitch point to contact stresses considering the flank curvature at the inner point of single pair contact.

The single pair tooth contact factor, Z_B for pinions and Z_D for wheels, are to be determined as follows:

For cylindrical (spur) gears when $\varepsilon_\beta = 0.0$

$Z_B = Z_{MB} = M_1$ or 1, whichever is the larger value

$Z_D = Z_{MB} = M_2$ or 1, whichever is the larger value

$$M_1 = \frac{\tan \alpha_{tw}}{\left(\left(\frac{d_{a1}^2}{d_{b1}^2} - 1 \right) - \frac{2\pi}{z_1} \right) \cdot \left(\left(\frac{d_{a2}^2}{d_{b2}^2} - 1 \right) - (\varepsilon_a - 1) \frac{2\pi}{z_2} \right)}$$

$$M_2 = \frac{\tan \alpha_{tw}}{\left(\left(\frac{d_{a2}^2}{d_{b2}^2} - 1 \right) - \frac{2\pi}{z_2} \right) \cdot \left(\left(\frac{d_{a1}^2}{d_{b1}^2} - 1 \right) - (\varepsilon_a - 1) \frac{2\pi}{z_1} \right)}$$

For bevel gears α_{wt} , d_a , d_b , ε_a and z are to be substituted by α_{vt} , d_{va} , d_{vb} , ε_{va} and z_v , respectively, in the above formulas.

For cylindrical (helical) gears when $\varepsilon_\beta \geq 1.0$

$$Z_B = Z_D = 1$$

For helical gears having $\varepsilon_\beta < 1$, the values of Z_B , Z_D are determined by linear interpolation between Z_B , Z_D for spur gears and Z_B , Z_D for helical gears having $\varepsilon_\beta \geq 1$.

$$Z_B = M_1 - \varepsilon_\beta (M_1 - 1) \quad \text{and} \quad Z_B \geq 1$$

$$Z_D = M_2 - \varepsilon_\beta (M_2 - 1) \quad \text{and} \quad Z_D \geq 1$$

For internal gears, Z_D shall be taken as equal to 1.

6.5 Zone factor, Z_H

The zone factor, Z_H , accounts for the influence on the Hertzian pressure of tooth flank curvature at pitch point and transforms the tangential load at the reference cylinder to the normal force at the pitch cylinder. The zone factor, Z_H is to be calculated as follows:

For cylindrical (spurs and helical) gears:

$$Z_H = \sqrt{\frac{2 \cos \beta_b}{\cos^2 \alpha_t \tan \alpha_{tw}}}$$

For bevel gears:

$$Z_H = 2 \cdot \sqrt{\frac{\cos(\beta_{vb})}{\sin(2\alpha_{vt})}}$$

6.6 Elasticity factor, Z_E

The elasticity factor, Z_E , accounts for the influence of

the material properties E (modulus of elasticity) and ν (Poisson's ratio) on the contact stress. The zone factor, Z_E can be calculated as follows:

$$Z_E = \sqrt{\frac{1}{\pi \left(\frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2} \right)}}$$

with Poisson's ratio of 0.3 and same E and ν for pinion and wheel, Z_E may be obtained from the following :

$$Z_E = \sqrt{0.175 \cdot E}$$

where E denotes the Young's modulus of elasticity. The elasticity factor, Z_E for steel gears ($E = 206000 \text{ N/mm}^2$, $\nu=0.3$) is equal to

$$Z_E = 189.8 \sqrt{\text{N/mm}^2}$$

For other material combinations, refer to the Table 7.7. The value of E for combination of different materials for pinion and wheel should be calculated as follows:

$$E = \frac{2E_1E_2}{E_1 + E_2}$$

6.7 Contact ratio factor (Pitting), Z_ϵ

The contact ratio factor, Z_ϵ , accounts for the influence of the transverse contact ratio and the overlap ratio on the specific surface load of gears. The contact ratio factor Z_ϵ is to be calculated as follows:

For spur gears:

$$Z_\epsilon = \sqrt{\frac{4 - \epsilon_\alpha}{3}}$$

For helical gears:

$$\text{For } \epsilon_\beta < 1 \quad Z_\epsilon = \sqrt{\frac{4 - \epsilon_\alpha}{3} (1 - \epsilon_\beta) + \frac{\epsilon_\beta}{\epsilon_\alpha}}$$

$$\text{For } \epsilon_\beta \geq 1 \quad Z_\epsilon = \sqrt{\frac{1}{\epsilon_\alpha}}$$

6.8 Bevel gear load distribution factor, Z_{LS}

The load sharing factor, Z_{LS} , accounts for the load

sharing between two or more pair of teeth in contact.

$$\text{For } \epsilon_{v\gamma} \leq 2 \quad Z_{LS} = 1$$

For $\epsilon_{v\gamma} > 2$ and $\epsilon_{v\beta} > 1$

$$Z_{LS} = \left\{ 1 + 2 \left[1 - \left(\frac{2}{\epsilon_{v\gamma}} \right)^{1.5} \right] \sqrt{1 - \frac{4}{\epsilon_{v\gamma}^2}} \right\}^{-0.5}$$

For other cases; the calculation of Z_{LS} is described in ISO 10300-2, Annex A, Load Sharing Factor, Z_{LS} .

6.9 Bevel gear factor (flank), Z_K

The bevel gear factor (flank), Z_K , accounts the difference between bevel and cylindrical loading and adjusts the contact stresses so that the same permissible stresses may apply.

$$Z_K = 0.8$$

6.10 Helix angle factor, Z_β

The helix angle factor, Z_β , accounts for the influence of helix angle on surface durability, allowing for such variables as the distribution of load along the lines of contact. Z_β is dependent only on the helix angle. The helix angle factor, Z_β , is to be calculated as follows:

For cylindrical gears:

$$Z_\beta = \sqrt{\frac{1}{\cos \beta}}$$

For bevel gears:

$$Z_\beta = \sqrt{\frac{1}{\cos \beta_m}}$$

6.11 Endurance limit for contact stress, σ_{Hlim}

For a given material, σ_{Hlim} is the limit of repeated contact stress which can be permanently endured. The value of σ_{Hlim} can be regarded as the level of contact stress which the material will endure without pitting for at least 5×10^7 load cycles.

For this purpose, pitting is defined as follows:

- For not surface hardened gears:

- Pitted area > 2% of total active flank area.
- For surface hardened gears:
Pitted area > 0.5% of total active flank area,
or > 4% of one particular tooth flank area.
- Residual stresses;
- Hardening process, depth of hardened zone,
hardness gradient;
- Material structure (forged, rolled bar, cast).

The endurance limit depends mainly on:

- Material composition, cleanliness and defects;
- Mechanical properties;

The σ_{Hlim} values correspond to a failure probability of 1% or less. Endurance limit for contact stress σ_{Hlim} is to be determined, in general, making reference to values indicated in ISO 6336-5, for material quality M_Q

Table 7.6 Values of the elasticity factor Z_E and young's modulus of elasticity E

PINION			WHEEL			
Material	Young's modulus of elasticity (E_1 N/mm ²)	Poisson's ratio ν	Material	Young's modulus of elasticity (E_2 N/mm ²)	Poisson's ratio ν	Elasticity factor, Z_E N ^{1/2} /mm
Steel	206000	0.3	Steel	206000	0.3	189.8
			Cast steel	202000		188.9
			Nodular cast iron	173000		181.4
			Cast tin bronze	103000		155.0
			Tin bronze	113000		159.8
			Lamellar graphite cast iron (gray cast iron)	126000-118000		165.4-162.0
Cast steel	202000	0.3	Cast steel	202000	0.3	188.0
			Nodular cast iron	173000		180.5
			Lamellar graphite cast iron (gray cast iron)	118000		161.4
Nodular cast iron	173000	0.3	Nodular cast iron	173000	0.3	173.9
			Lamellar graphite cast iron (gray cast iron)	118000		156.6
Lamellar graphite cast iron (gray cast iron)	126000-118000	0.3	Lamellar graphite cast iron (gray cast iron)	118000	0.3	146.0-143.7
Steel	206000	0.3	Nylon	7850 (mean value)	0.5	56.4

6.12 Life factor, Z_N

The life factor, Z_N , accounts for the higher permissible contact stress in case a limited life (number of cycles) is required.

The factor mainly depends on:

- Material and heat treatment;
- Number of cycles;
- Influence factors (Z_R , Z_V , Z_L , Z_W , Z_X).

The life factor, Z_N , is to be determined according to method B outlined in the ISO 6336-2 standard.

6.13 Influence factors on lubrication film, Z_L , Z_V and Z_R

The lubricant factor, Z_L , accounts for the influence of the type of lubricant and its viscosity.

The velocity factor, Z_V , accounts for the influence of the pitch line velocity.

The roughness factor, Z_R , accounts for the influence of the surface roughness on the surface endurance capacity.

The factors may be determined for the softer material where gear pairs are of different hardness. The factors mainly depend on:

- Viscosity of lubricant in the contact zone;
- The sum of the instantaneous velocities of the tooth surfaces;
- Load;
- Relative radius of curvature at the pitch point;
- Surface roughness of teeth flanks;
- Hardness of pinion and gear.

The lubricant factor, Z_L , the speed factor, Z_V , and the roughness factor Z_R can be calculated as follows:

6.13.1 Lubricant factor, Z_L

The lubricant factor, Z_L , is to be calculated from the following equation:

$$Z_L = C_{ZL} + \frac{4(1 - C_{ZL})^2}{\left(1.2 + \frac{134}{v_{40}}\right)}$$

or

$$Z_L = C_{ZL} + \frac{4(1 - C_{ZL})^2}{\left(1.2 + \frac{80}{v_{50}}\right)}$$

Where σ_{Hlim} is the allowable stress number (contact) of the softer material.

- With σ_{Hlim} is in the range of:
 $\sigma_{Hlim} < 850 \text{ N/mm}^2$
 $C_{ZL} = 0.83$
- With σ_{Hlim} is in the range of:
 $850 \text{ N/mm}^2 \leq \sigma_{Hlim} \leq 1200 \text{ N/mm}^2$
 $C_{ZL} = 0.83 + 0.08 \cdot \left(\frac{\sigma_{Hlim} - 850}{350} \right)$
- With σ_{Hlim} is in the range of:
 $\sigma_{Hlim} > 1200 \text{ N/mm}^2$
 $C_{ZL} = 0.91$

Where:

- v_{40} Nominal kinematic viscosity of oil at 40°C, in mm²/s
- v_{50} Nominal kinematic viscosity of oil at 50°C, in mm²/s

6.13.2 Velocity factor, Z_V

The velocity factor, Z_V , is to be calculated from the following equation:

$$Z_V = C_{ZV} + \frac{2(1 - C_{ZV})}{\sqrt{0.8 + \frac{32}{v}}}$$

Where σ_{Hlim} is the allowable stress number (contact) of the softer material.

For bevel gears, v is to be substituted by v_{mt} in the above formula.

- With σ_{Hlim} is in the range of:

$$\sigma_{Hlim} < 850 \text{ N/mm}^2$$

$$C_{Zv} = 0.85$$

- With σ_{Hlim} is in the range of:

$$850 \text{ N/mm}^2 \leq \sigma_{Hlim} \leq 1200 \text{ N/mm}^2$$

$$C_{Zv} = 0.85 + 0.08 \cdot \left(\frac{\sigma_{Hlim} - 850}{350} \right)$$

- With σ_{Hlim} is in the range of:

$$\sigma_{Hlim} > 1200 \text{ N/mm}^2$$

$$C_{Zv} = 0.93$$

6.13.3 Roughness factor, Z_R

The roughness factor, Z_R , is to be calculated from the following equation:

$$Z_R = \left(\frac{3}{R_{Z10}} \right)^{C_{ZR}}$$

The peak-to-valley roughness determined for the pinion R_{Z1} and for the wheel R_{Z2} are mean values for the peak-to-valley roughness R_z measured on several tooth flanks (R_z as defined in the ISO 6336-2)

$$R_z = \frac{R_{Z1} + R_{Z2}}{2}$$

Where roughness values are not available, roughness of the pinion $R_{Z1} = 6.3 \mu\text{m}$ and of the wheel $R_{Z2} = 6.3 \mu\text{m}$ may be used. R_{Z10} is to be given by:

$$R_{Z10} = R_z \cdot \sqrt[3]{\frac{10}{\rho_{red}}}$$

and the relative radius of curvature is to be given by:

$$\rho_{red} = \frac{\rho_1 \rho_2}{\rho_1 + \rho_2} \quad \text{for cylindrical gears}$$

$$\rho_{red} = \frac{\rho_{v1} \rho_{v2}}{\rho_{v1} + \rho_{v2}} \quad \text{for bevel gears}$$

$$\rho_1 = 0.5 \cdot d_{b1} \cdot \tan(\alpha_{wt})$$

$$\rho_{v1} = 0.5 \cdot d_{vb1} \cdot \tan(\alpha_{wt})$$

$$\rho_2 = 0.5 \cdot d_{b2} \cdot \tan(\alpha_{wt})$$

$$\rho_{v2} = 0.5 \cdot d_{vb2} \cdot \tan(\alpha_{wt})$$

It must be noted that $d_{b1,2}$ has negative sign for internal gears. The roughness of the tooth surface R_a depends on the manufacturing process and is rated as the arithmetic average deviation of the surface valleys and peaks expressed in micrometers. ISO standards use the term CLA (Center Line Average). Both are interpreted identical. If the stated roughness a value of R_a which is also known as the arithmetic average / mean roughness (AA) or the centreline average roughness (CLA), the following approximate relationship may be applied:

$$R_a = R_{CLA} = R_{AA} = \frac{R_z}{6}$$

Where R_z is either R_{Z1} for pinion or R_{Z2} for gear and σ_{Hlim} is the allowable stress number (contact) of the softer material.

- With σ_{Hlim} is in the range of:

$$\sigma_{Hlim} < 850 \text{ N/mm}^2$$

$$C_{ZR} = 0.15$$

- With σ_{Hlim} is in the range of:

$$850 \text{ N/mm}^2 < \sigma_{Hlim} < 1200 \text{ N/mm}^2$$

$$C_{ZR} = 0.32 - 2.0 \cdot 10^{-4} \cdot \sigma_{Hlim}$$

- With σ_{Hlim} is in the range of:

$$\sigma_{Hlim} > 1200 \text{ N/mm}^2$$

$$C_{ZR} = 0.08$$

6.14 Hardness ratio factor, Z_w

The hardness ratio factor, Z_w accounts for the increase of surface durability of a soft steel gear when meshing with a surface hardened gear with a smooth surface in the following cases:

6.14.1 Surface-hardened pinion with through-hardened wheel

$$\text{If } HB < 130 \quad Z_w = 1.2 \cdot \left(\frac{3}{R_{zH}} \right)^{0.15}$$

$$\text{If } 130 \leq \text{HB} \leq 470 \quad Z_w = \left(1.2 - \frac{\text{HB} - 130}{1700}\right) \cdot \left(\frac{3}{R_{zH}}\right)^{0.15}$$

$$\text{If } \text{HB} \geq 470 \quad Z_w = \left(\frac{3}{R_{zH}}\right)^{0.15}$$

Where:

HB = Brinell hardness of the tooth flanks of the softer gear of the pair

HV10 Vickers hardness with F=98.1 N

$$\text{For unalloyed steel:} \quad \text{HB} \approx \text{HV10} \approx \frac{U}{3.6}$$

$$\text{For alloyed steel:} \quad \text{HB} \approx \text{HV10} \approx \frac{U}{3.4}$$

R_{zH} = equivalent roughness, μm

$$R_{zH} = \frac{R_{z1} \cdot \left(\frac{10}{\rho_{red}}\right)^{0.33} \cdot \left(\frac{R_{z1}}{R_{z2}}\right)^{0.66}}{\left(\frac{V \cdot V_{40}}{1500}\right)^{0.33}}$$

ρ_{red} = relative radius of curvature

6.14.2 Through-hardened pinion and wheel

When the pinion is substantially harder than the wheel, the work hardening effect increases the load capacity of the wheel flanks. Z_w applies to the wheel only, not to the pinion.

$$\text{— If } \frac{\text{HB}_1}{\text{HB}_2} < 1.2 \quad Z_w = 1$$

$$\text{— If } 1.2 \leq \frac{\text{HB}_1}{\text{HB}_2} \leq 1.7$$

$$Z_w = 1 + (0.00898 \frac{\text{HB}_1}{\text{HB}_2} - 0.00829) \cdot (u - 1)$$

$$\text{— If } \frac{\text{HB}_1}{\text{HB}_2} \geq 1.7$$

$$Z_w = 1 + 0.00698 \cdot (u - 1)$$

If gear ratio $u > 20$ then the value $u = 20$ is to be used.

In any case, if calculated $Z_w < 1$ then the value $Z_w = 1.0$ is to be used.

6.15 Size factor, Z_x

The size factor, Z_x accounts for the influence of tooth dimensions on permissible contact stress and reflects the non-uniformity of material properties. The size factor mainly depends on:

Material and heat treatment,

- Tooth and gear dimensions,
- Ratio of case depth to tooth size,
- Ratio of case depth to equivalent radius of curvature.

For through-hardened gears and for surface hardened gears with minimum required effective case depth including root of 1.14 mm relative to tooth size and radius curvature $Z_x = 1$. When the case depth is relatively shallow, then a smaller value of Z_x should be chosen.

The size factors, Z_x are to be obtained from Table 7.8.

6.16 Safety factor for contact stress, S_H

The safety factor for contact stress, S_H can be assumed by **BCS** taking into account the type of application. Based on the application type, the safety factors for contact stress, S_H , are to be selected from Table 7.1.

7. Tooth Root Bending Stress

7.1 Scope and general remarks

The criterion for tooth root bending strength is the permissible limit of local tensile strength in the root fillet. The tooth root stress, σ_F and the permissible tooth root stress, σ_{FP} are to be calculated separately for the pinion and the wheel, whereby the existing maximum root bending stress σ_F of the teeth should not exceed the permissible tooth root stress σ_{FP} of the teeth.

The following formulas apply to gears having a rim thickness greater than $3.5m_n$ and further for all involute

basic rack profiles, with or without protuberance, however, with the following restrictions:

- The 30° tangents contact the tooth-root curve generated by the basic rack of the tool,
- The result of rating calculations made by following this method are acceptable for normal pressure angles up to 25° and reference helix angles up to 30°.
- The basic rack of the tool has a root radius $\rho_{fp} > 0$
- The gear teeth are generated using a rack type tool.
- For larger pressure angles and large helix angles, the calculated results should be confirmed by experience as by method A of ISO 6336-3.

For bevel gears:

$$\sigma_{F1,2} = \frac{F_{mt}}{b \cdot m_{mn}} \frac{Y_F Y_{Fa} Y_{S\alpha} Y_{LS} Y_{DT} Y_{\beta}}{K_F K_{Fa} K_{S\alpha} K_{LS} K_{DT} K_{\beta}} \leq \sigma_{FP1,2}$$

where:

Y_F, Y_{Fa} = Tooth form factor (root),

$Y_S, Y_{S\alpha}$ = Stress correction factor,

Y_{β} = Helix angle factor,

Y_B = rim thickness factor,

Y_{DT} = deep tooth factor,

Y_{ϵ} = Contact ratio factor,

Y_K = Bevel gear factor,

Y_{LS} = Load distribution (sharing) factor.

Table 7.8 Size factor Z_x for contact stress

Size factor for contact stress Z_x	Material
1.0	For through-hardened pinion treatment All modules (m_n)
1.0 1.05-0.005 m_n 0.9	For carburized and induction-hardened pinion heat treatment $m_n \leq 10$ $m_n < 30$ $m_n \geq 30$
1.0 1.08-0.011 m_n 0.75	For nitride pinion treatment $m_n \leq 7.5$ $m_n < 30$ $m_n \geq 30$
<i>For bevel gears, the m_n (normal module) is to be substituted by m_{mn} (normal module at mid-facewidth)</i>	

7.2 Basic equations

7.2.1 Tooth root bending stress for pinion and wheel

For cylindrical gears:

$$\sigma_{F1,2} = \frac{F_t}{b \cdot m_n} \frac{Y_F \cdot Y_{Fa} \cdot Y_S \cdot Y_{S\alpha} \cdot Y_{\beta} \cdot Y_B \cdot Y_{DT} \cdot Y_A \cdot Y_{\gamma} \cdot Y_v \cdot Y_{F\alpha} \cdot Y_{F\beta}}{K_F \cdot K_{Fa} \cdot K_{S\alpha} \cdot K_{LS} \cdot K_{DT} \cdot K_{\beta}} \leq \sigma_{FP1,2}$$

7.2.2 Permissible tooth root bending stress for pinion and wheel

$$\sigma_{FP1,2} = \frac{\sigma_{FE}}{S_F} Y_d Y_N Y_{\delta re1T} Y_{Rre1T} Y_X$$

where:

σ_{FE} = Bending endurance limit,

Y_d = Design factor,

Y_N = Life factor,

$Y_{\delta re1T}$ = Relative notch sensitivity factor,

Y_{Rre1T} = Relative surface factor,

Y_X = Size factor,

S_F = Safety factor for tooth root bending stress.

7.2.3. Tooth form factor, Y_F, Y_{Fa}

The tooth form factors, Y_F and Y_{Fa} represent the influence on nominal bending stress of the tooth form

with load applied at the outer point of single pair tooth contact.

The tooth form factors, Y_F and Y_{Fa} are to be determined separately for the pinion and the wheel. In the case of helical gears, the form factors for gearing are to be determined in the normal section, i.e., for the virtual spur gear with virtual number of teeth, z_n .

The tooth form factor, Y_F , is to be calculated as follows:

For cylindrical gears:

$$Y_F = \frac{6 \cdot \left(\frac{h_F}{m_n} \right) \cdot \cos(\alpha_{Fn})}{\left(\frac{s_{Fn}}{m_n} \right) \cdot \cos(\alpha_n)}$$

For bevel gears:

$$Y_{Fa} = \frac{6 \cdot \left(\frac{h_{Fa}}{m_{mn}} \right) \cdot \cos(\alpha_{Fan})}{\left(\frac{s_{Fn}}{m_{mn}} \right) \cdot \cos(\alpha_n)}$$

where:

h_F, h_{Fa} = Bending moment arm for tooth root bending stress for application of load at the outer point of single tooth pair contact, in mm,

s_{Fn} = Tooth root normal chord in the critical section (i.e. width of tooth at highest stressed section), in mm,

$\alpha_{Fn}, \alpha_{Fan}$ = Normal load pressure angle at the outer point of single tooth pair contact in the normal section, in degrees.

For determination of h_F, h_{Fa}, s_{Fn} and $\alpha_{Fn}, \alpha_{Fan}$, it should be refer to Figure 7.1.

For the calculation of h_F, s_{Fn} and α_{Fn} , the procedure outlined in ISO 6336-3 (Method B) is to be used.

7.2.4 Stress correction factor, Y_S, Y_{Sa}

The stress correction factor, Y_S and Y_{Sa} is used to convert the nominal bending stress to the local tooth root stress, taking into account that not only bending stresses arise at the root.

Y_S applies to the load application at the outer point of single tooth pair contact. Y_S shall be determined separately for the pinion and for the wheel.

The stress correction factor, Y_S , is to be determined with the following equation (having a valid range: $1 \leq q_s \leq 8$):

$$q_s = \frac{s_{Fn}}{2 \cdot \rho_F}$$

For cylindrical gears:

$$Y_S = (1.2 + 0.13L) \cdot q_s^{\left(\frac{1}{1.21 + (2.3/L)} \right)}$$

For bevel gears:

$$Y_{Sa} = (1.2 + 0.13L_a) \cdot q_s^{\left(\frac{1}{1.21 + (2.3/L_a)} \right)}$$

where:

q_s = Notch parameter,

ρ_F = Root fillet radius in the critical section at 30° tangent, in mm

For the calculation of ρ_F the procedure outlined in ISO 6336-3 is to be used.

L = s_{Fn}/h_F for cylindrical gears, in mm

L_a = s_{Fn}/h_{Fa} for bevel gears, in mm.

7.2.5 Helix angle factor, Y_β

The helix angle factor, Y_β converts the stress calculated for a point loaded cantilever beam representing the substitute gear tooth to the stress induced by a load along an oblique load line into a cantilever plate which represents a helical gear tooth.

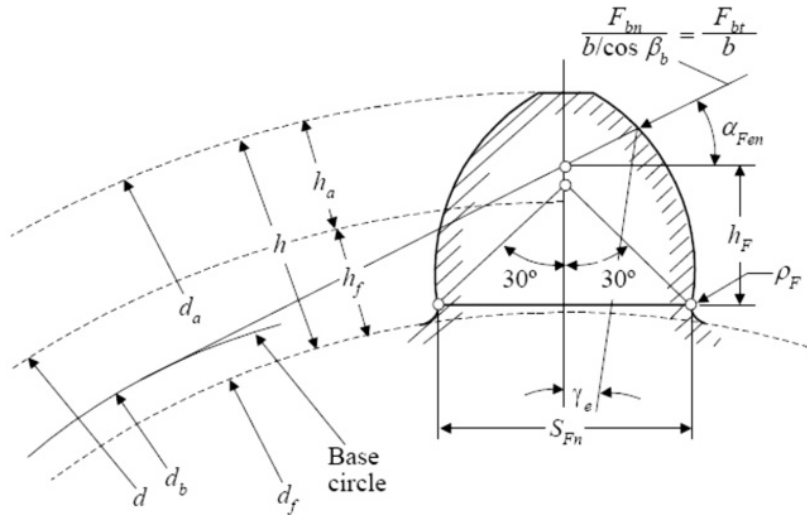


Figure 7.1 Measurements on cross-section of the tooth profile of a typical external cylindrical gear

The helix angle factor, Y_β is to be calculated as follows :

$$Y_\beta = 1 - \varepsilon_\beta \cdot \frac{\beta}{120}$$

where:

β : Reference helix angle in degrees for cylindrical gears

If $\varepsilon_\beta > 1.0$ then $\varepsilon_\beta = 1.0$

If $\beta > 30^\circ$ then $\beta = 30^\circ$

7.2.6 Rim thickness factor, Y_B

The rim thickness factor, Y_B , is a simplified factor used to de-rate thin rimmed gears. For critically loaded applications, this method should be replaced by a more comprehensive analysis. Factor Y_B is to be determined as follows:

7.2.6.1 for external gears:

$$\text{if } \frac{S_R}{h} \leq 1.2 \quad Y_B = 1$$

$$\text{If } 0.5 < \frac{S_R}{h} < 1.2 \quad Y_B = 1.6 \cdot \ln \left(2.242 \frac{h}{S_R} \right)$$

where:

S_R = rim thickness of internal gears, mm

h = tooth height, mm

The case $S_R / h \leq 0.5$ is to be avoided.

7.2.6.2 for internal gears:

$$\text{If } \frac{S_R}{m_n} \leq 3.5 \quad Y_B = 1$$

$$\text{If } 1.75 < \frac{S_R}{m_n} < 3.5 \quad Y_B = 1.15 \cdot \ln \left(8.342 \frac{m_n}{S_R} \right)$$

where:

S_R = rim thickness of internal gears, mm

The case $S_R / m_n \leq 1.75$ is to be avoided.

7.2.7 Deep tooth factor, Y_{DT}

The deep tooth factor, Y_{DT} , adjusts the tooth root stress to take into account high precision gears and contact ratios within the range of virtual contact ratio $2.05 \leq \varepsilon_{\alpha n} \leq 2.5$, where:

$$\varepsilon_{\alpha n} = \frac{\varepsilon_\alpha}{\cos^2 \beta^b}$$

Factor Y_{DT} is to be determined as follows:

- if ISO accuracy grade ≤ 4 and $\epsilon_{\alpha n} > 2.5$
 $Y_{DT} = 0.7$
- if ISO accuracy grade ≤ 4 and $2.05 \leq \epsilon_{\alpha n} \leq 2.5$
 $Y_{DT} = 2.366 - 0.666\epsilon_{\alpha n}$
- In all other cases
 $Y_{DT} = 1.0$

7.2.8 Bending endurance limit, σ_{FE}

For a given material, σ_{FE} is the limit of repeated tooth root stress that can be sustained. For most materials, their stress cycles may be taken at 3×10^6 as the beginning of the endurance limit, unless otherwise specified.

The endurance limit, σ_{FE} is defined as the unidirectional pulsating stress with a minimum stress of zero (disregarding residual stresses due to heat treatment). Other conditions such as e.g., alternating stress or pre-stressing are covered by the design factor Y_d .

The endurance limit mainly depends on:

- Material composition, cleanliness and defects
- Mechanical properties,
- Residual stress,
- Hardening process, depth of hardened zone, hardness gradient,
- Material structure (forged, rolled bar, cast).

The σ_{FE} values are to correspond to a failure probability of 1% or less. The values of σ_{FE} are to be determined from Table 7.9 or to be advised by the manufacturer, together with technical justification for the proposed values.

For gears treated with controlled shot peening process, the value of σ_{FE} may be increased by 20%.

7.2.9 Design factor, Y_d

The design factor, Y_d , takes into account the influence of load reversing and shrink fit pre-stressing on the

tooth root strength, relative to the tooth root strength with unidirectional load as defined for σ_{FE} .

The design factor, Y_d , for load reversing, is to be determined as follows:

$$Y_d = 1.0 \quad \text{in general;}$$

$Y_d = 0.9$ for gears with part load in reversed direction, such as main wheel in reversing gearboxes;

$Y_d = 0.7$ for idler gears.

7.2.10 Life factor, Y_N

The life factor, Y_N , accounts for the higher tooth root bending stress permissible in case a limited life (number of cycles) is required.

The life factor mainly depends on:

- Material and heat treatment;
- Number of load cycles (service life);
- Influence factors ($Y_{\delta re1T}$, Y_{Rre1T} , Y_X).

The life factor, Y_N , is to be determined according to Method B outlined in ISO 6336-3 standard.

7.2.11 Relative notch sensitivity factor, $Y_{\delta re1T}$

The relative notch sensitivity factor, $Y_{\delta re1T}$, indicates the extent to which the theoretically concentrated stress lies above the fatigue endurance limit.

The factor mainly depends on material and relative stress gradient.

The relative notch sensitivity factor, $Y_{\delta re1T}$, is to be determined as follows :

$$Y_{\text{rel}T} = \frac{1 + \sqrt{0.2\rho'(1+2q_s)}}{1 + \sqrt{1.2\rho'}}$$

where:

q_s = notch parameter (see clause 7.2.4)

ρ' = slip-layer thickness, mm, from the following table

Material		ρ' , mm
case hardened steels, flame or induction hardened steels		0.0030
through-hardened steels *, yield point $R_e =$	500 N/mm ²	0.0281
	600 N/mm ²	0.0194
	800 N/mm ²	0.0064
	1000 N/mm ²	0.0014
nitrided steels		0.1005
*The given values of ρ' can be interpolated for values of R_e not stated above		

7.2.12 Relative surface factor, $Y_{\text{Rel}T}$

The relative surface factor, $Y_{\text{Rel}T}$, takes into account the dependence of the root strength on the surface condition in the tooth root fillet, mainly the dependence on the peak to valley surface roughness.

The relative surface factor, $Y_{\text{Rel}T}$ is to be determined as defined on the following table:

$R_z < 1$	$1 \leq R_z \leq 40$	Material
1.120	$1.674 - 0.529(R_z + 1)^{0.1}$	case hardened steels, through - hardened steels ($\sigma_B \geq 800$ N/mm ²)
1.070	$5.306 - 4.203(R_z + 1)^{0.01}$	Normalised steels ($\sigma_B < 800$ N/mm ²)
1.025	$4.299 - 3.259(R_z + 1)^{0.0058}$	nitrided steels

Where:

R_z = Mean peak to-valley roughness of tooth root fillets, in μm

σ_B = Tensile strength, in N/mm²

The method applied here is only valid when scratches or similar defects deeper than $2 \cdot R_z$ are not present.

If the roughness stated is an arithmetic mean roughness, i.e. R_a value (= CLA centreline average value) (= AA arithmetic average value) the following approximate relationship can be applied:

$$R_a = \text{CLA} = \text{AA} = R_z/6$$

Table 7.9 Endurance limits for tooth bending stress

σ_{FE}

Material	σ_{FE} N/mm ²
Case hardened carburized CrNiMo steel	
- of ordinary grade	920
- of specially approved high quality grade	1050
Other case hardened (carburized) steels	840
Gas nitrided steels: hardened, tempered and gas nitrided, Surface hardness: 700-850 HV10	920
Through hardened steels: hardened, tempered and gas nitrided, Surface hardness: 500-650 HV10	740
Through hardened steels: hardened, tempered or normalized and nitro-carburized, Surface hardness: 450-650 HV10	780
Flame or induction hardened steels, Surface hardness: 520-620 HV10	0.25-HV10+580
Alloyed through hardening steels, Surface hardness: 195-360 HV10	0.78 HV10+400
Through hardened carbon steels, Surface hardness: 135-210 HV10	0.50-HV10+320
Alloyed cast steels, Surface hardness: 198-358 HV10	0.68 HV10+325
Cast carbon steels, Surface hardness: 135-210 HV10	0.50-HV10+225

7.2.13 Size factor, Y_x

The size factor, Y_x , takes into account the decrease of the strength with increasing size. The size factor mainly

depends on:

- Material and heat treatment;
- Tooth and gear dimensions;
- Ratio of case depth to tooth size.

The size factor, Y_x , is to determined by Table 7.10.

Table 7.10 Size factor Y_x

Case	Condition	Y_x
Generally	$m_n < 5$	1.00
Normalised and through-hardened steels	$5 < m_n < 30$	$1.03 - 0.06 * m_n$
	$m_n \geq 30$	0.85
Surface hardened steels	$5 < m_n < 25$	$1.05 - 0.01 * m_n$
	$m_n \geq 25$	0.80

7.2.14 Safety factor for tooth root bending stress, S_F

The safety factor for tooth root bending stress, S_F , is to be selected from Table 7.1 according to the type of application.

For gearing of duplicated independent propulsion or auxiliary machinery, duplicated beyond that required for class, a reduced value can be assumed by **BCS**

D. Gear Shafts

1. Minimum Diameter

The dimensions of shafts of reversing and reduction gears are to be calculated by applying the following formula.

$$d_a \geq d \geq F k \sqrt[3]{\frac{C_w P/n}{1 - \left(\frac{d_i}{d_a}\right)^4}} \quad (5)$$

where:

d = Minimum required outer diameter of shaft, [mm]

d_a = Actual outer shaft diameter, [mm]

d_i = Actual inner diameter of shaft bore, where present. If the bore in the shaft is $\leq 0.4 d_a$ the expression, [mm]

$$1 - \left(\frac{d_i}{d_a}\right)^4 = 1.0 \quad \text{may be applied}$$

P = Driving power of shaft, [kW]

n = Shaft speed, [min^{-1}]

F = Factor for the type of drive, [-]

= 95 for turbine plants, electrical drives and engines with slip couplings,

= 100 for all other types of drive. **BCS** reserves the right to specify higher F values if this appears necessary in view of the loading of the plant.

C_w = Material factor explained in Section 5, B.1.6 and C.2.1. However, for wheel shafts the value substituted for R_m in the formula shall not be higher than 800 N/mm^2 . For pinion shafts the actual tensile strength value may generally be substituted for R_m . [-],

k = Factor for the type of the shaft [-],

= 1.10 for gear shafts,

= 1.15 for gear shafts in the area of the pinion or wheel body is this is keyed to the shaft and for multiple-spline shafts.

Higher values of k may be specified by **BCS** where increased bending stresses in the shaft are liable to occur because of the bearing arrangement, the casing design, the tooth pressure, etc.

E. Equipment

1. Oil Level Indicator

For monitoring the lubricating oil level in main and auxiliary gears, equipment must be fitted to enable the oil level to be determined.

2. Pressure and Temperature Control

Temperature and pressure gauges are to be fitted to monitor the lubricating oil pressure and the lubricating oil temperature at the oil-cooler outlet before it enters the gears.

Plain journal bearings are also to be fitted with temperature indicators.

Where gears are fitted with anti-friction bearings, a temperature indicator is to be mounted at a suitable point. For gears rated up to 2000 kW, special arrangements may be agreed with **BCS**.

Where ships are equipped with automated machinery, **BCS** Rules Chapter 4 -1 - Automation are to be complied with.

3. Lubricating Oil Pumps

Lubricating oil pumps driven by the gearing must be mounted in such a way that they are accessible and can be replaced.

For the pumps to be fitted, see Section 16, H.3.3.

4. Gear Casings

The casings of gear belonging to the main propulsion and to essential auxiliaries must be fitted with removable inspection covers to enable the toothing to be inspected and the thrust bearing clearance to be measured and the oil sump to be cleaned.

5. Seating of Gears

The seating of gears on steel or cast resin adapters is to conform to the **BCS** 's relevant Rules for seating of the propulsion plants and the auxiliaries.

In the case of cast resin seating, the thrust must be absorbed by means of stoppers. The same applies to cast resin seating of separate thrust bearings.

F. Balancing and Testing

1. Balancing

1.1 Gear wheels, pinions, shafts, gear couplings and, where applicable, high-speed flexible couplings must be assembled in a properly balanced condition.

1.2 The generally permissible residual imbalance U per balancing plane of gears for which static or dynamic balancing is rendered necessary by the method of manufacture and by the operating and loading conditions can be determined by applying the formula:

$$U = 9.6 \frac{Q \cdot G}{z \cdot n} \quad [\text{kgmm}] \quad (6)$$

where;

G = Mass of component to be balanced, [kg]

n = Operating speed of component to be balanced, [min^{-1}]

z = Number of balancing planes, [-]

Q = Degree of balance, [-]

= 6.3

for gear shafts, pinions and coupling members for engine gears,

= 2.5

for torsion shafts and couplings, pinions and gear wheels belonging to turbine transmissions.

2. Testing of Gears

2.1 Testing in the manufacturer's works

When the testing of materials and component tests

have been carried out, gearing systems for the main propulsion plant and for important auxiliaries in accordance with Section 1, D.8 are to be presented to **BCS** for final inspection and operational testing in the manufacturer's works. The final inspection is to be combined with a trial run lasting several hours under part or full -load conditions, on which occasion the tooth clearance and contact pattern of tooting are to be checked. In the case of a trial at full -load, any necessary running -in of the gears must have been completed

beforehand. Where no test facilities are available for the operational and on-load testing of large gear trains, these tests may also be performed on board ship on the occasion of the dock trials.

Tightness tests are to be performed on those components to which such testing is appropriate.

Reductions in the scope of the tests require the consent of **BCS**.

2.2 Tests during sea trials

2.2.1 Priority at sea trials, the teeth of gears belonging to the main propulsion plant are to be coloured with suitable dye to enable the contact pattern to be established. During the sea trials, the gears are to be checked at all forward and reverse speeds to establish their operational efficiency and smooth running as well as the bearing temperatures and the pureness or the contamination of lubricating oil. On conclusion of the sea trials, the gearing is to be examined via the inspection openings and the contact pattern checked. If possible the contact pattern should be checked after conclusion of every load step. Assessment of the contact pattern is to be based on the guide values for the proportional area of contact in the axial and radial directions of the teeth given in Table 7.11 and shall take account of the running time and loading of the gears during the sea trial.

2.2.2 In the case of multistage gear trains and planetary gears manufactured to a proven high degree of accuracy, checking of the contact pattern after sea

trials may, with the consent of **BCS**, be reduced in scope.

Table 7.11 Percentage area of contact

Material / manufacturing of teeth	Working depth (without tip relief)	Width of tooth (without end relief)
heat-treated, hobbled, formed by generating method	33% average values	70%
surface-hardened, ground, shaved	40% average values	80%

2.2.3 For checking the gears of rudder propellers as main propulsion, see Section 9, B.

G. Design and Construction of Couplings

1. Tooth Couplings

1.1 Adequate loading capacity of the tooth flanks of straight-flanked tooth couplings requires that the following conditions be satisfied:

$$p = 2.55 \cdot 10^7 \frac{P \cdot K_A}{b \cdot h \cdot d \cdot z \cdot n} \leq p_{\text{perm}} \quad (7)$$

$$\text{for } \frac{10^{15} P}{n^3 d_m^2 G_K} \geq 4.5 \quad (8)$$

(Values close to 4.5 only with high manufacturing accuracy and little residual imbalance)

Where methods of calculation recognized by **BCS** are used for determining the Hertzian pressure on the flanks of tooth couplings with convex tooth flanks, the permissible Hertzian pressures are equal to 75% of the values of σ_{HP} shown in C.6.3 with influence factors Z_{NT} to Z_X set to 1.0:

p = Actual contact pressure or loading capacity of the tooth flanks, [N/mm²]

P = Driving power at coupling, [kW]

d	=	Pitch circle diameter, [mm]
K_A	=	Application factor in accordance with C.5.1, [-]
Z	=	Number of teeth, [-]
n	=	Speed, [min ⁻¹]
h	=	Working depth of teeth, [mm]
b	=	Load-bearing tooth width, [mm]
d_m	=	Diameter of gyration, [mm]
G_K	=	Mass of coupling sleeve, [kg]
σ_{HP}	=	Permissible Hertzian pressure according to C.6.3. [N/mm ²]
p_{perm}	=	400-600 for the toothing made of quenched and tempered steel; Higher values apply to high strength steels with superior tooth manufacturing and surface finish quality. [N/mm ²]
	=	800-1000 for the toothing made of hardened steel (case or nitrogenised) Higher values apply for superior tooth manufacturing and surface finish quality.
	=	$0.7 \cdot R_{eH}$ for ductile steel.
	=	$0.7 \cdot R_m$ for brittle steel.

1.2 The coupling teeth are to be effectively lubricated. For this purpose a constant oil level maintained in the coupling may generally be regarded as adequate where;

$$d \cdot n^2 < 6.0 \cdot 10^9 \quad [\text{mm/min}^2] \quad (9)$$

For higher values of $(d \cdot n^2)$, couplings in main propulsion plants are to be provided with a circulating lubrication oil system.

1.3 For the dimensional design of the coupling sleeves, flanges and bolts of tooth couplings, the formulae given in Section 5 are to be applied.

2. Flexible Couplings

2.1 Flexible couplings must be approved for the loads specified by the manufacturer and for use in main propulsion plants and essential auxiliary machinery. In general, the flexible couplings are to be type approved. For the further detailed requirements for type approvals of flexible couplings are defined by Regulations for the Performance of the Type Tests Part 7 – Test Requirements for Mechanical Components and Equipment.

2.2 Flexible couplings in the main propulsion plant and power-generating plants must be so dimensioned that they are able to withstand for a reasonable time operation with one engine cylinder out of service, see Section 16, C.6.3. Additional dynamic loads for ships with ice classes are to be taken into account. In this connection reference is made to Section 19.

2.3 With regard to the routine supervision of coupling types already approved by **BCS** and in order to prove adequate dynamic fatigue strength prior to the issue of a general type approval for flexible couplings to be introduced into shipbuilding for the first time, **BCS** reserves the right to call for the execution of special dynamic loading tests appropriate to the design of the coupling in question.

2.4 With regard to the casings, flanges and bolts of flexible couplings, the requirements specified in Section 5, D are to be complied with.

2.5 If a flexible coupling is so designed that it exerts an axial thrust on the coupled members of the driving mechanism, provision must be made for the absorption of this thrust. If torsional limit devices are applicable, the functionality shall be verified.

2.6 Flexible couplings for diesel generator sets must be capable of absorbing impact moments due to electrical short circuits up to a value of 6 times the nominal torque of the coupling.

2.7 The flexible element of rubber couplings shall be so designed that the average shear stress in the rubber/metal bonding surface relating to T_{KN} does not exceed a value of 0.5 N/mm².

2.8 For the shear stress within the rubber element due to T_{KN} it is recommended not to exceed a value subjected to the Shore hardness according to Table 7.12.

Higher values can be accepted if appropriate strengths of rubber materials have been documented by means of relevant tests and calculations.

Table 7.12 Limits of shear stress

Shore hardness (-)	Limits of shear stress (N/mm ²)
40	0.4
50	0.5
60	0.6
70	0.7

For special materials, e.g. silicon, corresponding limit values shall be derived by experiments and experiences.

3. Flange and Clamp-Type Couplings

In the dimensional design of the coupling bodies, flanges and bolts of flange and clamp-type couplings, the requirements specified in Section 5 are to be complied with.

4. Clutches

4.1 Definition and application

Clutches are couplings which can be engaged and disengaged mechanically, hydraulically or pneumatically.

The following requirements apply for their use in shaft lines and as integrated part of gear boxes.

Clutches intended for trolling operation are subject to special consideration.

4.2 Materials

The mechanical characteristics of materials used for the

elements of the clutch shall conform to the **BCS** Rules Chapter 2 - Material.

4.3 Design requirements

4.3.1 Safety factors

For the connections to the shafts on both sides of the clutch and all torque transmitting parts the requirements of Section 5 have to be considered. The mechanical part of the clutch may be of multiple disc type. All components shall be designed for static loads with a friction safety factor between 1.8 and 2.5 in relation to the nominal torque of the driving plant.

A dynamic switchable torque during engaging of 1.3 times the nominal torque of the driving plant has generally to be considered. In case of combined multiple engine plants the actual torque requirements will be specially considered.

4.3.2 Ice class

For clutches used for the propulsion of ships with ice class the reinforcements defined in Section 19, C.1 have to be considered.

4.3.3 The multiple disc package shall be kept free of external axial forces.

4.3.4 Measures for a controlled switching of the coupling and an adequate cooling in all working conditions have to be provided.

4.3.5 Auxiliary systems for engaging/disengaging

If hydraulic or pneumatic systems are used to engage/disengage a clutch within the propulsion system of a ship with single propulsion plant an emergency operation shall be possible. This may be done by a redundant power system for engagement/ disengagement or in a mechanical way, e.g. by installing connecting bolts. For built-in clutches this would mean that normally the connecting bolts shall be installed on the side of the driving plant equipped with turning facilities.

The procedure to establish emergency service has to be described in the operating manual of the clutch and has to be executed in a reasonable time.

5. Testing of Clutches and Couplings

Couplings for ship's propulsion plants and couplings for generator sets and transverse thrusters are to be presented to the **BCS** for final inspection and , where appropriate , for the performance of functional and tightness tests.

If a type approval is requested, the requirements will be defined on a case by case basis by **BCS**.

For single approvals, the scope of tests may be reduced by agreement with **BCS**.

As part of the sea trials, the installed clutches and couplings shall be tested for correct functioning on board in presence of a **BCS** Surveyor , according to the Additional Rules and Guidelines.

6. Controls and Alarms

Local operation of remotely controlled clutches for the propulsion plants shall be possible.

The pressure of the clutch activating medium has to be indicated locally. Alarms according to the **BCS** Rules of Automation have to be provided.

SECTION 8

PROPELLERS

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A. General

projected blade outline. (See Figure 8.1)

1. Scope

These requirements apply to propellers intended for propulsion. It covers fixed pitch and controllable pitch propeller. Performance of propellers, intending to improve the designed output, is to be demonstrated during sea trials. Additional requirements dealing with the technical and material properties for propellers intended for ships strengthened for navigation in ice are provided in Section 19.

- Skewed propeller : Skewed propellers are propellers whose blades have a skew angle other than zero.

- Highly skewed propeller : A highly skewed propeller is one whose skew angle is more than 25°.

- Rake : Propeller rake (e) is the horizontal distance between the line connecting the blade tip to the blade root and the vertical line crossing the propeller axis in the same point where the prolongation of the first line crosses it, taken in correspondence of the blade tip (see Figure 8.2). Aft rakes are considered positive, fore rakes are considered negative.

2. Definitions

Basic concept and definitions applied in this section are described in following items:

- Fixed (solid) pitch propeller, FPP : A fixed (solid) pitch propeller is a propeller (including hub and blades) cast in one piece.

- Built-up propeller : A built-up propeller is a propeller cast in more than one piece. In general, built up propellers have the blades cast separately and fixed to the hub by a system of bolts and studs.

- Controllable pitch propeller, CPP : Controllable pitch propellers are built-up propellers which include in the hub a mechanism to rotate the blades in order to have the possibility of controlling the propeller pitch in different service conditions.

- Nozzle : A nozzle is a circular structural casing enclosing the propeller.

- Ducted propeller : A ducted propeller is a propeller installed in a nozzle.

- Skew angle : Skew angle (ψ) of a propeller is the angle measured from ray "I" passing through the tip of blade at mid-chord line to ray "II" tangent to the mid-chord line on the

- Rake angle : Rake angle (ϵ) is the angle measured from the plane perpendicular to shaft centreline to the tangent to the generating line at a specified radius (propeller shaft line for the purpose of this section, see Figure 8.2).

- Leading angle : The leading edge of a propeller blade is the edge of the blade at side entering the water while the propeller rotates.

- Trailing angle : The trailing edge of a propeller blade is the edge of the blade opposite the leading edge.

- Blade developed area : Blade developed area is the area of the blade surface expanded in one plane.

- Developed area ratio : Developed area ratio is the ratio of the total blade developed area to the area of the ring included between the propeller diameter and the hub diameter.

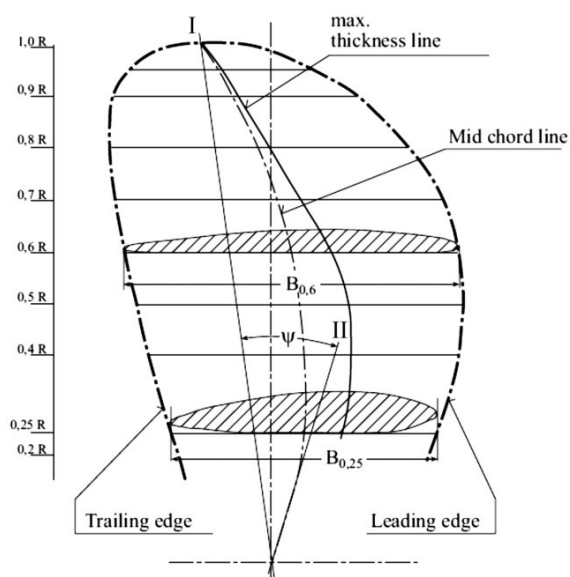


Figure 8.1 Blade sections and maximum skew angle

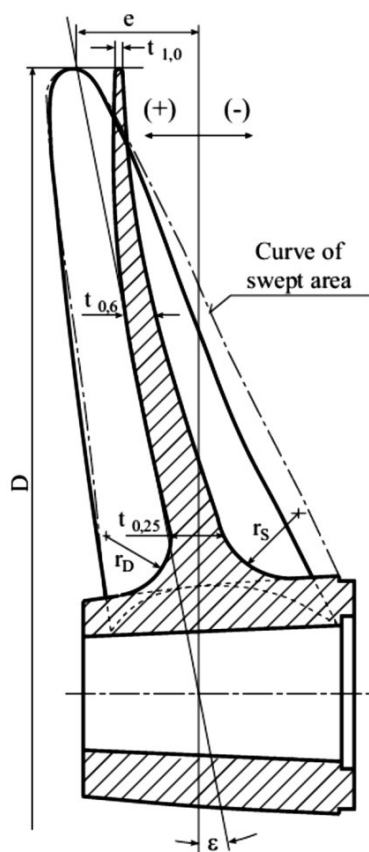


Figure 8.2 Rake and rake angle

3. Documents for Approval

3.1 Design drawings, plans and particulars of propellers in main propulsion systems having an engine output of in excess of 300 kW and in transverse thrust systems of over 500 kW, are to be submitted to **BCS** in triplicate for examination. The drawings are required to

contain all the details necessary to carry out an examination in accordance with the following requirements.

3.2 In case of a conventional fixed pitch propeller application, the following items shall be provided to **BCS** for approval:

- Material properties of propeller,
- Design characteristics of propeller, rating (power, rpm etc),
- Dimensions, allowable tolerances, blade and hub details,
- Propeller drawing plans, sectional assembly,
- Blade thickness calculations,
- Data and procedures for fitting propeller to the shaft.

The manufacturing tolerance class (ISO 484) shall be specified on the propeller drawings.

3.3 In case of controllable pitch propeller systems, general drawings and sectional drawings are to be submitted in triplicate in addition to the design drawings for blade, boss and pitch control mechanism.

Documents submitted to **BCS** for approval about controllable pitch propellers are itemized as follows:

- Same documents requested for fixed propellers,
- Hub and hub to tail shaft flange attachment bolts,
- Propeller blade flange, bolts and pre-tensioning procedures,
- Internal mechanism,
- Pitch corresponding to maximum propeller thrust and to normal service condition,

- Hydraulic piping control system (control and hydraulic diagrams are to be attached to a description of the functional characteristics)
- Instrumentation and alarm system,
- Strength calculations for internal mechanism.

In the case of new designs or controllable pitch propeller systems which are being installed for the first time on vessel with the **BCS** classification, a description of the controllable pitch propeller system is also to be provided.

3.4 When highly skewed propeller application or any other unconventional designs are in question, **BCS** guards further requirements including a detailed hydrodynamic load and stress analysis in addition to the foregoing. Where propeller blade designs are of the types for which the requirements do not provide simplified blade thickness calculations, such as

- Highly skewed propeller with $\psi > 50^\circ$;
- Highly skewed propellers not made of nickel-aluminium-bronze material with $25^\circ < \psi \leq 50^\circ$;
- Controllable pitch propellers with $\psi > 25^\circ$;
- Cycloidal propellers;

propeller load and stress analyses demonstrating adequacy of blade strength are to be submitted.

3.5 Where propellers are to be fitted to the shaft without keys, stress calculations for hub stresses and holding capacity, along with fitting instructions, are to be submitted to **BCS**.

B. Materials

1. Normally used materials for propeller blades and hubs

Table 8.1 shows the properties of materials normally used for propellers. If an alternative material

specification is proposed, the detailed chemical composition and mechanical properties shall be submitted to **BCS** for approval.

Propellers and vane wheels are to be made of seawater-resistant cast copper alloys or cast steel alloys with a minimum tensile strength of 440 N/mm², according to the **BCS** Rules for Materials and Welding.

Table 8.1 Tensile strength of materials, C_w

Material	Description (1)	C _w N/mm ²
Cu 1	Cast manganese bronze	440
Cu 2	Cast nickel manganese bronze	440
Cu 3	Cast nickel aluminium bronze	590
Cu 4	Cast manganese aluminium bronze	630
Fe 1	Unalloyed cast steel	440
Fe 2	Low-alloy cast steel	440
Fe 3	Martensitic cast chrome steel 13/1-6	600
Fe 4	Martensitic-austenitic cast steel 17/4	600
Fe 5	Ferritic-austenitic cast steel 24/8	600
Fe 6	Austenitic cast steel 18/8-11	500
(1) For the chemical composition of the alloys, see the <i>BCS's Rules for Materials and Welding</i> .		

For the purpose of the following design requirements governing the thickness of the propeller blades, the requisite resistance to seawater of a cast copper alloy or cast steel alloy is considered to be achieved if the alloy used is capable to withstand a fatigue test under alternating bending stresses comprising 10⁸ load cycles amounting to about 20% of the minimum tensile strength and carried out in a 3% NaCl solution, and proved that the fatigue strength under alternating bending stresses in natural seawater can be proven to be not less than about 65% of the values established in 3% NaCl solution. Sufficient fatigue strength under alternating bending stresses must be proved by a method recognized by **BCS**.

2. Materials for the Stud Components of CPP and Assembled FPP

In general, steel (preferably nickel-steel) is to be used for manufacturing the studs connecting steel blades to the hub of built-up or controllable pitch propellers, and

high tensile brass or stainless steel is to be used for studs connecting bronze blades

The material of the studs securing detachable blades to the hub is to be of at least Grade 2 forged steel or equally satisfactory materials which should comply with the **BCS** regulations pertaining to metal materials , (see **BCS** Rules Chapter 2 - Material.)

The blade retaining bolts of assembled fixed propellers or controllable pitch propellers are to be made of seawater-resistant materials, if they are not protected against contact with seawater.

3. Novel Materials

Where propeller materials with not sufficient experience for their reliability are applied, the suitability has to be proven particularly to **BCS** and the detailed chemical composition and mechanical properties are to be submitted for approval.

4. Material Testing

The material of propellers, vane wheels, propeller bosses and all essential components involved in the transmission of torque is to be tested in accordance with **BCS** Material and Welding regulations. This also applies to components which are used to control the blades and also to propellers in main propulsion systems with less than 300 kW power and transverse thrust systems of less than 500 kW power.

C. Dimensions and Design of Propellers

1. Symbols and Terms

A = Effective area of a shrink fit, [mm²]

A_s = Shear area of key, [mm²]

B = Developed blade width of cylindrical sections at radii 0.25R, 0.35R and 0.6R in an expanded view, [mm]

C_G = Size factor in accordance with formula (2), [-]

C_{Dyn} = Dynamic factor in accordance with formula (3), [-]

C_w = Characteristic value for propeller material as shown in Table 8.1, corresponds to the minimum tensile strength R_m of the propeller material where sufficient fatigue strength under alternating bending stresses in accordance with item B.1 is proven. [-]

d = Pitch circle diameter of blade or propeller-fastening bolts, [mm]

d_k = Shaft diameter at mid-length of key, [mm]

d_r = Root diameter of blade or propeller-fastening bolts, [mm]

d_s = Line shaft diameter, [mm] D

= Diameter of propeller, [mm]

= 2·R

e = Blade rake to aft according to Fig. 8.2,

= R·tan(ε) [mm]

E_T = Thrust stimulating factor in accordance with formula (5), [-]

f₁, f₂, f₃ = Factors in formulas (2), (3), (4), [-]

f₁ = 7.2 for solid propellers,

= 6.2 for separately cast blades of variable-pitch or built-up propellers,

f₂ = 0.4~0.6 for single-screw ships, the lower value applying to stern shapes with a wide propeller tip clearance and no rudder heel, and the larger value to sterns with little clearance and with rudder heel. Intermediate values are to be selected accordingly,

	= 0.2 for twin-screw ships,	T	= Rated propeller thrust, [N]
f_3	= 0.2 for propeller materials which satisfy the requirements of B.1,	T_M	= Impact moment, [Nm]
H	= Pitch of propeller blade at radii 0.25R, 0.35R and 0.6R, [mm]	V_S	= Speed of ship, [kn]
H_m	= Mean effective pitch of propeller blade for pitch varying with the radius, [mm]	w	= Wake factor, [-]
	$= \frac{\sum(R \cdot B \cdot H)}{\sum(R \cdot B)}$	$W_{0.35R}$	= Section modulus of cylindrical section at 0.35R, [mm ³]
	in which R, B and H are corresponding measures of the various sections.	$W_{0.6R}$	= Section modulus of cylindrical section at 0.6R, [mm ³]
k	= Coefficient for various profile shapes in accordance with Table 8.2, [-]	Z	= Total number of bolts used to retain one blade or propeller, [-]
L_M	= 2/3 of the leading edge part of the blade width at 0.9R, but at least 1/4 of the total blade width at 0.9R for propellers with high skew blades. [mm]	z	= Number of blades, [-]
M	= Rated torque transmitted according to rated nominal power of driving engine P_w and speed of propeller shaft, n_2 [Nm]	α	= Pitch angle of profile at radii 0.25R, 0.35R and 0.6R, [°]
n_2	= Propeller speed at rated power, [min ⁻¹]		$\alpha_{0.25} = \arctan \left(\frac{1.27 \cdot H}{D} \right)$
P_w	= Nominal power of driving engine, [kW]		$\alpha_{0.35} = \arctan \left(\frac{0.91 \cdot H}{D} \right)$
R_{eH}	= Yield strength, [N/mm ²]		$\alpha_{0.6} = \arctan \left(\frac{0.53 \cdot H}{D} \right)$
R_{eHs}	= Specified yield strength of shaft material, [N/mm ²]	α_A	= Tightening factor for retaining bolts depending on the method of tightening used (see VDI 2230 or equivalent standards)
R_{eHk}	= Specified yield strength of key material, [N/mm ²]		Guidance values;
$R_{p0.2}$	= 0.2% proof stress of propeller material, [N/mm ²]		= 1.2 for angle control
t_b	= Maximum blade thickness of developed cylindrical section at radii 0.25R ($t_{0.25}$), 0.35R ($t_{0.35}$) and 0.6R ($t_{0.6}$), [mm]		= 1.3 for bolt elongation control
		ε	= Angle included by face generatrix and normal, [°]
		Ψ	= Skew angle according to Fig. 8.1, [°]
		σ_{max}/σ_m	= Ratio of maximum to mean stress at side of blade face. [-]

Table 8.2 Values of “k” for various profile shapes

Profile shape	Values of k		
	0.25R	0.35R	0.6R
Segmental profiles with circular arced suction side,	73	62	44
Segmental profiles with parabolic suction side,	77	66	47
Blade profiles as for Wageningen B series propellers	80	66	44

Table 8.3 Material constants according to BCS- R K3

Material	Elasticity modulus	Poisson's Ratio	Expansion coefficient
	E [kgf/mm ²]	ν [–]	α [mm/mm°C]
Cast and forged steel	2.1x10 ⁴	0.29	12.0x10 ⁻⁶
Cast iron	1.0x10 ⁴	0.26	12.0x10 ⁻⁶
Cu 1	1.1x10 ⁴	0.33	17.5x10 ⁻⁶
Cu 2	1.1x10 ⁴	0.33	17.5x10 ⁻⁶
Cu 3	1.2x10 ⁴	0.33	17.5x10 ⁻⁶
Cu 4	1.2x10 ⁴	0.33	17.5x10 ⁻⁶
<i>Note: For austenitic stainless steel see manufacturer's specification.</i>			

2. Calculation of Blade Thickness

2.1 At radii 0.25R ($t_{0.25}$) and 0.6R ($t_{0.6}$), the maximum blade thicknesses of solid propellers must, as a minimum requirement, comply with formula (1).

$$t_b \geq K_o \cdot k \cdot K_1 \cdot C_G \cdot C_{Dyn} \quad (1)$$

Where the size factor C_G should satisfy the following condition:

$$0.85 \leq \left\{ C_G = \sqrt{\frac{f_1 + \frac{D}{1000}}{12.2}} \right\} \leq 1.1 \quad (2)$$

$$K_o = 1 + \frac{e \cdot \cos(\alpha)}{H} + \frac{n_2}{15000}$$

Specific values of k for several profile shapes are shown in Table 8.2

$$K_1 = \sqrt{\frac{10^{-5} \cdot P_w \cdot \left[2 \cdot \left(\frac{D}{H_m} \right) \cdot \cos(\alpha) + \sin(\alpha) \right]}{n_2 \cdot B \cdot Z \cdot C_w \cdot \cos^2(\epsilon)}}$$

If $\frac{\sigma_{max}}{\sigma_m} > 1.5$ then the dynamic factor C_{Dyn} should satisfy the following condition:

$$\left\{ C_{Dyn} = \sqrt{\frac{\left(\frac{\sigma_{max}}{\sigma_m} - 1 \right) + f_3}{0.5 + f_3}} \right\} \geq 1.0 \quad (3) \quad (3)$$

else $C_{Dyn} = 1.0$

σ_{max}/σ_m is generally to be taken from the detailed calculation according to 2.5. If, in exceptional cases, no such calculation exists, the stress ratio, σ_{max}/σ_m , may be calculated approximately according to formula (4)

$$\frac{\sigma_{max}}{\sigma_m} = 1 + f_2 \cdot E_T \quad (4)$$

$$E_T = \frac{4.3 \cdot 10^{-9} \cdot V \cdot n_2 \cdot (1-w) \cdot D^3}{T} \quad (5)$$

2.2 The blade thickness of controllable pitch propellers are to be determined at radii 0.35R and 0.6R by applying formula (1).

For the controllable pitch propellers of tugs, trawlers as well as special-duty ships with similar operating conditions, the diameter/pitch ratio D/H_m for the maximum bollard pull is to be used in formula (1).

For other ships, the diameter/pitch ratio D/H_m applicable to open-water navigation at maximum engine power (MCR) can be used in formula (1).

2.3 The blade thicknesses calculated by applying formula (1) are the lowest acceptable values for the finish-machined propellers or for the propeller processed by CNC-Computer Numerical Control Machine.

2.4 The fillet radii at the transition from the face (pressure side) and the back (suction side) of the blades to the propeller boss should correspond, in the case of three and four-bladed propellers, to about 3.5% of the propeller diameter. For propellers with a larger number of blades, the maximum fillet radii should be aimed at, but the radii shall not in any case be chosen than %40 of the blade root thickness, $0.4 \cdot t_{0.25}$.

Designs applying variable fillet radii, aiming to achieve a uniform stress distribution, may be accepted if an adequate proof of stress calculation is given case by case. The resulting calculated maximum stress shall not exceed the values, occurring from a design with constant fillet radius in accordance to the first paragraph of 2.4.

2.5 For special designs such as propellers with skew angle $\Psi \geq 25^\circ$, end plate propellers, tip fin propellers, special profiles etc, special mechanical strength calculations are to be submitted to **BCS**.

Furthermore, for re-calculation of the blade stress of these special propeller designs, a complete file about blade geometry data and the details on the measured wake field shall be submitted to **BCS** together with the design documentation. All the data and measurements shall be supplied in as compact as to be used in computers.

Supplementary information can be requested by **BCS** for approval.

Note: A safety factor of $\geq 8,0$ with respect to the ultimate tensile strength of the propeller material R_m can be used.

2.6 If the propeller is subjected to an essential wear due to special operational conditions, e.g. abrasion in tidal flats or dredgers, the thickness determined in 2.1 has to be increased to ensure an adequate life time. If the actual thickness in service drops below 50% at the blade tip or 90% at other radii of the rule thickness obtained from 2.1, effective

counter measurements have to be taken, respectively. For unconventional blade geometries as defined in 2.5, the design thickness on the approved drawings shall be replaced by the thickness requested in 2.1.

3. Design of the propellers

3.1 The propeller has to be protected against to the electro-chemical corrosion according to the requirements in **BCS** Rules Chapter 1 - Hull, Section 22.

D. Controllable Pitch Propeller

1. Hydraulic Control Equipment

Where the pitch-control mechanism is operated hydraulically, two mutually independent, power-driven pump sets are to be installed. For propulsion plants up to 200 kW, one power-driven pump set is sufficient provided that, in addition, a hand-operated pump is provided, capable for controlling the blade pitch and being the blades to be moved from the ahead to the astern position in a duration as short as possible for safe manoeuvring.

The selection and arrangement of filters must ensure an uninterrupted supply with filtered oil, also during filter cleaning or exchange. In general, main filters are to be arranged on the pressure side directly after the pump. An additional coarse filtration of the hydraulic oil at the suction side of pump should be provided.

Section 16, A. to D. is to be applied in an analogous manner to hydraulic pipes and pumps.

2. Pitch control mechanism

For the pitch-control mechanism, proof is required that, when subjected to impact moments T_M as defined by formula (6), the individual components still have a safety factor of 1.5 with respect to the yield strength of the materials used. The resulting equivalent stresses at the different components are to be compared with their yield strength.

$$T_M = \frac{1.5 \cdot R_{P0.2} \cdot W_{0.6R}}{\sqrt{\left(\frac{0.15 \cdot D}{L_M}\right)^2 + 0.75}} \quad (6)(6)$$

$W_{0.6R}$ can be calculated by applying formula (7).

$$W_{0.6R} = 0.11 \cdot B \cdot t_{b,0.6R} \quad (7)(7)$$

3. Blade Retaining Bolts

3.1 The blade retaining bolts shall be designed in such a way as to safely withstand the forces induced in the event of plastic deformation at 0.35R caused by force acting on the blade at 0.9R. At this occasion, the bolt material shall have at least a safety margin of 1.5 against the yield strength.

The thread core diameter of the blade retaining bolts shall not be less than

$$d_r = 2.6 \sqrt{\frac{M_{0.35R} \cdot \alpha_A}{d \cdot Z \cdot R_{eH}}} \quad (8)(8)$$

$$M_{0.35R} = W_{0.35R} \cdot R_{P0.2}$$

$W_{0.35R}$ may be calculated analogously the formula (7) or (9).

For nearly elliptically sections at the root area of the blade, the following formula may be used instead:

$$W_{0.35R} = 0.10 \cdot (B \cdot t_{b,0.35R}^2) \quad (9)(9)$$

3.2 The blade retaining bolts are to be tightened in a controlled manner in such a way that the initial tension on the bolts is about 60~70% of their yield strength.

The shank of blade retaining bolts may be reduced to not less than 0.9 times the root diameter of the threaded part.

3.3 Blade retaining bolts must be secured against unintentional loosening.

4. Indicators

4.1 Controllable pitch propeller systems are to be provided with a direct acting indicator at engine room showing the actual setting of the blades. Further blade position indicators are to be mounted on the bridge and in the engine room (see also Chapter 4-1 - Automation, and Chapter 5 - Electrical Installations).

4.2 Hydraulic pitch control systems are to be provided with means to monitor the oil level. For controlling the propeller pitch position, an oil pressure gauge is to be fitted onto system. A suitable indicator for filter clogging must be provided. An oil temperature indicator is to be fitted at a suitable position.

Where ships are equipped with automated machinery, the requirements of Chapter 4-1 - Automation are to be compiled with.

5. Failure of the Control System

Suitable devices are to be fitted to ensure that an alteration of the blade setting cannot overload the propulsion plant or cause it to stall.

Steps must taken to ensure that, in the event of failure of the control system, the setting of the blades

- Does not change or
- Drifts to a final position slowly enough to allow the emergency control system to be put into operation.

6. Emergency Control

Controllable pitch propeller systems must be equipped with means of emergency control enabling the controllable pitch propeller to remain in operation in any failure case of the remote control system. It is recommended to provide a device enabling the propeller blades to be locked in the "ahead" setting position.

E. Propeller Mounting

1. General

Screw propeller hubs are to be properly adjusted and fitted on the propeller shaft cone.

The forward end of the hole in the hub is to have the edge rounded to a radius of approximately 6 mm.

In order to prevent any entry of sea water under the liner and onto the end of the propeller shaft, the suitable arrangements under supervision of **BCS** surveyor are to be adopted for assembling the liner and propeller boss.

The external stuffing gland is to be provided with a seawater resistant rubber ring preferably without joints. The clearance between the liner and the internal air space of the boss is to be as small as possible. The internal air space is to be filled with an appropriate protective material which is insoluble in sea water and non-corrodible or fitted with a rubber ring.

All free spaces between the propeller shaft cone, propeller boss, nut and propeller cap are to be filled with a material which is insoluble in sea water and non-corrodible. Arrangements are to be made to allow any air present in these spaces to withdraw at the moment of filling. It is recommended that these spaces be tested under a pressure at least equal to that corresponding to the immersion of the propeller in order to check the tightness obtained after filling.

2. Tapered (Cone) Mountings

2.1 Keyed fitting

Where the tapered joint between the shaft and the propeller is fitted with a key, the propeller is to be mounted on the tapered shaft in such a way that approximately 120% of the mean torque can be transmitted from the shaft to the propeller by friction.

Keyed connections are in general not to be used in installations with a barred speed range.

For shape of keyway in the shaft and size of the key, see Section 5, Figure 5.1.

In general, the key material is to be of equal or higher strength than the shaft material. The effective area of the key in shear is to be not less than A_s , given below. The effective area is to be the gross area subtracted by materials removed by saw cuts, set screw holes, chamfer, etc., and is to exclude the portion of the key in way of spooning of the key way.

It should be noted that the keyways are, in general, not to be used in installations with slow speed, crosshead or two-stroke engines with a barred speed range.

$$A_s = \frac{d_s^3 R}{2.55 \cdot d_k R_{eHk}} \quad (10)$$

For symbols or terms see C.1.

2.2 Keyless fitting

2.2.1 Symbols and Terms

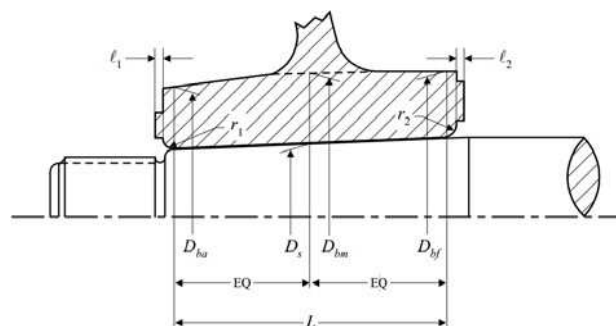


Figure 8.3 Theoretical Contact Surface Between Hub and Shaft

A = 100% theoretical contact area (mm²) between boss and shaft, as read from drawings and disregarding oil grooves

$$= \pi \cdot D_s \cdot L$$

C = Conicity of shaft ends, [-]

$$= \frac{\text{difference in taper diameter}}{\text{length of taper}}$$

D_b	= Mean outer diameter of propeller hub corresponding to D_s ; mm (in.) D_b is to M_{be} calculated as the mean of D_{bm} , D_{bf} and D_{ba} , outer diameters of hub corresponding to D_s , the forward point of contact and the aft point of contact, respectively, see Figure 8.3	H	= Rated brake horsepower (PS)
D_b	= $(D_{ba}+D_{bm}+D_{bf}) / 3$	N	= Propeller speed (r.p.m.) at rated brake horsepower
D_{bm}	= Mean outer diameter of propeller boss, in mm (in.), at the axial position corresponding to D_s , see Figure 8.3.	P	= Mean propeller pitch (mm)
D_s	= Diameter of shaft at mid-point of the taper in axial direction; mm (in.), taking into account the exclusion of forward and aft counterbore length and the forward and aft edge radii, see Figure 8.3.	P_{35}	= Surface pressure (kgf/mm ²) between mating surfaces at 35°C
K	= D_b/D_s	P_t	= Surface pressure (kgf/mm ²) between mating surfaces at temperature t°C
E_b	= Modulus of elasticity (kgf/mm ²) of boss material (see Table 8.3)	P_0	= Surface pressure (kgf/mm ²) between mating surfaces at temperature 0°C
E_s	= Modulus of elasticity (kgf/mm ²) of shaft material (see Table 8.3)	P_{max}	= Maximum allowable surface pressure (kgf/mm ²) at 0°C
F_v	= Shear force at interface = $2cQ/D_s$ (kgf)	S	= Factor of safety against friction slip at 35°C
Q	= Rated torque (kgf•mm) transmitted according to rated horsepower, H , and speed of propeller shaft	θ	= Half taper of propeller shaft (C/2), (e.g. taper (C) = 1/15, θ = 1/30).
c	= Constant, $c = 1,0$ for turbines, geared diesel drives, electric drives and for direct diesel drives with a hydraulic or an electromagnetic or high elasticity coupling $c = 1,2$ for a direct diesel drive. The Classification Society reserves the right to increase the c constant if the shrinkage has to absorb an extreme high pulsating torque.	μ	= Coefficient of friction between mating surfaces
		t	= The temperature at which the propeller is mounted, [°C]
		T	= Rated thrust (kgf)
		V_s	= Ship speed (knots) at rated horsepower
		W_t	= Push-up load (kgf) at temperature t°C
		δ	= Pull-up length of propeller on taper, (mm)
		δ_{35}	= Pull-up length (mm) at temperature 35°C
		δ_t	= Pull-up length (mm) at temperature t°C

δ_{\max}	= Maximum allowable pull-up length (mm) at temperature 0°C
σ_E	= Equivalent uniaxial stress (kgf/mm ²) in the boss according to the Mises-Hencky criterion
α_s	= Coefficient of linear expansion (mm/mm°C) of shaft material (see Table 8.3)
α_b	= Coefficient of linear expansion (mm/mm°C) of boss material (see Table 8.3)
ν_s	= Poisson's ratio for shaft material
ν_b	= Poisson's ratio for boss material
σ_y	= Yield point or 0,2% proof stress (0,2% offset yield strength) of propeller material (kgf/mm ²)

Where the connection between propeller shaft cone and propeller is realised by hydraulic oil technique without the use of a key, the taper of propeller shaft cone shall not exceed 1/15.

The formulas, etc., given herein are not applicable for propellers where a sleeve is introduced between shaft and boss.

The factor of safety against (s) slip of the propeller hub on the tail shaft taper at 35°C is to be at least 2.8 under the action of maximum continuous ahead rated torque due to the torsional vibrations.

For oil injection method of fit, the coefficient (μ) of friction shall be less equal than 0.13 for bronze-steel propeller hubs on steel shafts and for the bosses made in copper-based alloy and steel, 0.15 for dry fitted shrink joints bronze/steel, 0.18 for dry fitted shrink joints steel/steel.

The maximum equivalent uni-axial stress in the boss at 0°C based on the Von Mises-Hencky criterion (σ_E) should not exceed 70% of the yield point or 0.2% proof-

stress (0.2% offset yield strength) for the propeller material based on the test piece value. For the cast iron materials, the mentioned value should not exceed 30% of the nominal tensile strength.

Stress calculations and fitting information shall be submitted to **BCS** and should include at least the following items:

- Theoretical contact surface area,
- The maximum permissible pull-up length at 0°C as limited by the maximum permissible uni-axial stress specified above,
-
- The minimum pull-up length and contact pressure at 35°C to attain a safety factor against slip of 2.8,
- The safety factor of against to the friction slip at 35°C is not to be less than 2.8 under the action of rated torque (based on rated power, rpm) plus torque due to the torsional vibrations.
- The proposed pull-up length and contact pressure at fitting temperature,
- The rated propeller ahead thrust.

Prior to final pull-up, the contact area between the mating surfaces is to be checked and should not be less than 70% of the theoretical contact area (100%). Non-contact bands extending circumferentially around the boss or over the full length of the boss are not acceptable.

After final pull-up, the propeller is to be secured by a nut on the propeller shaft. The nut should be secured to the shaft.

The formulae given below, for the ahead condition, will also give sufficient safety in the astern condition.

The formulae are applicable for solid shafts only.

The minimum mating surface pressure "P₃₅" at a water temperature of 35°C is to be:

$$P_{35} = \frac{S \cdot T}{A \cdot B} \left[-S \cdot \theta + \sqrt{\mu^2 + B \cdot \left(\frac{F_v}{T} \right)^2} \right] \quad (11)$$

The rated propeller thrust, T , submitted by the designer is to be used in these calculations. In the event that this is not submitted, one of the equations (12) and (13) for estimating the propeller thrust may be used, subject to whichever yields the larger value of P_{35} .

$$T = 132 \frac{H}{v_s} \quad (12)$$

$$T = 4.3 \cdot 10^6 \frac{H}{PN} \quad (13)$$

The shear force at interface, F_v is given by

$$F_v = \frac{2 \cdot c \cdot Q}{D_s} \quad (14)$$

Constant B is given by:

$$B = \mu_0^2 - S^2 \theta^2 \quad (15)$$

The corresponding minimum pull-up length δ_{35} at 35°C, is:

$$\delta_{35} = P_{35} \cdot \frac{D_s}{2 \cdot \theta} \left[\frac{1}{E_b} \left(\frac{K^2 + 1}{K^2 - 1} + v_b \right) + \frac{1}{E_s} (1 - v_s) \right] \quad (16)$$

$$K = \frac{D_b}{D_s} \quad (17)$$

Where the connection between propeller shaft cone and propeller is realised by hydraulic oil technique without the use of a key, the necessary pull up distance δ on the tapered shaft is to be determined according to formula (10). Where appropriate, allowance is also to be made for surface smoothing when calculating δ .

The minimum pull-up length, δ_t at temperature t , where $t < 35^\circ\text{C}$, is:

$$\delta_t = \delta_{35} + \frac{D_s}{\theta} (\alpha_b - \alpha_s) (35 - t) \quad (18)$$

Values for α_b and α_s can be taken from Table 8.3. At least the temperature range between 0 °C and 35 °C has to be considered.

Hence, the corresponding minimum surface pressure, P_t is:

$$P_t = P_{35} \cdot \frac{\delta_t}{\delta_{35}} \quad (19)$$

The minimum push-up load, W_t at temperature t is:

$$W_t = A \cdot P_t \cdot (\mu + \theta) \quad (20)$$

The corresponding maximum permissible mating surface pressure, P_{\max} at 0°C is:

$$P_{\max} = \frac{0.7 \cdot \sigma_y \cdot (K^2 - 1)}{\sqrt{3K^4 + 1}} \quad (21)$$

and the corresponding maximum permissible pull-up length, δ_{\max} at 0°C is:

$$\delta_{\max} = \delta_{35} \cdot \frac{P_{\max}}{P_{35}} \quad (22)$$

For direct coupled propulsion plants with a barred speed range it has to be confirmed by separate calculation that the vibratory torque in the main resonance is transmitted safely. For this proof the safety against slipping for the transmission of torque

shall be at least $S=2.0$ (instead of $S=2.8$), the coefficient c_A may be set to 1.0. For this additional proof the respective influence of the thrust from (11) may be disregarded.

2.3 The von Mises' equivalent stress resulting from the maximum specific pressure P and the tangential stress in the bore of the propeller hub shall not exceed 75% of the yield strength or the 0.2% proof stress or yield strength of the propeller material in the installed condition and 90% during mounting and dismounting procedure.

2.4 The cones (tapers) of propellers which are mounted on the propeller shaft by means of the hydraulic oil technique shall not be more than 1:15 or not be less than 1:25. For keyed connections, the taper shall not be more than 1:10.

2.5 The propeller nut must be strongly secured to the propeller shaft. Screwing direction of the propeller nut is to be opposite to propeller shaft's ahead rotation direction.

3. Flange Connections

3.1 Flanged propellers and hubs of controllable pitch propellers are to be connected to the flange of the propeller shaft by means of fitted pins and retaining bolts (necked down bolts for preference).

3.2 The diameter of the fitted pins is to be calculated by applying formula (4) given in Section 5, C.5.2.

3.3 The propeller retaining bolts are to be of similar design to those described in D.3. However, the thread core diameter shall not be less than:

$$d_r = 4.4 \sqrt{\frac{M_{0.35R} \cdot \alpha_A}{d \cdot Z \cdot R_{eH}}} \quad (23)$$

for symbols and terms see C.1.

3.4 The propeller retaining bolts have to be secured against unintentional loosening.

F. Balancing and Testing

1. Balancing

All propellers including monoblock propellers ready for mounting as well as the blades of controllable pitch propellers and built fixed pitch propellers are required to undergo static balancing in accordance with specified ISO 484 tolerance class (or equivalent) as specified in the approved drawing in presence of a surveyor. Thereby the mass difference between blades of controllable-or built-up fixed-pitch propeller has to be not more than 1.5%.

Dynamic balancing is required for propellers with an operating speed of more than 500 rpm or propellers with

tip speed exceeding 60 m/s. The manufacturer shall demonstrate that the assembled propeller shall be within the specified limits.

For built-up propellers, the required static balancing may be replaced by an individual control of blade weight and gravity centre position.

2. Testing

2.1 Fixed pitch propellers, controllable pitch propellers and controllable pitch propeller systems and vane wheels are to be presented to **BCS** for final inspection.

The verification of dimensions, the dimensional and geometrical tolerances is the responsibility of the manufacturer.

The report on the relevant examinations is to be submitted to the Surveyor, who may require checks to be made in his/her presence.

In addition, controllable pitch propeller systems are required to undergo pressure, tightness and operational tests.

BCS reserves the right to require non-destructive tests to be conducted to detect surface cracks or casting defects.

2.2 Casted propeller boss caps, have to be tested for tightness at the manufacturer's workshop, so far they also serve the purpose of corrosion protection.

BCS reserves the right to require a tightness test of the aft propeller boss sealing in assembled condition.

2.3 If the propeller is mounted onto the shaft by a hydraulic shrink fit connection, a blue print test showing at least a 70% contact area has to be demonstrated to the satisfaction of the Surveyor. The blue print pattern should not show any larger areas without contact, especially not at the forward cone end. The blue print pattern has to be demonstrated using the original components.

If alternatively a male/female calibre system is used, between the calibres a contact area of at least 80% of the cone area has to be demonstrated and certified. After ten applications or five years, the blue print proof has to be renewed.

2.4 The propeller blades shall be manufactured according to the specified tolerance class (ISO 484). As a minimum, verification of the following is required:

- Surface finish
- Pitch (local and mean pitch)
- Thickness and length of blade sections
- Form of blade sections
- Location of blades, reference line and blade contour

- Balancing (see also [1])
- For propellers running in nozzle or tunnel:
 - extreme radius of blades (for controllable pitch propellers with outer section at zero pitch).

Verification of blade section form may include the use of edge templates as specified for manufacturing tolerance classes S and I in ISO 484. Equivalent methods can be accepted, for instance the use of multi-axial milling machines, which have proven to be capable of producing the specified geometry with such an accuracy that only a slight grinding is necessary to obtain the specified surface finish.

SECTION 9**STEERING GEARS AND THRUSTERS**

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A. Steering Gears

1. General

1.1 Scope

This section is applicable to ships for which steering is affected by means of a rudder and an electric, hydraulic or electro-hydraulic steering gear. The requirements contained in this subsection apply to the steering gear including all the equipment used to operate the rudder, the steering station and all transmission elements from the steering station to the steering gear. For the rudder and manoeuvring arrangement, see Chapter 1 - Hull, Section 18. For the purposes of these requirements, steering gears comprise all the equipment used to operate the rudder from the rudder actuator to the steering station including the transmission elements.

The requirements set out in 1974 SOLAS Chapter II-1, Regulation 29 and 30, are integral part of this rule and are to be applied in their full extent.

The requirements in this section may be applied to other vessels at the discretion of **BCS**.

Steering gears intended for ships strengthened for navigation in ice are to comply also with the additional requirements in Section 19.

Additional requirements for alternative propulsion and steering arrangements, such as but not limited to, azimuthing propulsors or water jet propulsion systems, are given in B. (See Chapter 7 - High Speed Crafts, Annex 11 for Water Jets)

1.2 Documents for approval

All relevant assembly and general drawings of the steering gears, diagrams of the hydraulic and electrical equipments together with the detailed drawings of all important load-transmitting components and their specifications are to be submitted to **BCS** in triplicate for approval.

BCS demands a private report identifying the design targets and objectives to be submitted for approval. The report shall cover the followings:

- The design targets and objectives of the analysis,
- The standards applied to the design and analysis,
- The assumptions in the design & analysis,
- The components of the steering system and its sub-systems,
- Operational modes of each components,
- Probable failure modes and acceptable deviations from the intended or required service and running principles,
- Consideration of the local effects and their possible effects on the steering system in case of failure,
- Trials and testing necessary to prove conclusions.

The report is to be submitted prior to approval of the design plans in detail. The report may be submitted in two parts:

The first report covers a preliminary analysis as soon as the initial arrangements of different compartments and propulsion plant are known which can form the basis of discussion. This shall include a structured assessment of all essential systems supporting the propulsion plant after a failure in equipment, fire or flooding in any compartment casualty. The second report should denote the final design with a detailed evaluation of any critical system identified in the preliminary report. Verification of the report contents shall be agreed between the shipbuilder and **BCS**.

The drawings and other documents must contain all the information relating to materials, working pressures, pump delivery rates, drive motor ratings etc. necessary to enable the documentation to be checked.

The plans and related documents submitted for approval are itemized as follows:

- Arrangement of steering gear machinery,
- Hydraulic piping system diagram,
- Power supply system diagrams,
- Motor control system diagrams,
- Steering control system diagrams,
- Instrumentation and alarm system diagrams,
- Drawings and details for rudder actuators,
- Drawings and details for torque transmitting parts and parts subjected to internal hydraulic pressure,
- Details and specifications of welding procedure,
- Rated torque.

1.3 Definitions and regulations

For the purpose of this section, the following definitions apply:

1.3.1 Steering gear control system

Steering gear control system means the equipment by which orders are transmitted from the navigating bridge to the steering gear power units. Steering gear control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables required to control the steering gear power actuating system. For the purpose of the requirements, steering wheels, steering levers, and rudder angle feedback linkages are not considered to be part of the control system.

1.3.2 Main steering gear

Main steering gear means the machinery, rudder actuator(s), the steering gear power units, if any, and ancillary equipment and the means of applying torque to

the rudder stock (e.g. tiller or quadrant) necessary for effecting movement of the rudder for the purpose of steering the ship under normal service conditions.

1.3.3 Steering gear power unit

Steering gear power unit means:

- In the case of electric steering gear, an electric motor and its associated electrical equipment,
- In the case of electro-hydraulic steering gear, an electric motor and its associated electrical equipment and connected pump,
- In the case of other hydraulic steering gear, a driving engine and connected pump.

1.3.4 Auxiliary steering gear

Auxiliary steering gear means the equipment other than any part of the main steering gear necessary to steer the ship in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose.

1.3.5 Power actuating system

Power actuating system means the hydraulic equipment provided for supplying power to turn the rudder stock, comprising a steering gear power unit or units, together with the associated pipes and fittings, and a rudder actuator. The power actuating systems may share common mechanical components (i.e. tiller, quadrant and rudder stock) or components serving the same purpose.

1.3.6 Maximum ahead service speed

Maximum ahead service speed means the greatest speed which the vessel is designed to maintain in service at sea at the deepest seagoing draught at maximum propeller RPM and corresponding engine MCR.

1.3.7 Rudder actuator

Rudder actuator means the component which converts directly hydraulic pressure into mechanical action to move the rudder. This may be a hydraulic cylinder or a hydraulic motor.

For all vessels with non-duplicated actuators, isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly fitted on the actuator.

Steering gears may be composed of a single rudder actuator for all vessels except the following:

- For oil carriers, fuel oil carriers, chemical carriers and gas carriers of 100,000 tonnes deadweight and above, the steering gear is to be comprised of two or more identical rudder actuators.
- For oil carriers, fuel oil carriers, chemical carriers and gas carriers of 10,000 gross tonnages and above but less than 100,000 tonnes deadweight, the steering gear may be comprised of a single, non-duplicated rudder actuator, provided it complies with the Additional Requirements of **BCS** for Oil or Fuel Oil Carriers, Chemical Carriers and Gas Carriers

Rudder actuators other than those covered by SOLAS Chapter II-1, Regulation 29.17 and relating Guidelines should be designed in accordance with Class 1 Pressure Vessels (not withstanding any exemptions for hydraulic cylinders).

1.3.8 Maximum working pressure (P_p)

Maximum working pressure means the maximum expected pressure in the system when the steering gear is operated to comply with 3.2.1.2 or 3.3.1.2.

Frictional losses in the steering gear including piping have to be considered within the determination of the maximum working pressure.

1.3.9 Design pressure

Design pressure for calculation to determine the scantlings of piping and other steering gear components subjected to internal hydraulic pressure is to be at least equal to the greater of the following:

- 1.25 times the maximum working pressure,
- The relief valve setting as mentioned in 3.8.2.

1.3.10 Test pressure

The pressure to which the components are to undergo a pressure test according to 5.4.

1.3.11 Hydraulic accumulators

Hydraulic accumulators having operating pressure above 6.9 bars, are to be certified in accordance with **BCS** requirements Section 14 , A as pressure vessels regardless of their diameters.

Each accumulator which may be isolated from the system is to be protected by its own relief valve or equivalent. Where a gas charging system is used, a relief valve is to be provided on the gas side of the accumulator.

1.5 Steering gear compartment

The steering gear is to be protected from the weather. Steering gear compartments are to be easily accessible and, as far as practicable, separated from the machinery spaces. Working access is to be provided to the steering gear machinery and controls with handrails, gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

The steering gear compartment is to be provided with visual compass readings.

2. Materials and welding

2.1 Approved materials

2.1.1 Ram cylinders; pressure housings of rotary vane type actuators; hydraulic power piping valves, flanges and fittings; and all steering gear components transmitting mechanical forces to the rudder stock (such as tillers, quadrants, or similar components) should be of cast steel or other approved ductile material, duly tested in accordance with the requirements of **BCS**. In general, such material should not have an elongation of less than 12% nor a tensile strength in excess of 650 N/mm².

Pressure vessels should be generally made of steel, cast steel or nodular cast iron (with a predominantly ferritic matrix).

With the consent of the **BCS**, cast iron may be used for certain components. Gray cast iron may be accepted for redundant parts with low stress level, excluding cylinders, upon special consideration.

Gray cast iron or other material having an elongation ($L_0/d = 4$) less than 12% in 50 mm is not to be used for these parts

2.1.2 Casings which integrated house journal and guide bearings on ships with a nozzle rudder and ice class are not to be made of grey cast iron.

2.1.3 The pipes of hydraulic steering gears are to be made of seamless or longitudinally welded steel tubes. The use of cold-drawn, unannealed tubes is not permitted.

At points where they are exposed to danger or damage, copper pipes for control lines are to be provided with a protective shielding and are to be safeguarded against hardening due to the vibration by the use of suitable fastenings.

2.1.4 High-pressure hose assemblies may be used for short pipe connections subject to compliance with Section 16, U, if this is necessary due to vibrations or flexibly mounted units.

2.1.5 Materials used for the pressurized components including the seals must be suitable for the hydraulic oil in use.

Oil seals between the non-moving parts, forming part of the exterior pressure boundary, shall be of the metal upon metal type or of an equivalent type.

Oil seals between the moving parts, forming part of the external boundary, shall be fitted in duplicate so that the failure of one seal does not render the actuator inoperative. Alternative seal arrangements providing equivalent protection against leakage may be acceptable provided protection against leakage can be assured.

2.2 Testing of materials

2.2.1 The materials of essential load-transmitting components of the steering gear as well as of the pressurized casings of hydraulic steering gears are to be tested under supervision of **BCS** in accordance with the requirements of Chapter 2 - Material.

For pressurized oil pipes, the requirements according to Section 16, Table 16.6 are to be observed.

2.2.2 In the case of small hand-operated main steering gears and small manually operated auxiliary steering gear **BCS** may dispense with testing the materials of individual components such as axiometer gear shafts, etc.

2.3 Welding features

2.3.1 For welded structures such as pressurized casings etc, the **BCS** Rules Chapter 3 - Welding are to be applied.

2.3.2 The welding details and welding procedures should be approved by **BCS** or an IACS Member Classification Society.

All welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads should be full penetration type or of equivalent strength.

3. Steering Components and Design Principles

All vessels are to be provided with power-operated means of steering. Such means, as a minimum, are to be supported by duplication of power units, and by redundancy in piping, electrical power supply, and control circuitry. Steering is to be capable of being readily regained in the event of the failure of a power unit, a piping component, a power supply circuit or a control circuit.

The main and auxiliary steering gears shall be so arranged that the failure of one of them will not render the other one inoperative.

All the steering gear components and the rudder stock are to be of sound and reliable construction to the satisfaction of **BCS**. Special consideration shall be given to the suitability of any essential component which is not duplicated. Any such essential component shall, where appropriate, utilize anti-friction bearings such as ball bearings, roller bearings or sleeve bearings which shall be permanently lubricated or provided with lubrication fittings.

The construction should be such as to minimize local concentrations of stress.

All steering gear components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength at least equivalent to that of the rudder stock in way of tiller.

3.1 Number of steering gears

3.1.1 Each ship must be equipped with at least one main and one auxiliary steering gear. Both steering gears are to be independent of each other and, wherever possible, act separately upon the rudderstock.

BCS may agree to components being used jointly by the main and auxiliary steering gear.

3.2 Main steering gear and rudder stock

3.2.1 The main steering gear and rudder stock shall be:

3.2.1.1 Of adequate strength and capable of steering the ship at maximum ahead at the ship's service speed for which the rudder has been designed in accordance with Chapter 1 - Hull, Section 18. which shall be demonstrated;

3.2.1.2 Capable of putting the rudder over from 35° on one side to 35° on the other side with the ship at its deepest seagoing draught and running ahead at maximum ahead service speed and, under the same conditions, from 35° on either side to 30° on the other side in not more than 28 s; where it is impractical to demonstrate compliance with this item during sea trials with the ship at its deepest seagoing draught and running ahead at the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch, ships regardless of date of construction may demonstrate compliance with this requirement by one of the following methods:

- During sea trials the ship is at even keel and the rudder fully submerged whilst running ahead at the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch; or
- Where full rudder immersion during sea trials cannot be achieved, an appropriate ahead speed shall be calculated using the submerged rudder blade area in the proposed sea trial loading condition. The calculated ahead speed shall result in a force and torque applied to the main steering gear which is at least as great as if it was being tested with the ship at its deepest seagoing draught and running ahead at the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch; or
- The rudder force and torque at the sea trial loading condition have been reliably predicted and extrapolated to the full load condition. The

speed of the ship shall correspond to the number of maximum continuous revolutions of the main engine and maximum design pitch of the propeller;

3.2.1.3 Operated by power where necessary to meet the requirements of above paragraph and in any case when **BCS** requires a rudder stock of over 120 mm diameter in way of the tiller, excluding strengthening for navigation in ice; and

Note: The mentioned diameter is to be taken as having been calculated for rudder stock of mild steel with a yield stress of 235 N/mm², i.e. with a material factor $k_r = 1$.

3.2.1.4 So designed that they will not be damaged at maximum astern speed ; however , this design requirement need not be proved by trials at maximum astern speed and maximum rudder angle.

3.2.2 Manual operation is acceptable for rudderstock diameters up to 120 mm. calculated for torsional loads in accordance with the Rules Chapter 1 - Hull, Section 18, C.1. Not more than 25 turns of the handwheel shall be necessary to put the rudder from one hard over position to the other. Taking account of the efficiency of the system, the force required to operate the handwheel should generally not exceed 200 N.

3.3 Auxiliary steering gear

3.3.1 The auxiliary steering gear shall be:

3.3.1.1 Of adequate strength and capable of steering the ship at navigable speed and of being brought speedily into action in an emergency;

3.3.1.2 Capable of putting the rudder over from 15° on one side to 15° on the other side in not more than 60 s. with the ship at its deepest seagoing draught and running ahead at 1/2 of the maximum ahead service speed or 7 knots, whichever is the greater; where it is impractical to demonstrate compliance with this item during sea trials with the ship at its deepest seagoing draught and running ahead at one half of the speed corresponding to the number of maximum continuous

revolutions of the main engine and maximum design pitch or 7 knots, whichever is greater, ships regardless of date of construction, including those constructed before 1 July 2009, may demonstrate compliance with this requirement by one of the following methods:

- During sea trials the ship is at even keel and the rudder fully submerged whilst running ahead at one half of the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch or 7 knots, whichever is greater; or
- Where full rudder immersion during sea trials cannot be achieved, an appropriate ahead speed shall be calculated using the submerged rudder blade area in the proposed sea trial loading condition. The calculated ahead speed shall result in a force and torque applied to the auxiliary steering gear which is at least as great as if it was being tested with the ship at its deepest seagoing draught and running ahead at one half of the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch or 7 knots, whichever is greater; or
- The rudder force and torque at the sea trial loading condition have been reliably predicted and extrapolated to the full load condition; and

3.3.1.3 Operated by power where necessary to meet the requirements of paragraph 3.3.1.2 and in any case when **BCS** requires a rudder stock of over 230 mm diameter in way of the tiller , excluding strengthening for navigation in ice.

Hydraulically operated auxiliary steering gears must be fitted with their own piping system independent of that of the main steering gear. The pipe or hose connections of steering gears must be capable of being shut-off directly at the pressurized casings.

Note: The mentioned diameter is to be taken as having been calculated for rudder stock of mild steel with a yield stress of 235 N/mm², i.e. with a material factor $k_r = 1$

3.3.2 Manual operation of auxiliary steering gear systems is permitted up to a theoretical stock diameter of 230 mm referring to steel with a minimum nominal upper yield stress $R_{eH}=235 \text{ N/mm}^2$.

3.4 Power unit

3.4.1 Main and auxiliary steering gear power units shall be arranged to restart automatically when power is restored after a power failure and capable of being brought into operation from a position on the navigation bridge.

In the event of a power failure to any one of the steering gear power units, an audible and visual alarm shall be given on the navigation bridge.

3.4.2 Where power operated hydraulic main steering gears are equipped with two or more identical power units, auxiliary steering gear need not be installed provided that the following conditions are fulfilled.

3.4.2.1 In passenger ships, the main steering gear is capable of operating the rudder as required by paragraph 3.2.1.2 while any one of the power units is out of operation.

3.4.2.2 In cargo ships, the main steering gear is capable of operating the rudder as required by paragraph 3.2.1.2 while operating with all power units.

3.4.2.3 In the event of failure of a single component of the main steering gear including the piping, excluding the rudder tiller or similar components as well as the cylinders, rotary vanes and casing, means must be provided for quickly regaining control of one steering system.

3.4.2.4 In the event of a loss of hydraulic oil, it must be possible to isolate the damaged system in such a way that the second control system remains fully operable.

3.4.3 In every tanker, chemical tanker or gas carrier of 10,000 GRT and upwards and in every other ship of 70,000 GRT and upwards, the main steering gear must consist of two or more identical power units complying with the provisions of 3.4.2.

3.4.4 The power units are required to be type tested, see 5.1.

3.5 Rudder angle limitation and power gear stops

Power-operated steering gears are to be provided with positive arrangements, such as limit switches, for stopping the gear before the rudder stops are reached. These arrangements are to be synchronized with the rudder stock or the position of the gear itself and may be an integral part of rudder actuator. Arrangements to satisfy this requirement through the steering gear control system are not permitted.

The rudder angle in normal service is to be limited by devices fitted to the steering gear (e.g. limit switches) to a rudder angle of 35° on both sides. Deviations from this requirement are permitted only with the consent of **BCS**.

3.6 End position limitation

For the limitation by means of stoppers of the end positions of tillers and quadrants, see Chapter 1 - Hull, Section 18, G.

In the case of hydraulic steering gears without an end position limitation of the tiller and similar components, a mechanical end position limiting device must be fitted within the rudder actuator.

3.7 Locking equipment

Steering gear systems are to be equipped with a locking system effective in all rudder positions (see also Chapter 1 - Hull, Section 18, G).

Where hydraulic plants are fitted with shut-offs directly at the cylinders or rotary vane casings, special locking equipment may be dispensed with.

In the case of steering gears with cylinder units which have mutually independent operation, these shut-off devices do not have to be fitted directly on the cylinders.

3.8 Overload protection and relief valves

3.8.1 Power-operated steering gear systems are to be equipped with overload protection (slip coupling, relief valve) to ensure that the driving torque is limited to the maximum permissible value.

The design and setting of safety valves must be such that their response threshold does not allow the maximum permissible working pressure to be exceeded by more than 10% of the setting pressure of the valve.

The overload protection device must be secured to prevent re-adjustment by unauthorized persons. Means must be provided for checking the setting while in service.

The pressurized casings of hydraulic steering gears which also fulfil the function of the locking equipment mentioned in 3.7 are to be fitted with relief valves unless they are so designed that the pressure generated when the elastic-limit torque is applied to the rudderstock cannot cause rupture, deformation or any other damages of the pressurized casings.

3.8.2 Relief valves have to be provided for protecting any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces, as required by SOLAS II-1, Regulations 29.2.3 should comply with the following:

- The relief valves are to be set to a pressure value at least 1.25 times of the maximum working pressure but lower than the design pressure of the steering gear (definition of maximum working pressure and design pressure in accordance to 4.2).
- The minimum discharge capacity of the relief valves is not to be less than 1.1 times the total capacity of the pumps, which can deliver through them.

With this setting any higher peak pressure in the systems than 1.1 times the setting pressure of the

valves is to be prohibited. In this regard, due consideration should be given to extreme foreseen ambient conditions in respect of oil viscosity.

BCS may require, for the relief valves, discharge capacity tests and/or shock tests.

3.9 Controls

3.9.1 Control of the main and auxiliary steering gears must be exercised from a steering station on the bridge. Controls must be mutually independent and so designed that the rudder cannot move unintentionally.

3.9.2 Means must also be provided for exercising control from the steering gear compartment. The transmission system must be independent of that serving the main steering station.

3.9.3 Suitable equipment is to be installed to provide means of communication between the bridge, all steering stations and the steering gear compartment.

3.9.4 Failures of single control components (e.g. control system for variable displacement pump or flow control valve) which may lead to loss of steering shall be monitored by an audible and visible alarm system on the navigating bridge, if loss of steering cannot be prevented by other measures.

3.9.5 Where the steering gear is so arranged that more than one system (either power or control) can be simultaneously operated, the risk of hydraulic locking caused by single failure is to be considered.

Steering gear control shall be provided for the main steering gear, both on the navigation bridge and in the steering gear compartment;

- Where the main steering gear is arranged in accordance with 3.4.2, by two independent control systems, both operable from the navigation bridge. This does not require duplication of the steering wheel or steering lever. Where the control system consists of a hydraulic telemotor, a second independent system need not be fitted, except in a tanker,

chemical tanker or gas carrier of 10,000 tons gross tonnage and upwards;

- For the auxiliary steering gear, in the steering gear compartment and, if power-operated, it shall also be operable from the navigation bridge and shall be independent of the control system for the main steering gear.

Where SOLAS stipulates two steering gear control systems independent of each other (SOLAS II-1, Reg. 29/6.1, 29/7.2, 29/7.3, Reg. 29/15 and Reg. 29/16). Two independent steering gear control systems must be provided, each of which can be operated from the navigation bridge separately and shall be so arranged that a mechanical or electrical failure in one of them will not render the other one inoperative. These control systems are to allow rapid transfer of steering power units and of control between the units (See 3.4.2.3 and 3.4.2.4).

Wires, terminals and the components for duplicated steering gear control systems installed in units, control boxes, switchboards or bridge consoles shall be separated as far as practicable.

Where physical separation is not practicable, separation may be achieved by means of a fire retardant plate.

3.9.5.1 Any main and auxiliary steering gear control system operable from the navigation bridge shall comply with the following:

3.9.5.1.1 If electric, it shall be served by its own separate circuit supplied from a steering gear power circuit from a point within the steering gear compartment, or directly from switchboard busbars supplying that steering gear power circuit at a point on the switchboard adjacent to the supply to the steering gear power circuit;

3.9.5.1.2 Means shall be provided in the steering gear compartment for disconnecting any control system operable from the navigation bridge from the steering gear it serves;

3.9.5.1.3 The system shall be capable of being brought into operation from a position on the navigation bridge;

3.9.5.1.4 In the event of a failure of electrical power supply to the control system, an audible and visual alarm shall be given on the navigation bridge; and

3.9.5.1.5 Short circuit protection only shall be provided for steering gear control supply circuits.

3.9.5.2.1 All electric components of the steering gear control systems shall be duplicated. This does not require duplication of the steering wheel or steering lever.

3.9.5.2.2 If a joint steering mode selector switch (uniaxial switch) is employed for both steering gear control systems, the connections for the circuits of the control systems shall be divided accordingly and separated from each other by an isolating plate or by air gap.

3.9.5.2.3 In the case of double follow-up control (see Fig. 9.3), the amplifiers shall be designed and fed so as to be electrically and mechanically separated. In the case of nonfollow-up control and follow-up control, it shall be ensured that the follow-up amplifiers are protected selectively (see Fig. 9.4).

3.9.5.2.4 Control circuits for additional control systems, e.g. steering lever or autopilot shall be designed for all - pole disconnection (see Fig. 9.2, 9.3 and 9.4).

3.9.5.2.5 The feed-back units and limit switches, if any, for the steering gear control systems shall be separated electrically and mechanically connected to the rudder stock or actuator separately.

3.9.5.2.6 Hydraulic system components in the power actuating or hydraulic servo systems controlling the power systems of the steering gear (e.g. solenoid valves, magnetic valves) are to be considered as part of the steering gear control system and shall be duplicated and separated.

Hydraulic system components in the steering gear control system that are part of a power unit may be regarded as being duplicated and separated when there are two or more separate power units provided and the piping to each power unit can be isolated.

3.9.5.3 For failure detection and response of control systems, see **BCS** Electric Rules Chapter 5 Section 7 item A.6.10.

3.10 Rudder angle indication

3.10.1 The rudder position must be clearly indicated on the bridge and at all steering stations. Where the steering gear is operated electrically or hydraulically, the rudder angle must be indicated by a device (rudder position indicator) which is actuated either by the rudderstock itself or by parts which are mechanically connected to it. In case of time-dependent control of the main and auxiliary steering gear, the midship position of the rudder must be indicated on the bridge by some additional means (signal lamp or similar). In general, this indicator is still to be fitted even if the second control system is a manually operated hydraulic system. See also Chapter 5 - Electrical Installations, Section 9, C.

3.10.2 The actual rudder position during the service must be indicated at the steering gear itself.

It is recommended that an additional rudder angle indicator should be fitted at the main engine control station.

3.11 Piping and hoses

3.11.1 Pipes of the hydraulic steering gear systems are to be installed in such a way as to ensure maximum protection while remaining readily accessible.

The power piping for hydraulic steering gears is to be arranged so that transfer between units can be readily affected.

Arrangements for bleeding air from the hydraulic system are to be provided where necessary.

Pipes are to be installed at a sufficient distance from the ship's shell. As far as possible, pipes should not pass through cargo spaces.

Connections to other hydraulic systems are not permitted.

3.11.2 Piping, joints, valves, flanges and other fittings are to comply with **BCS**'s requirements for Class 1 components. The design pressure is to be in accordance with paragraph 1.3.9.

For the design and dimensions of pipes, valves, fittings, pressure vessels etc., see Section 14 and Section 16 A, B, C, D and U.

3.11.3 Hose assemblies of type approved by **BCS** may be installed between two points where flexibility is required but should not be subjected to torsional deflection (twisting) under normal operating conditions. In general, the hose should be limited to the length necessary to provide for flexibility and for proper operation of machinery.

Hoses should be high pressure hydraulic types according to recognized standards and suitable for the fluids, pressures, and temperatures and ambient conditions in question.

Burst pressure of hoses should not be less than 4 times of the design pressure.

3.12 Oil level indicators, filters

3.12.1 Each tanks of the hydraulic system are to be fitted with oil level indicators.

3.12.2 The lowest permissible oil level is to be monitored. Audible and visual alarms are to be provided for the navigation bridge and in the machinery space or machinery control room. The alarm on the navigation bridge shall be an individual alarm.

3.12.3 Filters or equivalent arrangements for cleaning the operating fluid are to be fitted in the piping system, to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system.

3.13 Storage tank

In hydraulically operated main steering gear systems, an additional permanently installed storage tank is to be fitted which has a capacity sufficient to refill at least one of the control systems including the service tank.

The storage tank is to be permanently connected by pipes to the control systems so that the latter can be refilled from a position inside the steering gear compartment.

3.14 Arrangement

Steering gears are to be so installed that they are easily accessible and to be maintainable.

3.15 Electrical installations

Electrical installations should comply with the requirements of **BCS** (see Chapter 5 - Electrical Installations, Section 7, A).

3.16 Alternative source of power

Where the alternative power source required by SOLAS II-1 Regulations 29.14 is a generator, or an engine driven pump, the automatic starting arrangements must comply with the requirements relating to the automatic starting arrangements of emergency generators.

Where the rudder stock is required to be over 230 mm diameter in way of the tiller, excluding strengthening for navigation in ice, an alternative power supply, sufficient at least to supply the steering gear power unit which complies with the requirements of 3.3.1.2 and also its associated control system and the rudder indicator, shall be provided automatically, within 45 s, either from the emergency source of electrical power or from an independent source of power located in the steering gear compartment. This

independent source of power shall be used only for this purpose.

In every ship of 10,000 gross tonnage and upwards, the alternative power supply shall have a capacity for at least 30 min of continuous operation and in any other ship for at least 10 min.

Note: The mentioned diameter is to be taken as having been calculated for rudder stock of mild steel with a yield stress of 235 N/mm², i.e. with a material factor $k_r=1$.

3.17 Seating

Seating of the steering gear has to be applied according to Section 2, K. In case of seating on cast resin the forces according to the elastic limit torque of the rudder shaft as well as the rudder bearing forces have to be transmitted to the ship's structure by welded stoppers.

3.18 Monitoring and alarm systems

3.18.1 Monitoring and alarm systems, including the rudder angle indicators, should be designed, built and tested to the satisfaction of **BCS**.

3.18.2 Where the hydraulic locking, caused by a single failure, may lead to loss steering, an audible and visual alarm, which identifies the failed system, shall be provided on the navigating bridge.

Audible and visual alarm should be activated whenever:

- Position of the variable displacement pump control system does not correspond with given order; or
- Incorrect position of 3-way full flow valve or similar in constant delivery pump system is detected.

3.19 Operating instructions

3.19.1 Where applicable, the following standard signboard should be fitted at a suitable place on steering control post on the bridge or incorporated into operating instruction board:

CAUTION

IN SOME CIRCUMSTANCES WHEN 2 POWER UNITS ARE RUNNING SIMULTANEOUSLY, THE RUDDER MAY NOT RESPOND TO HELM. IF THIS HAPPENS, STOP EACH PUMP IN TURN UNTIL CONTROL IS REGAINED.

The above signboard is related to steering gears provided with 2 identical power units intended for simultaneous operation, and normally provided with either their own control systems or two separate (partly or mutually) control systems which are/may be operated simultaneously.

3.19.2 Existing vessels according to SOLAS 1986 shall have minimum the above signboard, when applicable.

4. Power and Dimensioning

The power of the steering gear has to comply with the requirements set out in 3.2 and 3.3, see also SOLAS Chapter II-1, Part C, Reg.29.

4.1 Steering torques

4.1.1 Minimum required rated torque

The rated torque of the steering gear is not to be less than the expected torque which is indicated on the submitted rudder or steering plan as capable to operate the rudder.

It should here be noted that the expected torque is not the design torque for rudder scantlings.

4.1.2 Transmitted effective torque

Transmitted torque M_{\max} of the steering gear is not to be greater than the maximum permissible torque M_{perm} , as defined in 4.1.3. Transmitted torque M_{\max} is to be based on the relief valve setting and to be determined with the following equations (1a, b, c and 2), whichever is the greater:

For ram type actuator:

$$M_{\max} = P \cdot N \cdot A \cdot L_2 / (C \cdot \cos^2 \theta) \quad [\text{Nm}] \quad (1a)$$

For rotary vane type actuator:

$$M_{\max} = P \cdot N \cdot A \cdot L_2 / C \quad [\text{Nm}] \quad (1b)$$

For linked cylinder type actuator:

$$M_{\max} = P \cdot N \cdot A \cdot L_2 / (C \cdot \cos^2 \theta) \quad [\text{Nm}] \quad (1c)$$

For all types of steering gears:

$$M_{\max} = \frac{\left(\frac{D_t}{N_u} \right)^3}{k_r} \quad [\text{Nm}] \quad (2)$$

$$r \left\{ \begin{array}{l} n \\ k = \frac{y}{R} \\ R_{eH} \end{array} \right\}^e \quad (3)$$

Where;

A = Area of piston or vane, [mm²]

C = 10,000, Factor,

D_t = Theoretical rudder stock diameter derived from the required hydrodynamic rudder torque for the ahead and astern running condition in accordance with Chapter 1 - Hull, Section 18, C.1 and 14, D.10. [mm]

e = 0.75 for $R_{eH} > 235 \text{ N/mm}^2$,

= 1.00 for $R_{eH} \leq 235 \text{ N/mm}^2$,

k_r = Material factor for rudder stock in accordance with formula (3),

L_2 = Torque arm, equal the distance from the point of application of the force on the arm to the center of the rudder stock at zero (0) degrees of rudder angle, [m]

$n_y = 235 \text{ N/mm}^2$, reference value for yield strength, [N/mm²]

N = Number of active pistons or vanes,

$N_u = 4.2$, Factor,

R_{eH} = Specified minimum yield strength of the rudderstock material; but is not to be taken as greater than $0.7R_m$ or 450 N/mm^2 whichever is less. [N/mm²]

R_m = Minimum tensile strength of the material [N/mm²]

θ = Maximum permissible rudder angle, (normally 35 degrees). [degrees]

4.1.3 Maximum permissible torque for rudder stock

The design calculations for those parts of the steering gear which are not protected against overload are to be based on the maximum permissible torque of the rudderstock. The maximum permissible torque M_{perm} for the actual rudder stock diameter is to be determined in accordance with the following equation:

$$M_{perm} = \frac{2 \cdot \left(\frac{D}{N_u} \right)^3}{k_r} \quad [\text{Nm}] \quad (4)$$

Where;

D = Minimum actual rudderstock diameter. Value of the actual rudderstock diameter need not be greater than $1.145 D_t$. [mm].

(1) *maximum pressure is comparable with the design pressure according to SOLAS Chapter II-1, Regulation 29, item 2.2 and 2.3.*

4.1.4 The working torque of the steering gear is to be larger than the hydrodynamic torque Q_R of the rudder according to Chapter 1 - Hull, Section 18, B.1.2, B.2.2 and B.2.3 and cover the friction moments of the related bearing arrangement.

4.2 Stresses and dynamic loads in steering system

4.2.1 The maximum working pressure is the maximum expected pressure in the system, when the steering gear is operated to comply with the power requirements in 4.1.

4.2.2 Frictional losses in the steering gear including piping have to be considered within the determination of the maximum working pressure (1). The relief valves are to be set at this pressure value.

4.2.3 Design pressure P_d for calculations to determine the scantlings of piping and other steering gear components subjected to internal hydraulic pressure is to be at least 1.25 times the maximum working pressure as defined above and has not to be less than the setting of relief valves (see 3.8.2).

4.2.4 Rudder actuators are to be designed in accordance with the requirements of Section 14, except that the maximum permissible stress S is not exceed the lower of the following ratios:

$$\frac{U}{A} \quad \text{or} \quad \frac{Y}{B}$$

Where;

Y = Specified minimum yield strength or %2 proof stress of the material, at ambient temperature, [N/mm²]

U = Specified minimum tensile strength of the material at ambient temperature. [N/mm²]

A = 3.5, Factor for Steel,
 = 4.0, Factor for Cast Steel,
 = 5.0, Factor for Nodular Cast Iron

B = 1.7, Factor for Steel,
 = 2.0, Factor for Cast Steel,
 = 3.0, Factor for Nodular Cast Iron

4.2.5 The dynamic loading to be assumed in the fatigue and fracture mechanics analysis considering SOLAS Chapter II-1, Regulation 29.2.2 and 29.17.2 and relating Guidelines will be established at the discretion of **BCS**.

Both the case of high cycle and cumulative fatigue are to be considered.

4.3 Equivalent rudder stock diameter

4.3.1 In the case of multi-surface rudders controlled by a common steering gear the relevant diameter is to be determined by applying the formula of equivalent rudder stock diameter:

$$D_{ti} = \sqrt[3]{D_{t1}^3 + D_{t2}^3 + \dots + D_{tn}^3} \quad (5)$$

4.3.2 Synchronisation

4.3.2.1 General

A system for synchronising the movement of the rudders is to be fitted, either:

- By a mechanical coupling, or
- By other systems giving automatic synchronising adjustment.

4.3.2.2 Non-mechanical synchronisation

Where the synchronisation of the rudder motion is not achieved by a mechanical coupling, the following provisions are to be met:

a) The angular position of each rudder is to be indicated on the navigation bridge

b) The rudder angle indicators are to be independent from each other and, in particular, from the synchronising system

c) In case of failure of the synchronising system, means are to be provided for disconnecting this system so that steering capability can be maintained or rapidly regained. See also A,7.

4.4 Design of the power transmission components

4.4.1 Design calculations for the parts of the steering gear which are not protected against overload are to be based on the maximum permissible torque (elastic limit torque) of the rudderstock as mention in 4.1.3.

Stresses in the components of steering gear determined in this way are not to exceed the yield strength of the materials used. Design of the parts of steering gear with overload protection is to be based on the loads corresponding to the response threshold of the overload protection.

4.4.2 Tiller and rotary vane hubs made of material with a tensile strength of up to 500 N/mm² must satisfy the following conditions in the area where the force is applied (see Figure 9.1):

Height of hub $H \geq 1.0 D$ [mm]

Outside diameter $D_a \geq 1.8 D$ [mm]

In special cases the outside diameter may be reduced to

$$D_a = 1.7 \cdot D \quad [\text{mm}] \quad (6)$$

but the height of the hub must then be at least

$$H = 1.14 \cdot D \quad [\text{mm}] \quad (7)$$

4.4.3 Where materials with a tensile strength greater than 500 N/mm² are used, the section of the hub may be reduced by 10%.

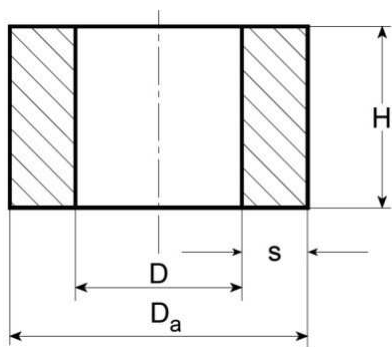


Figure 9.1 Hub dimensions

4.4.4 Where the force is transmitted by clamped or tapered connections, the elastic-limit torque may be transmitted by a combination of frictional resistance and a positive locking mechanism using adequately tightened bolts and a key.

For the maximum permissible (or elastic limit) torque according to formula (4), the thread root diameter of the bolts can be determined by applying the following formula:

$$d_k \geq 9.76 \cdot D \sqrt{\frac{1}{Z \cdot k_r \cdot R_{eH, \text{bolt}}}} \quad [\text{mm}] \quad (8)$$

Where

Z = Total number of bolts, [-]

$R_{eH, \text{bolt}}$ = Specified minimum yield strength of the bolt material. [N/mm²]

4.4.5 Split hubs of clamped joints must be joined together with at least four bolts.

The key is not to be located at the joint in the clamp.

4.4.6 Where the oil injection process is utilized for joining the rudder tiller or rotary vanes to the rudderstock, the approved calculation methods with the elasticity theory are requested. Calculations are to be based on the elastic-limit torque allowing for a coefficient of friction $\mu_o = 0.15$ for steel and 0.12 for nodular cast iron. The von Mises' equivalent stress

calculated from the specific pressure p and the corresponding tangential load based on the dimensions of the shrunk joint shall not exceed 80% of the yield strength of materials.

4.4.7 Where circumferential tension components are used to connect the rudder tiller or rotary vanes to the rudder stock, calculations are to be based on two and a half times the maximum torque (but not more than the elastic limit torque) allowing for a coefficient of friction of $\mu_o = 0.12$. The von Mises' equivalent stress calculated from the contact pressure p and the corresponding tangential load based on the dimensions of the shrunk-on connection shall not exceed 80% of the yield strength of the materials used.

When more than one circumferential tension component is used, the transmittable torque capacity of the connection is to be determined by adding the individual torques of the sole tension components and applying a reduction factor of 0.9.

5. Testing and Certification

5.1 General

Steering gear components are to be inspected, tested and certified by **BCS** surveyor at the plant of manufacture in accordance with the following requirements. Hydraulic oil pumps are to be certified according to Section 16 and 5.3.1.3.

The requirements of **BCS** relating to the testing of Class 1 pressure vessels, piping, and relating fittings including hydraulic testing apply. See Section 14.

5.2 Material testing

For testing of steering gear component materials, see 2.2.

5.3 Prototype tests of power units

5.3.1 The power units are required to undergo test on a test stand in the manufacturer's works.

A prototype of each new design power unit pump is to be subjected to a type test.

The type test shall be for duration of not less than 100 hours.

The test arrangements are to be such that the pump may run in idling conditions, and at maximum delivery capacity at maximum working pressure.

The testing is to be carried out in accordance with an approved program, which shall include the following as a minimum:

- The pump and stroke control (or directional control valve) is to be operated continuously from full flow and relief valve pressure in one direction through idle to full flow and relief valve pressure in the opposite direction.
- Pump suction conditions are to simulate lowest anticipated suction head. The power unit is to be checked for abnormal heating, excessive vibration or other irregularities. Following the test, the power unit pump is to be disassembled and inspected in the presence of a Surveyor.
- During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another should occur at least as quickly as on board.
- During the whole test, any abnormal heating, excessive vibration or other irregularities are not permitted.
- After the test, the pump should be disassembled and inspected.

Type tests may be waived for a power unit which has been proven to be reliable in marine service.

5.3.1.1 For diesel engines, see Section 2.

5.3.1.2 For electric motors, see Chapter 5 - Electrical Installations, Section 7-A.

5.3.1.3 For hydraulic pumps and motors, the “Guidelines for the Design, Construction and Testing of Pumps” are to be applied analogously. When the drive power is equal or more than 50 kW, this testing is to be carried out in the presence of a **BCS** Surveyor.

5.3.2 All components transmitting mechanical forces to the rudder stock should be tested according to the requirements of **BCS**.

5.3.3 After installation on board the vessel, the complete piping system, including power units, rudder actuators and piping, is to be subjected to the required running and hydrostatic tests equal to 110% of the relief valve setting, including a check of the relief valve operation in the presence of **BCS** Surveyor (see 5.4 and 5.5).

5.4 Pressure and tightness tests

Pressure components are to undergo a pressure test.

The test pressure, P_t

$$P_t = 1.5 \cdot P_d \quad (9)$$

P_d = Design pressure for which a component or piping system is designed with its mechanical characteristics [bar].

However, for working pressures above 200 bars, the test pressure need not exceed over than P_t plus 100 bars, [bar]

For pressure testing of pipes, their valves and fittings see Section 16, B.4 and U.5.

Tightness test are to be performed on components to which this is appropriate.

5.5 Final inspection and operational test

Following testing of the individual components and after completion of assembly, the steering gear is required to undergo final inspection and an operational test. Among other things the overload protection is to be adjusted at this time.

6. Shipboard Trials

The operational efficiency of the steering gear is to be proved during the sea trials. For this purpose, the Z manoeuvre corresponding to 3.2.1.2 and 3.3.1.2 is to be executed as a minimum requirement.

The steering gear should be tried out on the trial trip in order to demonstrate to the Surveyor's satisfaction that the requirements of the Rules have been met. The trial is to include the operation of the following:

- The steering gear, including demonstration of the performances required by SOLAS II-1 Regulation 29.3.2 and 29.4.2 (items 3.2.1.2 and 3.3.1.2). For controllable pitch propellers, the propeller pitch is to be at the maximum design pitch approved for the maximum continuous ahead of engine speed (rpm) at the main steering gear trial.
- The steering gear power units, including transfer between steering gear power units.
- The isolation of one power actuating system checking the time for regaining steering capability.
- The hydraulic fluid recharging system.
- The emergency power supply required by SOLAS II-1 Regulation 29.14 (item 3.16).
- The steering gear controls, including transfer of control and local control.
- The means of communication between the wheelhouse, engine room, and the steering gear compartment.

- The alarms and indicators required by the requirements in 3.18 and by SOLAS II-1 Regulations 29, 30, these tests may be effected at dockside.
- Where steering gear is designed to avoid hydraulic locking this feature shall be demonstrated.
- The stopping times, ship headings and distances recorded on trials, together with the results of trials to determine the ability of ships having multiple propellers to navigate and manoeuvre with one or more propellers inoperative, shall be available on board for the use of the master or designated personnel.

In order for ships to comply with the performance requirements stated in regulations 29.3.2 and 29.4.2 of SOLAS II-1, they are to have steering gear capable of meeting these performance requirements when at their deepest seagoing draught. In order to demonstrate this ability, the trials may be conducted in accordance with Section 6.1.5.1 of ISO 19019 "Seagoing vessels and marine technology – Instructions for planning, carrying out and reporting sea trials".

On all occasions when trials are conducted with the vessel not at the deepest seagoing draught the loading condition can be accepted on the conditions that either:

1. the rudder is fully submerged (at zero speed waterline) and the vessel is in an acceptable trim condition
2. the rudder torque at the trial loading condition have been reliably predicted (based on the system pressure measurement) and extrapolated to the maximum seagoing draught condition using the following method to predict the equivalent torque and actuator pressure at the deepest seagoing draught:

$$Q_F = Q_T \alpha$$

$$\alpha = 1.25 \left(\frac{A_F}{A_T} \right) \left(\frac{V_F}{V_T} \right)^2$$

Where:

α is the extrapolation factor.

Q_F is the rudder stock moment for the deepest service draught and maximum service speed condition.

Q_T is the rudder stock moment for the trial condition.

A_F is the total immersed projected area of the movable part of the rudder in the deepest seagoing condition.

A_T is the total immersed projected area of the movable part of the rudder in the trial condition.

V_F is the contractual design speed of the vessel corresponding to the maximum continuous revolutions of the main engine at the deepest seagoing draught.

V_T is the measured speed of the vessel (considering current) in the trial condition.

Where the rudder actuator system pressure is shown to have a linear relationship to the rudder stock torque the above equation can be taken as:

$$P_F = P_T \alpha$$

Where:

P_F is the estimated steering actuator hydraulic pressure in the deepest seagoing draught condition.

P_T is the maximum measured actuator hydraulic pressure in the trial condition.

Where constant volume fixed displacement pumps are utilised then the regulations can be deemed satisfied if the estimated steering actuator hydraulic pressure at the deepest draught is less than the specified maximum working pressure of the rudder actuator. Where a variable delivery pump is utilised pump data should be supplied and interpreted to

estimate the delivered flow rate corresponds to the deepest seagoing draught in order to calculate the steering time and allow it to be compared to the required time.

Where A_T is greater than $0.95A_F$ there is no need for extrapolation methods to be applied.

3. Alternatively the designer or builder may use computational fluid dynamic (CFD) studies or experimental investigations to predict the rudder stock moment at the full sea going draught condition and service speed. These calculations or experimental investigations are to be to the satisfaction of **BCS**.

In any case for the main steering gear trial, the speed of the ship corresponding to the number of maximum continuous revolution of main engine and maximum design pitch applies.

7. Requirements for tankers

7.1 General

In addition to the requirements for main class, the steering gear of tankers of 10.000 GT and above is to comply with the following requirements.

7.2 Design and Arrangement of Steering Gear

Every tanker of 10.000 GT and upwards is, subject to the provisions of 7.3, comply with the following:

7.2.1 The main steering gear is to be so arranged that in the event of loss of steering capability due to a single failure in any part of one of the power actuating systems of the main steering gear, excluding the tiller, quadrant or components serving the same purpose, or seizure of the rudder actuators, steering capability is to be regained in not more than 45 s after the loss of one power actuating system.

7.2.2 The main steering gear is to comprise either:

7.2.2.1 Two independent and separate power actuating systems, each capable of putting the rudder over from 35° on one side to 35° on the other side with

the ship at its deepest seagoing draught and running ahead at maximum ahead service speed and, under the same conditions, from 35° on either side to 30° on the other side in not more than 28 s.

7.2.2.2 At least two identical power actuating systems which, acting simultaneously in normal operation, are to be capable of putting the rudder over from 35° on one side to 35° on the other side with the ship at its deepest seagoing draught and running ahead at maximum ahead service speed and, under the same conditions, from 35° on either side to 30° on the other side in not more than 28 s. Where necessary to comply with this requirement, interconnection of hydraulic power actuating systems is to be provided. Loss of hydraulic fluid from one system is to be capable of being detected and the defective system automatically isolated so that the other actuating system or systems is to remain fully operational.

7.2.3 Steering gear other than of the hydraulic type is to achieve equivalent standards.

7.3 Alternative Solution for Tankers of 10.000 GT and Upwards, but of Less Than 100.000 DWT

7.3.1 General

For tankers 10.000 GT and upwards, but of less than 100.000 DWT, solutions other than those set out in 7.2.1, which need not apply the single failure criterion to the rudder actuator or actuators, may be permitted provided that an equivalent safety standard is achieved and that:

7.3.1.1 Following loss of steering capability due to a single failure of any part of the piping system or in one of the power units, steering capability is to be regained within 45 s, and

7.3.1.2 Where the steering gear includes only a single rudder actuator, special consideration is given to stress analysis for the design including fatigue analysis and fracture mechanics analysis, as appropriate, to the material used, to the installation of sealing arrangements and to testing and inspection and to the provision of effective maintenance.

For requirements relative to ships intended to carry oil, chemicals, or liquefied gases in bulk of 10,000 GRT and over, but less than 100,000 tonnes deadweight, fitted with non-duplicated rudder actuators, see the additional requirements set out in 7.3.2 to 7.3.6.

7.3.2 Materials

Parts subject to internal hydraulic pressure or transmitting mechanical forces to the rudder stock are to be made of duly tested ductile materials complying with recognized standards. Materials for pressure retaining components are to be in accordance with recognized pressure vessel standards. These materials are not to have an elongation of less than 12 % nor a tensile strength in excess of 650 N/mm².

7.3.3 Design

7.3.3.1 Design pressure

7.3.3.1.1 The design pressure is assumed to be at least equal to the greater of the following:

7.3.3.1.1.1 1.25 times the maximum working pressure to be expected under the operating conditions,

7.3.3.1.1.2 The relief valves setting.

7.3.3.2 Analysis

7.3.3.2.1 The manufacturers of rudder actuators are to submit detailed calculations showing the suitability of the design for the intended service.

7.3.3.2.2 A detailed stress analysis of the pressure retaining parts of the actuator is to be carried out to determine the stresses at the design pressure.

7.3.3.2.3 Where considered necessary because of the design complexity or manufacturing procedures, a fatigue analysis and fracture mechanics analysis may be required. In connection with these analyses, all foreseen dynamic loads are to be taken into account. Experimental stress analysis may be

required in addition to, or lieu of, theoretical calculations depending on the complexity of the design.

7.3.3.3 Allowable stresses

7.3.3.3.1 For the purpose of determining the general scantlings of parts of rudder actuators subject to internal hydraulic pressure the allowable stresses are not to exceed:

$$\sigma_m \leq f$$

$$\sigma_t \leq 1.5 f$$

$$\sigma_b \leq 1.5 f$$

$$\sigma_t + \sigma_b \leq 1.5 f$$

$$\sigma_m + \sigma_b \leq 1.5 f$$

where;

σ_m = Equivalent primary general membranestress

σ_t = Equivalent primary local membranestress

σ_b = Equivalent primary bendingstress

f = The lesser of σ_B/A or σ_y/B

σ_B = Specified minimum tensile strength of material at ambient temperature

σ_y = Specified minimum yield stress or 0.2 per cent proof stress of material at ambient temperature

A and B are as follows:

	Steel	Cast steel	Nodular cast iron
A	4	4.6	5.8
B	2	2.3	3.5

7.3.3.4 Burst test

7.3.3.4.1 Pressure retaining parts not requiring fatigue analysis and fracture mechanics analysis may be accepted on the basis of a certified burst test at the discretion of **BCS** and the detailed stress analysis required by 7.3.3.2.2 need not be provided.

7.3.3.4.2 The minimum bursting pressure is to be calculated as follows:

$$P_b = P \cdot A \cdot \frac{\sigma_{Ba}}{\sigma_B}$$

where;

P_b = Minimum bursting pressure

P = Design pressure as defined in 7.3.3.1.1

A = As from table in 7.3.3.3.

σ_{Ba} = Actual tensile strength

σ_B = Tensile strength as defined in 7.3.3.3.

7.3.4 Construction details

7.3.4.1 General

The construction is to be such as to minimize local concentrations of stress.

7.3.4.2 Welds

7.3.4.2.1 The welding details and welding procedures are to be approved.

7.3.4.2.2 All welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads are to be full penetration type or equivalent strength.

7.3.4.3 Oil seals

7.3.4.3.1 Oil seals between non-moving parts, forming part of the external pressure boundary, are to be of the metal upon metal type or of an equivalent type.

7.3.4.3.2 Oil seals between moving parts, forming part of the external pressure boundary, are to be duplicated, so that the failure of one seal does not render the actuator inoperative. Alternative arrangements providing equivalent protection against leakage may be accepted at the discretion of **BCS**.

7.3.4.4 Isolating valves

Isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly mounted on the actuator.

7.3.4.5 Relief valves

Relief valves for protecting the rudder actuator against over-pressure are to comply with the following:

7.3.4.5.1 The setting pressure is not to be less than 1.25 times the maximum working pressure expected under operating conditions,

7.3.4.5.2 The minimum discharge capacity of the relief valves is not to be less than the total capacity of all pumps which provide power for the actuator, increased by 10 %. Under such conditions the rise in pressure is not to exceed 10 % of the setting pressure. In this regard, due consideration is to be given to extreme foreseen ambient conditions in respect of oil viscosity.

7.3.5 Non-destructive testing

The rudder actuator is to be subjected to suitable and complete non-destructive testing to detect both surface flows and volumetric flows. The procedure and acceptance criteria for non-destructive testing is to be in accordance with requirements of recognized standards.

If found necessary, fracture mechanics analysis may be used for determining maximum allowable flaw size.

7.3.6 Testing

7.3.6.1 Tests, including hydrostatic tests, of all pressure parts at 1.5 times the design pressure are to be carried out.

7.3.6.2 When installed on board the ship, the rudder actuator is to be subjected to a hydrostatic test and a running test.

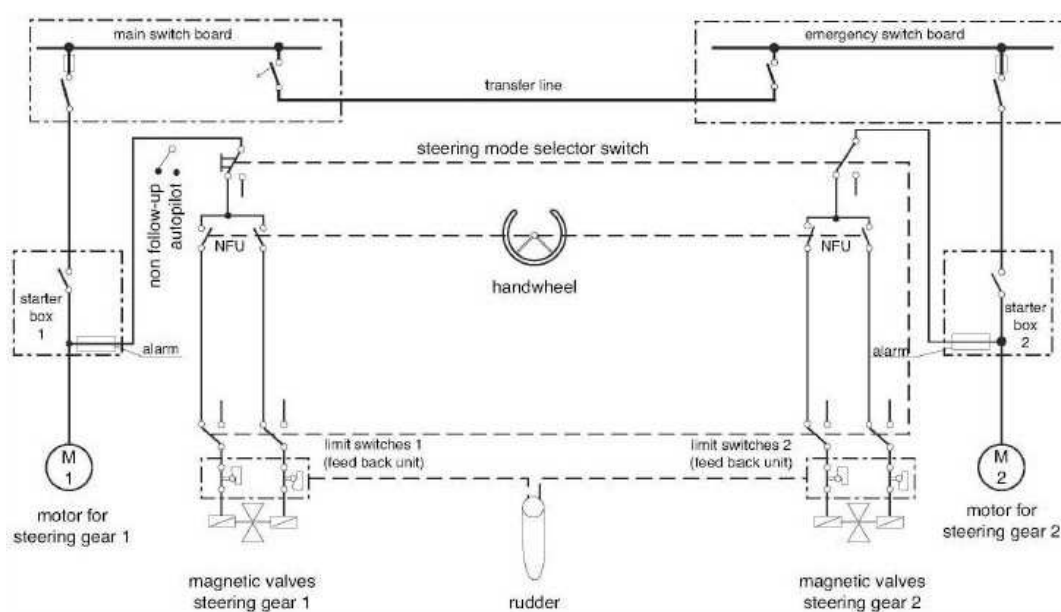


Fig. 9.2 Principle scheme for double non follow-up control and autopilot or other additional control

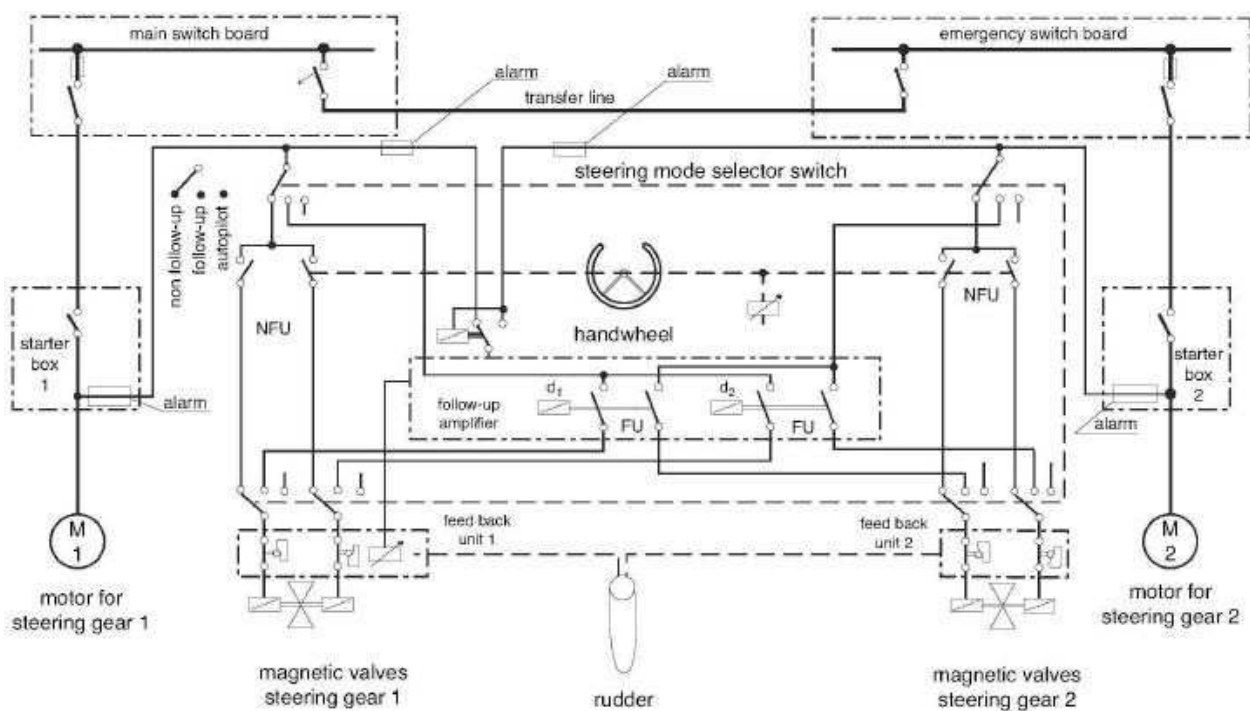
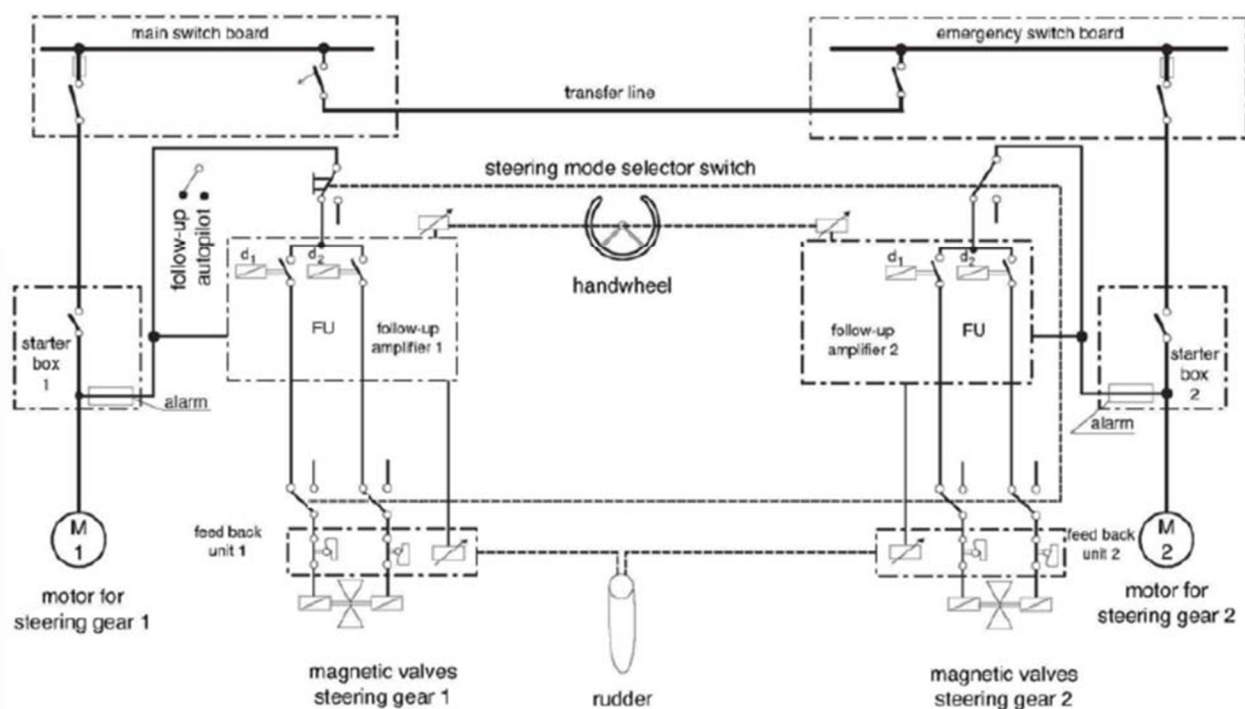


Fig. 9.4 Principle scheme for double non follow-up control and autopilot or other additional control

B. Rudder Propeller Units**1. General****1.1 Scope**

The requirements in this sub-section are to be applied to the rudder propeller as main drive, the ship's manoeuvring station and all transmission elements from the manoeuvring station to the rudder propeller.

They are to be applied analogously for other integrated propulsion and steering units, such as waterjets, cycloidal propellers, etc. Refer to Section 19 for dimensioning and materials of rudder propeller units for vessels with ice class.

Manoeuvring thrusters intended to assist manoeuvring and dynamic positioning thrusters where fitted may, at the request of the owners, be certified in accordance with the provisions of this section. In such cases, appropriate class notations will be assigned upon verification of compliance with corresponding provisions of this section.

1.2 Definitions

For the purpose of this section, the following definitions apply:

1.2.1 Thrusters**1.2.1.1 General**

Thrusters are devices capable of delivering side thrust or thrusts through 360° to improve the ship's manoeuvrability, particularly in confined waters. There are three major types of thrust units:

- The lateral or tunnel thrusters known as 'bow-thrusters', which consists of a propeller installed in an athwart-ship tunnel;
- Jet type thrusters, which consist of a pump taking suction from the keel and discharge to either side,

- Azimuth thrusters, which can be rotated through 360° so that the thrust can be developed in any direction. Cycloid propellers can be considered a type of azimuth thrusters.

1.2.1.2 Propeller-type thrusters

Regardless of whether they are normally used for propulsion, propellers intended to be operated for an extended period of time during service in a condition where the vessel is not free running approximately along the direction of the thrust are to be considered thrusters for the purposes of this section.

1.2.2 Continuous duty thrusters

Continuous duty thrusters are designed for continuous operation, such as dynamic positioning thrusters, propulsion assist, or main propulsion units.

1.2.3 Intermittent duty thrusters

Intermittent duty thrusters are designed for operation at peak power or rpm levels, or both, for periods not exceeding 1 hour followed by periods at the continuous rating or less, with total running time not exceeding 8 hours in 20 hours. Generally, such kind of thrusters is not meant to operate more than 1000 hours per year.

1.2.4 Class Notation DK 1, 2, 3

Self-propelled or non-self-propelled vessels, where fitted with a system of thrusters, positioning instruments and control systems to enable the vessel to maintain position at sea without external aid, at the discretion of the owners, may comply with the requirements in this section. Upon request by the owner and upon verification of compliance with the applicable requirements, the class notation **DK** (dynamic positioning system) followed by a numeral of **1, 2 or 3**, to indicate the degree of redundancy of the system, will be assigned.

1.3 Documents for approval

Assembly and sectional drawings as well as part drawings of the gears and propellers giving all the data

necessary for the examination are to be submitted in triplicate to **BCS** for approval.

The general arrangement of the thruster installation, its location of installation, along with its supporting auxiliary machinery and systems, fuel oil tanks, foundations, watertight boundary fittings, etc., are to be submitted.

The rated power/rpm and the rated thrust are to be indicated.

In addition, plans of each component and of the systems associated with the thruster are to be also submitted to **BCS**.

2. Materials

2.1 Approved materials

As a rule, essential torque transmitting components of the thrusters are to be made of materials complying with **BCS's** Rules of Materials.

For instance, material requirements for propellers are to be in accordance with Section 8, B, materials for shafting to be in accordance with Section 5, B, materials for gears to be in accordance with Section 7, B.1 and materials for steering systems to be in accordance with A.2.1, etc.

Where alternative material specifications are proposed, complete chemical composition and mechanical properties similar to the material required by these requirements are to be submitted to **BCS** for approval.

2.2 Testing of materials

All essential components of the rudder propeller involved in the transmission of torques and bending moments should be tested in the presence of a **BCS** Surveyor for verification of their material compliance with the applicable requirements for Chapter 2 - Material, or such other appropriate material specifications as may be approved in connection with a particular design. The materials of the following components shall be tested:

- Shaft, shaft flanges, keys,
- Gears (propulsion and steering),
- Propellers,
- Impellers,
- Couplings,
- Coupling bolts.

Bolts manufactured to a recognized standard and used as coupling bolts does not need to be tested in the presence of **BCS** Surveyor.

3. Design and equipment

3.1 Number of rudder propellers

Each ship is to have at least two rudder propellers. Both units are to be capable of being operated independently of the other.

For a ship fitted with multiple steering propulsion units, such as but not limited to azimuthing propulsors or water jet propulsion systems, each of the steering-propulsion units shall be provided with a main steering gear and an auxiliary steering gear or with two or more identical steering actuating systems in compliance with 3.3.5. The main steering gear and the auxiliary steering gear shall be so arranged that the failure of one of them will not render the other one inoperative.

For a ship fitted with a single steering-propulsion unit, the requirement in item A.3.1.1 is considered satisfied if the steering gear is provided with two or more steering actuating systems and is in compliance with 3.3.5. A detailed risk assessment is to be submitted in order to demonstrate that in the case of any single failure in the steering gear, control system and power supply the ship steering is maintained.

3.2 Locking devices

Each rudder propeller is to be provided with a locking device to prevent the unintentional rotation of the propeller and the unintentional movements of the steering mechanism of the unit which is out of service at any time.

The locking device shall be designed to lock securely the non-operated rudder propeller unit while the ship is cruising with maximum (full) power of remaining rudder propeller units, at a ship speed of not less than 7 knots. Furthermore, it should be possible to lock the steering mechanism at midship position and operate the locked rudder propeller unit with full power.

3.3 Steering

3.3.1 Each rudder propeller is to be fitted with its own dedicated steering gear.

3.3.2 All components used in steering arrangements for ship directional control are to be of sound reliable construction to the satisfaction of the Administration or **BCS** if authorized. Special consideration shall be given to the suitability of any essential component which is not duplicated.

Any such essential component shall, where appropriate, utilize anti-friction bearings such as ball bearings, roller bearings or sleeve bearings which shall be permanently lubricated or provided with lubrication fittings.

3.3.3 The main steering arrangements for ship directional control shall be:

- of adequate strength and capable of steering the ship at maximum ahead service speed which shall be demonstrated;
- capable of changing direction of the steering-propulsion unit from one side to the other at declared steering angle limits at an average turning speed of not less than 2.3°/s with the ship running ahead at maximum ahead service speed;

- for all ships, operated by power; and
- so designed that they will not be damaged at maximum astern speed; this design requirement need not be proved by trials at maximum astern speed and declared steering angle limits.

Ship manoeuvrability tests, such as according to Resolution MSC.137(76) on Standards for ship manoeuvrability, are to be carried out with steering angles not exceeding the declared steering angle limits.

Definition: Declared steering angle limits are the operational limits in terms of maximum steering angle, or equivalent, according to manufacturers' guidelines for safe operation, also taking into account the ship's speed or propeller torque/speed or other limitation; the "declared steering angle limits" are to be declared by the directional control system manufacturer for each ship specific non-traditional steering mean; ship manoeuvrability tests, such as those in the Standards for ship manoeuvrability (resolution MSC.137(76)) are to be carried out with steering angles not exceeding the declared steering angle limits.

3.3.4 The auxiliary steering arrangements for ship directional control shall be:

- of adequate strength and capable of steering the ship at navigable speed and of being brought speedily into action in an emergency;
- capable of changing direction of the ship's directional control system from one side to the other at declared steering angle limits at an average turning speed of not less than 0.5°/s with the ship running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater; and
- for all ships, operated by power where necessary to meet the requirements of SOLAS regulation II-1/29.4.2 (A.3.3.1.2) and in any ship having power of more than 2,500

kW propulsion power per steering-propulsion unit.

Ship manoeuvrability tests, such as according to Resolution MSC.137(76), are to be carried out with steering angles not exceeding the declared steering angle limits.

The definition of "declared steering angle limits", set out in the above item 3.3.3, applies.

3.3.5 For a ship fitted with a single steering-propulsion unit where the main steering gear comprises two or more identical power units and two or more identical steering actuators, an auxiliary steering gear need not be fitted provided that the steering gear:

- in a passenger ship is capable of satisfying the requirements in 3.3.3 while any one of the power units is out of operation;
- in a cargo ship, is capable of satisfying the requirements in 3.3.3 while operating with all power units; and
- is arranged so that after a single failure in its piping system or in one of the power units' steering capability can be maintained or speedily regained.

For a ship fitted with multiple steering propulsion units, where each main steering system comprises two or more identical steering actuating systems, an auxiliary steering gear need not be fitted provided that each steering gear:

- in a passenger ship, is capable of satisfying the requirements in 3.3.3 while any one of the steering gear steering actuating systems is out of operation;
- in a cargo ship, is capable of satisfying the requirements in 3.3.3 while operating with all steering gear steering actuating systems;

- is arranged so that after a single failure in its piping or in one of the steering actuating systems, steering capability can be maintained or speedily regained the above capacity requirements apply regardless whether the steering systems are arranged with common or dedicated power units.

Definition: Steering gear power unit – For the purposes of alternative steering arrangements, the steering gear power unit is to be considered as defined in A.1.3.3 (SOLAS regulation II-1/3). For electric steering gears, refer to A.1.3.3 (SOLAS regulation II-1/3); electric steering motors are to be considered as part of the power unit and actuator.

3.3.6 An auxiliary steering arrangement can be dispensed with if, in case of one rudder propeller unit out of operation, with the remaining rudder propeller unit(s) sufficient steering ability and ship speed is available for safe manoeuvring.

3.3.7 An emergency steering device is to be provided for each rudder propeller. In case of a failure of the main steering system the emergency steering device is at least to be capable of moving the rudder propeller to midship position in a reasonable time while the ship is at zero speed.

3.4 Control

3.4.1 Both the drive and the turning (slewing) mechanism of each rudder propeller shall be controlled from a manoeuvring station on the navigating bridge.

The controls must be mutually independent and so designed that the rudder propeller cannot be shifted or turned unintentionally.

Any additional combined control systems or mechanisms for the rudder propellers are also permitted.

Means have to be provided, fulfilling the same purpose as the steering angle limitation as in A.3.5. These may be dispensed with in cases where no danger for the ship is caused by unintentional turning (slewing) of the units at full power and ship speed to any angle.

3.4.2 The failure of a single element within the control and hydraulic system of one unit shall not lead to the failure of the other units.

3.4.3 Where the hydraulic systems of more than one rudder propeller are combined, it must be possible in case of any loss of hydraulic oil to isolate the damaged system in such a way that the other control systems remain fully operational.

3.5 Position indicators

3.5.1 The position of each rudder propeller must be clearly discernible on the navigating bridge and at each manoeuvring station.

3.5.2 The actual position must also be discernible at the rudder propeller itself.

3.6 Pipes

The pipes of hydraulic control systems are subject to the provisions of A.3.11 wherever relevant.

3.7 Oil level indicators, filters

Oil level indicators and filters are subject to the provisions of A.3.12 wherever relevant.

3.8 Lubrication

3.8.1 The lubricating oil supply is to be ensured by a main pump and an independent standby pump.

3.8.2 In the case of separate lubricating system in which the main lubricating oil pumps can be replaced with the means available on board, the standby pump may be replaced by a spare pump. The mentioned spare pump is to be carried on board and is to be ready for mounting.

3.9 Accessibility for inspection

Adequate access covers are to be provided to permit inspection of gear train without disassembling thruster units.

3.10 For a ship fitted with multiple steering systems, the requirements in Chapter 5 - Electrical Installation, Section 7, A.2.2 (SOLAS regulation II-1/30.2) are to be applied to each of the steering systems.

3.11 Alternative source of power

Where the alternative power source required by SOLAS II-1 Regulations 29.14 is a generator, or an engine driven pump, the automatic starting arrangements must comply with the requirements relating to the automatic starting arrangements of emergency generators.

Below paragraph is valid to the steering propulsion units having a certain proven steering capability due to ship speed also in case propulsion power has failed.

Where the propulsion power exceeds 2,500kW per thruster unit, an alternative power supply, sufficient at least to supply the steering arrangements which complies with the requirements of SOLAS regulation II-1/29.4.2(A.3.3.1.2) and also its associated control system and the steering gear response indicator, shall be provided automatically, within 45 s, either from the emergency source of electrical power or from an independent source of power located in the steering gear compartment. This independent source of power shall be used only for this purpose.

In every ship of 10,000 gross tonnage and upwards, the alternative power supply shall have a capacity for at least 30 min of continuous operation and in any other ship for at least 10 min.

4. Dimensioning

4.1 Gears

For the design of gears see Section 7.

The turning gears are in general to take the form of spur gears or bevel gears.

4.2 Shaft line

For the dimensioning of the propeller shaft, between propeller and gear wheel, see Section 5. For the dimensioning of the remaining part of this shaft and all other shafts see Section 7.

4.3 Propellers

For the design of propellers, see Section 8, Propellers.

4.4 Antifriction bearings and estimating of their life

Full bearing identification and life calculations are to be submitted. Calculations are to include all gear forces, thrust vibratory loads at maximum continuous rating, etc.

The minimum L_{10} (2) life for the antifriction bearings is not to be less than the following:

- 20,000 hours for continuous duty thrusters (propulsion and **DPS-0,-1,-2,-3**)
- 5,000 hours for intermittent duty thrusters

Shorter life may be considered in conjunction with an approved bearing inspection/replacement program reflecting calculated life.

The prediction of the life of a rolling-element bearing (ball, roller, needle) is a statistical calculation of the fatigue properties of the bearing components, in which life is stated as the number of hours that a specified percentage of a large population of apparently-identical bearings will survive under a specified load with a specified set of operating conditions. The usual life rating for industrial applications is called L_{10} . The L_{10} life is the number of hours in service that 90% of a large population of apparently-identical bearings will survive when subjected to the boundary conditions (load,

speed, lubrication, material and cleanliness) that are specific to the application. Stated another way, 10% of that population will have failed in the L_{10} number of service hours.

There is more than just one bearing life calculation method, but in all cases the following bearing life estimating formula is valid:

$$L_{10} = \left(\frac{C}{P} \right)^{\frac{10}{3}} \frac{B}{N^a} \quad (10)$$

Where:

- L = Estimated bearing life, [hours]
- R = Radial rating of the bearing, [N]
- P = Dynamic equivalent radial load applied on the bearing (2), [N]
- B = $10^6/60$ factor dependent on ISO method (i.e. life hours times rpm) [-]
- a = Life adjustment factor [-]
- = 1.0, when ambient conditions are omitted
- N = Rotational speed [rpm].

4.5 Support pipe

Dimensioning of the support pipe and its attachment to the ship's hull should take account of the loads due to the propeller and nozzle thrust including the dynamic components.

4.6 Pipes

For arrangement and design of pipes, valves, fittings and pressure vessels, see Section 14 and Section 16 A, B, C, D and U.

(2) L_{10} Bearing life is described in ISO and ABMA (American Bearing Manufacturer Association) Standards.

5. Further Requirements for Thruster Compartments

5.1 Ventilation

Thruster compartments are to be provided with suitable ventilation so as to allow simultaneously for crew attendance and for thruster machinery to operate at rated power in all weather conditions.

5.2 Fire fighting systems

In general, spaces where thrusters are located, including enclosed modules, are to be protected with fire fighting system in accordance with the requirements in Section 18.

5.3 Bilge system

Thrusters installed in normally unattended spaces are to be arranged such that bilge pumping can be effected from outside the space.

Alternatively, where bilge pumping can only be effected from within the space, a bilge alarm to warn of high bilge water level is to be fitted in a centralized control station, the navigation bridge or other normally manned control station.

For bilge systems in general, see Section 16.

Thrusters in enclosed modules (capsules) are to be provided with a high water level alarm.

At least one pump capable of bilging the module is to be operable from outside the module.

6. Tests in the Manufacturer's Work

6.1 Testing of power units

A.5.3 applies wherever relevant.

6.2 Pressure and tightness test

A.5.4 applies wherever relevant.

6.3 Final inspection and operational test

6.3.1 After inspection of the individual components and completion of assembly, rudder propellers are to undergo a final inspection and operational test. The final inspection shall be combined with a trial run lasting several hours under part or full-load conditions. A check is to be carried out on the tooth clearance and contact pattern.

6.3.2 When no suitable test bed is available for the operational and load testing of large rudder propellers, the tests mentioned in 6.3.1 can be carried out on the occasion of the dock test.

6.3.3 Limitations on the scope of the test require the consent of **BCS**.

7. Certification and Trials

7.1 Thrusters and associated equipment are to be inspected, tested and certified by **BCS**. Upon completion of the installation, performance tests are to be carried out in the presence of **BCS** Surveyor in a sea trial. This is to include but not limited to running tests at intermittent or continuous rating, variation through design range of the magnitude and/or direction of thrust, vessel turning tests and ship manoeuvring tests. See also Section 1 item I for test and trials.

7.2 The faultless operation, smooth running and bearing temperatures of the gears and control system are to be checked during the sea trials under all steaming conditions.

After the conclusion of the sea trials, the toothing is to be examined through the inspection openings and the contact pattern is to be checked. The tooth contact pattern is to be assessed on the basis of the reference values for the percentage area of contact given in Section 7, Table 7.11.

7.3 The scope of the check on contact pattern following the sea trials may be limited with the Surveyor's agreement provided that the checks on contact pattern called for in 6.3.1 and 6.3.2 have been satisfactory.

7.4 The stopping times, ship headings and distances recorded on trials, together with the results of trials to determine the ability of ships having multiple propulsion/steering arrangements to navigate and manoeuvre with one or more of these devices inoperative, shall be available on board for the use of the master or designated personnel.

C. Lateral Thrust Units (Bow Thrusters)

1. General

1.1 Scope

The requirements in this sub-section apply to the lateral thrust units, the control station and all the transmission elements from the control station to the lateral thrust units.

Refer to Section 19 for dimensioning and materials of lateral thrust units for vessels with ice class.

1.2 Documents for approval

Assembly and sectional drawings for lateral thrust units with an input power of 100 kW and more together with detail drawings of the gear mechanism and propellers containing all the data necessary for checking are each to be submitted to **BCS** in triplicate for approval. For propellers, this only applies to an input propulsive power exceeding 500 kW.

2. Materials

Materials are subject, as appropriate, to the provisions of Sections 5 and 7.

Section 8, Propellers applies analogously to the materials and the material testing of propellers.

In case of an input power of less than 100 kW, the properties of the materials used for shafts, gears and propellers must comply with Chapter 2 - Material, Section 1. Proof may take place by manufacturer's inspection certificates.

3. Dimensioning and Design

3.1 General requirements

Dimensioning of the relevant components of lateral thrust units is governed by Section 5 and Section 7, that of the propellers by Section 8.

The pipe connections of hydraulic drive systems are subject to the applicable requirements contained in A.2.1.3 and A.2.1.4.

Lateral thrust units must be capable of being operated independently of other connected systems.

Unmanned spaces located below the waterline, such as bow thruster compartment, emergency fire pump room, etc., for which bilge pumping is required, are to be arranged such that bilge pumping can be effected from outside the space, or alternatively, a bilge alarm is to be provided.

Windmilling of the propeller during sea passages has to be taken into account as an additional load case. Otherwise effective countermeasures have to be introduced to avoid windmilling, e.g. a shaft brake.

In the propeller area, the thruster tunnel must be protected against damages caused by cavitation erosion by effective measures, such as stainless steel plating.

For monitoring the lubricating oil level, equipment shall be fitted to enable the oil level to be determined.

For the electrical part of lateral thrust units, see Chapter 5 - Electrical Installations, Section 7, B.

3.2 Additional requirements for lateral thrust units for dynamic positioning (DK)

Bearings, sealings, lubrication, hydraulic system and all other aspects of the design must be suitable for continuous, uninterrupted operation.

Gears must comply with the safety margins for DP as specified in Section 7, Table 7.1. The lubrication system for the gearbox must comply with Section 7, E.

For units with controllable pitch propellers, the hydraulic system must comply with Section 8, D.4.2.

The selection and arrangement of filters has to ensure an uninterrupted supply with filtered oil, also during filter cleaning or exchange.

Where ships are equipped with automated machinery, the thruster unit has to comply with the requirements for main gears and main propellers in Chapter 4-1 - Automation.

4. Test in Manufacturer's Works

A.5 is applicable as appropriate. For hydraulic pumps and motors with a drive power of 100 kW or more, the tests are to be conducted in the presence of a **BCS** Surveyor.

For lateral thrust units with an input power of less than 100 kW final inspection and function tests may be carried out by the manufacturer, who will then issue the relevant Manufacturer Inspection Certificate.

5. Shipboard Trials

Testing is to be carried out during sea trials during which the operating times are to be established.

SECTION 10**HYDRAULIC SYSTEMS, FIRE DOORS AND STABILIZERS**

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A. Hydraulic Systems

1. General

1.1 Scope

The requirements in this section should be applied to hydraulic systems used, for example, to operate hatch covers, closing appliances in the ship's shell and bulkheads, and hoists.

The requirements are to be applied in analogous manner to the ship's other hydraulic systems except where covered by the requirements in Section 16.

1.2 Definitions

A power unit is the assembly formed by the hydraulic pump and its driving motor control and safety valves, oil reservoir and oil conditioning equipment

An actuator is a component which directly converts hydraulic pressure into mechanical action

1.3 Documents for approval

The diagram of the hydraulic system together with drawings of the cylinders and/or hydraulic motors containing all the data necessary for assessing the system, e.g. operating data, descriptions, materials used etc., are to be submitted in triplicate for approval.

1.4 Design principles

1.4.1 Hydraulic systems fitted in self-contained equipment not associated with propulsion and manoeuvring of the vessel (e.g., a crane) and completely assembled by the equipment manufacturer need not comply with this subsection. Such hydraulic systems, however, are to comply with the accepted industry standards.

Hydraulic oil systems essential for the propulsion and manoeuvring of the vessel are subject to further requirements. Controllable pitch propeller (CPP) hydraulic system and steering gear hydraulic systems are also to comply with the requirements in Section 8, D and Section 9, A and B respectively.

1.4.2 The hydraulic system failure is not to be resulted from machinery installation and arrangement.

Provision is to be made for hand operation of the systems in an emergency, unless an acceptable alternative is available.

Where hydraulic securing arrangements are applied, the system is to be capable of being locked in the closed position so that in the event of hydraulic system failure the securing arrangements will remain locked.

Where pilot operated non-return valves are fitted to hydraulic cylinders for locking purposes, the valves are to be connected directly to the actuating cylinder(s) without intermediate pipes or hoses.

Hydraulic circuits for securing and locking of bow, inner, stern or shell doors are to be arranged such that they are isolated from other hydraulic circuits when securing and locking devices are in the closed position. For requirements relating to hydraulic steering gear arrangements, see Section 9, A.

1.4.3 Hydraulic fluids are to be suitable for the intended purpose under all the ambient and the operating service conditions.

1.4.4 Connecting of the steering gear hydraulic pipelines and those of the hydraulic power systems of CPP to any other hydraulic systems are not permitted.

Connecting of pipelines of the engine room trunk closures hydraulic drive system to other hydraulic systems is not permitted.

For the passenger ships and the special purposed ships, the connections of the pipeline systems of power-operated watertight sliding doors to other hydraulic systems are not permitted.

1.4.5 If any pipeline connection between the servicing hydraulic anchor machinery and the other hydraulic systems is inevitable, the other hydraulic systems are to be driven by two separate pump units, each of which shall ensure the anchor gear operation with nominal pull and at nominal heaving-in speed.

1.4.6 For the passenger ships and the special purposed ships, the hydraulic systems of the power operated sliding doors may be centralized or independent from each other.

1.4.6.1 The centralize systems shall be provided with a low-level alarm for hydraulic fluid reservoirs serving the system and a low-level gas pressure alarm for hydraulic accumulators. Other effective means of monitoring of the energy loss in hydraulic accumulators may be also provided. These alarms shall be audible and visual and are to be situated on the operating console at the navigation bridge and at the engine room control station.

Centralize systems are to be so designed to minimize the possibility of a failure in the operation of more than one door caused by damage to a single part of the system.

1.4.6.2 An independent hydraulic system for each watertight sliding door is to have a low gas pressure group alarm or other effective means of monitoring loss of stored energy in hydraulic accumulators situated at the operating console on the navigating bridge. Loss of stored energy indication is to be provided at each local operating position.

Hydraulic accumulators having operating pressures above 690 kPa are to be certified in accordance with Section 14 as pressure vessels regardless of their diameters. (See also Section 9, A.1.3.10)

Each accumulator which may be isolated from the system is to be protected by its own relief valve or equivalent. Where a gas charging system is used, a relief valve is to be provided on the gas side of the accumulator.

1.4.7 The hydraulic systems are to be provided with the filters of appropriate capacity and filtration level of the pressurized fluid.

For the hydraulic systems of steering gear and couplings etc, suitable precautions and provisions are to be utilized for cleaning the filter without causing any interruption of the system operation.

1.4.8 Safety or relief valves are to be fitted to protect the system from overpressure. The relieving capacity is not to be less than full pump flow with a maximum pressure rise in the system of not more than 1.1 times the rated pressure of relief valve setting.

Valves are to meet the general requirements of certification in Section 16. Directional valves are to be treated as pipe fittings and are subject to pressure, temperature and fluid service restrictions specified by the manufacturers.

1.4.9 Over-pressure protection is to be provided on the discharge side of all pumps. Where relief valves are fitted for this purpose they are to be fitted in closed circuit, i.e. arranged to discharge back to the system oil tank.

Suitable oil collecting arrangements for leaks shall be fitted below hydraulic valves and cylinders.

Hydraulic oil tanks are not to be situated where spillage or leakage there from can constitute a hazard by dripping on heated surfaces in excess of 220°C

1.4.10 Arrangements for complete air escape during filling the pipeline and machinery with hydraulic fluid, as well as for leakage replenishment and drainage should be provided.

Hydraulic tank vents are to meet the requirements in Section 16. Vents from hydraulic oil tanks, other than double bottom or similar structural tanks, may be terminated in machinery and other enclosed spaces provided that their outlets are so located that overflow there from will not impinge on electrical equipment, heated surfaces or other sources of ignition.

1.4.11 Oil seals between the fixed parts assigning the level of external pressure limit are to be "metal on metal" type.

Oil seals between the moving parts of the hydraulic system are to be doubled in such a way that the failure of one seal would not disable the executive actuator.

Any other alternatives providing the equivalent leakage protection may be accepted upon the special agreement with **BCS**.

Materials used for all parts of hydraulic seals are to be compatible with the working fluid at the appropriate working temperature and pressure.

1.4.12 Hydraulic systems shall be provided with a sufficient amount of the instruments to monitor its operation.

1.4.13 Hydraulic power units, including pumps and other pressurized components, with working pressure above 1.5 MPa installed within machinery spaces are to be placed in separate room or shielded, as necessary, to prevent any oil or oil mist that may escape under pressure from coming into contact with surfaces with temperatures in excess of 220°C, electrical equipment or other sources of ignition. Piping and other components are to have as few joints as practicable.

1.4.14 Hydraulic power installations with a design pressure of less than 2.5 MPa and hydraulic power packs of less than 5 kW are to be given special consideration by **BCS**.

1.4.15 Hydraulic power installations with a design pressure exceeding 35 MPa will be given special consideration by **BCS**.

1.4.16 Oils used for hydraulic power installations are to have a flashpoint not lower than 150°C and be suitable for the entire service temperature range.

The hydraulic oil is to be replaced in accordance with the specification of the installation manufacturer.

1.4.17 Whenever practicable, hydraulic power units are to be located outside main engine or boiler rooms.

Where this requirement is not complied with, shields or similar devices are to be provided around the units in order to avoid an accidental oil spray or jet on heated surfaces which may ignite oil.

1.4.18 Where it is necessary, appropriate cooling devices are to be provided.

1.5 Dimensioning

See Section 14 for the design of pressure vessels, see Section 16 for the dimensions of pipes and hose assemblies.

2. Materials

2.1 Approved materials

2.1.1 Components fulfilling a major function in the power transmission system normally are to be made of steel or cast steel in accordance with Chapter 2 - Material. The use of other materials is subject to special agreement with **BCS**.

Cylinders are preferably to be made of steel, cast steel or nodular cast iron (with a predominantly ferritic matrix).

2.1.2 Pipes are to be made of seamless or longitudinally welded steel tubes according to their operating pressure.

2.1.3 The pressure-loaded walls of valves, fittings pumps, motors etc. are subject to the requirements of Section 16. B.

2.2 Testing of materials

The following components are to be tested under the supervision of **BCS** in accordance with Chapter 2

- Material:

- Pressure pipes $D_N > 32$ (see Section 16, Table 16.6)

- Cylinders, where the product of the pressure times the diameter:

$$p \cdot D_i > 20.000$$

Where;

p = Maximum permissible working pressure [bar],

D_i = Inner diameter of tube [mm].

- For testing the materials of hydraulic accumulators, see Section 14, B.

Testing of materials by **BCS** may be dispensed with in the case of cylinders for secondary applications provided that evidence in the form of a Manufacturer's Test Certificate (e.g. to EN 10204 – 2.3) is supplied.

3. Hydraulic Operating Equipment for Hatch Covers

3.1 Design and construction

3.1.1 Doors and hatches fitted with gaskets and dogs are to be provided with means of indicating locally and on the bridge whether they are open or secured closed. For this purpose, all dogs are to be monitored individually. When all dogs are linked to a single acting mechanism, then only the monitoring of a single dog is required.

3.1.2 Hydraulic operating equipment for hatch covers may be served either by one common power station for all hatch covers or by several power stations individually assigned to a single hatch cover. Where a common power station is used, at least two pump units are to be fitted. Where the systems are supplied individually, change-over valves or fittings are required so that operation can be maintained should one pump unit fail.

3.1.3 Movement of hatch covers may not be initiated merely by the starting of the pumps. Special control stations are to be provided for controlling the opening and closing of hatch covers. The controls are to be so designed that, as soon as they are released, movement of the hatch covers stops immediately.

The hatches should normally be visible from the control stations. Should this, in exceptional cases, be impossible, opening and closing of the hatches is to be signalled by an audible alarm. In addition, the control stations must then be equipped with indicators for monitoring the movement of the hatch covers.

At the control stations, the controls governing the opening and closing operations are to be appropriately marked.

3.1.4 Suitable equipment must be fitted in, or immediately adjacent to, each power unit (cylinder or similar) used to operate hatch covers to enable the hatches to be closed slowly in the event of a power failure, e.g. due to a pipe rupture.

3.2 Pipes

3.2.1 Pipes are to be installed and secured in such a way as to protect them from damage while enabling them to be properly maintained from outside.

Pipes may be led through tanks in pipe tunnels only. The laying of such pipes through cargo spaces is to be restricted to the essential minimum. The piping system is to be fitted with relief valves to limit the pressure to the maximum permissible working pressure.

3.2.2 The piping system is to be fitted with connectors for draining, cleaning and flushing for cleaning the hydraulic fluid.

Equipment is to be provided to enable the hydraulic system to be purged.

3.2.3 The oil chamber of the hydraulic accumulator must have permanent access to the relief valve of the connected system. The gas chamber of the accumulator may be filled only with inert gases. Gas and operating medium are to be separated by accumulator bags, diaphragms or similar.

3.2.4 Connection between the hydraulic system used for hatch cover operation and other hydraulic systems is permitted only with the consent of **BCS**.

3.2.5 For oil level indicators, see Section 9, A.3.12.

3.2.6 The hydraulic fluids must be suitable for the intended ambient and service temperatures.

3.3 Hose assemblies

The construction of hose assemblies shall conform to

Section 16, U. The requirement that hose assemblies should be of flame (or fire) resistant construction may be set aside for hose lines in spaces not subject to a fire hazard and in systems not important to the safety of the ship.

3.4 Emergency operation

It is recommended that devices be fitted which are independent of the main system and which enable hatch covers to be opened and closed in the event of failure of the main system. Such devices may, for example, take the form of loose rings enabling hatch covers to be moved by cargo winches, warping winches etc.

4. Hydraulically Operated Closing Appliances in the Ship's Shell

4.1 Scope

The following requirements apply to the power equipment of hydraulically operated closing appliances in the ship's shell such as shell and landing doors which are normally not operated while at sea. For the design and arrangement of the closures, see Chapter 1 - Hull, Section 6, F.

4.2 Design

4.2.1 Where bow doors and inner doors give access to a vehicle deck, or where side shell doors or stern doors are located partially or totally below the freeboard deck with a clear opening area greater than 6 m², an arrangement for remote control from a position above the freeboard deck is to be provided allowing closing and opening of the doors and associated securing and locking of every door.

4.2.2 The operating panels for doors are to be accessible to authorized persons only.

4.2.3 A notice plate giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour is to be placed at each operating panel and is to be supplemented by warning indicator lights.

4.2.4 The display system and the alarm system are to be of self-monitoring type. The alarm system is to be designed on the fail-safe principle. Separate indicator lights are to be provided on the navigation bridge and on each operating panel to show that the doors are closed and that their locking devices are properly positioned. Indicator lights are to be designed so that they cannot be manually turned off. The display panel on the navigation bridge is to be equipped with a mode selection function "harbour/sea voyage", arranged so that an audible and visible alarm is given on the navigation bridge if, in the sea voyage condition, the doors are not closed or any of the securing devices are not in the correct position. Display of the open/closed position of every door and every securing and locking device is to be provided at the operating panels. The display panel is to be also provided with a lamp test function.

4.2.5 The movement of shell doors etc. may not be initiated merely by the starting of the pumps at the power station.

4.2.6 Local control, inaccessible to unauthorized person, is to be provided for every closing appliance in the ship's shell. As soon as the controls (push-buttons, levers or similar) are released, movement of the appliance must stop immediately.

4.2.7 Closing appliances in the ship's shell should normally be visible from the control stations. If the movement cannot be observed, audible alarms are to be fitted. In addition, the control stations are then to be equipped with indicators enabling the execution of the movement to be monitored.

4.2.8 Closing appliances in the ship's shell are to be fitted with devices which prevent them from moving into their end positions at excessive speed. Such devices are not to cause the power unit to be switched off.

As far as is required, mechanical means must be provided for locking closing appliances in the open position.

4.2.9 Every power unit driving horizontally hinged or vertically operated closing appliances is to be fitted with

throttle valves, load holding valves or similar devices to prevent sudden dropping of the closing appliance.

4.2.10 It is recommended that the driving power be shared between at least two mutually independent pump sets.

4.3 Pipes, hose assemblies

Requirements 3.2 and 3.3 should be applied in analogous manner to the pipes and hose lines of hydraulically operated closing appliances in the ship's shell.

5. Bulkhead Closures

5.1 General

5.1.1 Scope

5.1.1.1 The following requirements apply to the power equipment of hydraulically operated watertight bulkhead doors on passenger and cargo ships.

5.1.1.2 For the quantity, design and arrangement of the watertight doors, see Chapter 1 - Hull, Section 11, A.5.

The SOLAS regulations, Chapter II-1 rules 15, 16 and Subsection 25.9 are not affected by these provisions.

5.1.2 Design

Bulkhead doors shall be power-driving sliding doors moving horizontally. Other designs require the approval of **BCS** and the provisions of additional safety measures, where necessary.

5.1.3 Piping

5.1.3.1 Wherever applicable, the requirements for pipes in hydraulic bulkhead closing systems are governed by the requirements in 3.2, with the restriction that the use of flexible hoses assemblies is not permitted.

5.1.3.2 The hydraulic fluids must be suitable for the

intended ambient and service temperatures.

5.1.4 Drive unit

5.1.4.1 A selector switch with the switch positions "local control" and "close all doors" is to be provided at the central control station on the bridge. Under normal conditions this switch should be set to "local control".

In the "local control" position, the doors may be locally opened and closed without automatic closure.

In the "close all doors" position, all doors are closed automatically. They may be reopened by means of the local control device but must close again automatically as soon as the local door controls are released. It is not to be possible to open the closed doors from the bridge.

5.1.4.2 Closed or open bulkhead doors shall not be set in motion automatically in the event of any power failures.

5.1.4.3 The control system is to be designed in such a way that an individual fault inside the control system, including the piping, does not have any adverse effect on the operation of other bulkhead doors.

5.1.4.4 The controls for the power drive are to be located at least 1.6 m. above the floor on both sides of the bulkhead close to the door. The controls are to be installed in such a way that a person passing through the door is able to hold both controls in the open position.

The controls must return to their original position automatically when released.

5.1.4.5 The direction of movement of the controls is to be clearly marked and must be the same as the direction of movement of the door.

5.1.4.6 In the event that an individual element fails inside the control system for the power drive, including the piping but excluding the closing cylinders on the door or similar components, the operational ability of the manually-operated control system must not be impaired.

5.1.4.7 The movement of the power driven bulkhead doors may not be initiated simply by switching on the drive units but only by actuating additional devices.

5.1.4.8 The control and monitoring equipment for the drive units is to be housed in the central control station on the bridge and locally on the unit.

5.1.5 Manual control

Each door must have a manual control system which is independent of the power drive.

5.1.6 Indicators

Visual indicators to show whether each bulkhead door is fully open or closed are to be installed at the central control station on the bridge.

5.1.7 Electrical equipment

For details of electrical equipment, see Chapter 5 - Electrical Installations Sections 9, D. and 14, D.

5.2 Passenger vessels

In addition to the requirements in 5.1, the following regulations are to be taken into consideration for passenger vessels:

5.2.1 Design and location

5.2.1.1 Bulkhead doors together with the power plants and including the piping, electric cables and control instruments must have a minimum distance of 0.2 B from the perpendiculars which intersect the hull contour line when the ship is at load draught (B=beam).

5.2.1.2 The bulkhead doors must be capable of being closed securely using the power drive as well as using the manual control even when the ship has a permanent heel of 15°.

5.2.1.3 The force required to close a door is to be calculated based on a static water pressure of at least 1 m. above the door coaming.

5.2.1.4 All power driven doors must be capable of being closed simultaneously from the bridge with the ship upright in no more than 60 seconds.

5.2.1.5 Closing speed of each individual door must have a uniform rate. Closing time for the power driven (or hydraulically operated) doors should be not more than 40 seconds and not less than 20 seconds while the ship is in the upright condition.

5.2.1.6 Power operated bulkhead closing systems may be fitted as an option with a central hydraulic drive for all doors or with mutually independent hydraulic or electric drives for each individual door.

5.2.1.7 Bulkhead closing system shall not be connected to other systems.

5.2.2 Central hydraulic system - power drives

5.2.2.1 Two mutually independent power/pump units are to be installed, if possible above the bulkhead or freeboard deck and outside the machinery spaces.

5.2.2.2 Each pump unit must be capable of closing all connected watertight doors simultaneously at full speed.

5.2.2.3 The hydraulic system must incorporate accumulators with sufficient capacity to operate all the connected doors three times, i.e. to close, open and reclose them, at the minimum allowable accumulator pressure.

5.2.3 Individual hydraulic drive

5.2.3.1 An independent power pump unit is to be fitted to each door for opening and closing the door.

5.2.3.2 An accumulator is to be provided with sufficient capacity to operate the door three times, i.e. to close, open and reclose, at a minimum permissible accumulator pressure.

5.2.4 Individual electric drive

5.2.4.1 An independent electric drive unit is to be fitted to each door for opening and closing the door.

5.2.4.2 In the event of a failure of either the main power supply or the emergency power supply, the drive unit is still to be capable of operating the door three times, i.e. close, open and reclose.

5.2.5 Manual control

5.2.5.1 Manual control shall be capable of being operated at the door from both sides of the bulkhead as well as from an easily reachable control station located above the bulkhead or freeboard decks and outside the machinery space.

5.2.5.2 The controls at doors should allow the doors to be opened and closed.

5.2.5.3 The control devices should be able to close the door from above deck.

5.2.5.4 Manual drive mechanisms shall be capable of closing a fully opened door within 90 seconds with the ship upright.

5.2.5.5 A means of communication is to be provided between the control stations for remote manual drive above the bulkhead or the freeboard deck and the central control station on the navigation bridge.

5.2.6 Indicators

The indicators described in 5.1.6 are to be installed at the operating stations for manual control above the bulkhead or the freeboard deck for each door.

5.2.7 Alarms

5.2.7.1 While all the doors are being closed from the bridge, an audible alarm must sound at each door. This alarm must commence at least 5 seconds – but not more than 10 seconds – before the door starts moving and must continue right throughout the door movement.

5.2.7.2 When the door is being closed by a remote control system above the bulkhead or the freeboard deck, the audible alarm system should be capable to sound the alarm siren during the time the door is actually moving.

5.2.7.3 The installation of an additional, intermittent visual alarm may be required in the passenger areas and in areas where there is a high level of background noise.

5.2.7.4 With a central hydraulic system, any decreases in the level of oil service tank according to a minimum acceptable reference level shall be signalled by means of an audible and visual alarm in the central control station on the navigation bridge.

5.2.7.5 An alarm similar to specified in 5.2.7.4 is also to be provided for the minimum acceptable accumulator pressure of the central hydraulic system.

5.2.7.6 A decentralized hydraulic system which has individual drive units on each door, the minimum permitted accumulator pressure is to be signalled by means of a group alarm at the central control station on the bridge.

Visual indicators are also to be fitted to the operating stations for each individual door.

5.3 Cargo vessels

In addition to the specifications laid down in 5.1 the following requirements are to be observed for cargo vessels:

5.3.1 Manual control

5.3.1.1 The manual control must be capable of being operated at the door from both sides of the bulkhead.

5.3.1.2 The controls must allow the door to be opened and closed.

5.3.2 Alarms

Whilst all the doors are being closed from the bridge, an audible alarm must be sounded all the time they are in motion. Pre-warning is required.

6. Hoists

6.1 Definition

For the purposes of these requirements, hoists include hydraulically operated appliances such as wheelhouse hoists, lifts, lifting platforms and similar equipment.

6.2 Design

6.2.1 Hoists may be supplied either by a combined power station or individually by several power stations for each single lifting appliance.

In the case of a combined power supply and hydraulic drives whose piping system is connected to other hydraulic systems, a second pump unit is to be fitted.

6.2.2 The movement of hoists shall not be capable of being initiated merely by starting the pumps. The movement of hoists is to be controlled from special operating stations. The controls are to be so arranged that, as soon as they are released, the movement of the hoist ceases immediately.

6.2.3 Local controls, inaccessible to unauthorized persons, are to be fitted. The movement of hoists should be visible from the operating stations. If the movement cannot be observed, audible and/or visual warning devices are to be fitted. In addition, the operating stations are then to be equipped with indicators for monitoring the movement of the hoist.

6.2.4 Devices are to be fitted which prevent the hoist from reaching its end position at excessive speed. These devices are not to cause the power unit to be switched off. As far as is necessary, mechanical means shall be provided for locking the hoist in its end positions.

If the locking devices cannot be observed from the operating station, a visual indicator is to be installed at the operating station to show the locking status.

6.2.5 Requirement 3.1.4 is to be applied in analogous manner to those devices which, if the power

unit fails or a pipe ruptures, ensure that the hoist is slowly lowered.

6.3 Pipes, hose assemblies

Requirements 3.2 and 3.3 apply in analogous manner to the pipes and hose lines of hydraulically operated hoists.

7. Tests in the Manufacturer's Works

7.1 Testing of power units

Power units are required to undergo testing on a test bed. The manufacturer test certificates for this testing are to be presented at the final inspection of the hydraulic system.

7.2 Pressure and tightness tests

Section 9, A.5.4 is applicable in analogous manner.

8. Shipboard Trials

After installation, the equipment is to undergo an operational test.

The operational test of watertight doors is to include the emergency operating system and determination of the closing times.

B. Fire Door Control Systems

1. General

1.1 Scope

The requirements of this section apply to power-operated fire door control systems on passenger vessels. (These Rules meet the requirements for the control systems of fire doors laid down in Chapter II-2, Regulation 9.4 of the International Convention for the Safety of Life at Sea, SOLAS 1974). The following requirements may be applied as appropriate to other fire door control systems.

1.2 Documents for approval

The electric and pneumatic diagrams together with drawings of the cylinders containing all the data necessary for assessing the system, e.g. operating data, descriptions, materials used etc., are to be submitted in triplicate for approval.

1.3 Dimensional design

See Section 14 for the design of pressure vessels; see Section 16 for the dimensions of pipes.

2. Materials

2.1 Approved materials

Cylinders are to be made of corrosion resistant materials.

Stainless steel or copper is to be used for pipes.

The use of other materials is subject to the special approval of **BCS**.

The use of hose lines is not permitted.

Insulation material has to be of an approved type.

The quality properties of all critical components for operation and safety must conform to recognized rules and standards.

2.2 Material testing

Suitable proof of the quality properties of the materials used is to be furnished. This proof may take the form of a BCS Material Test Certificate or a material certificate issued by the producer.

BCS Surveyor reserves the right to order supplementary tests of his own where he considers that the circumstances justify this.

See Section 14, B for details on the material testing of compressed air accumulators.

3. Design

3.1 Each door must be capable of being opened and closed by a single person from both sides of the bulkhead.

3.2 Fire doors shall be capable of closing automatically even against a permanent heeling angle of the ship of 3.5°.

3.3 Closing time of the hinged doors in the upright condition of ship may be no more than 40 seconds and no less than 10 seconds from the start of the movement of the door when fully open to its closed position for each individual door.

The closing speed of sliding doors is to be steady and, with the ship upright, may be no more than 0.2 m/s and no less than 0.1 m/s.

Measures should be taken to ensure that any persons in the door areas are protected from any physical harm .

3.4 All doors shall be capable of being closed from the central control station either jointly or in groups. It must be also possible to initiate closure at each individual door. The closing switch is to take the form of a locking switch.

3.5 Visual indicators are to be installed at the central control station to show that each fire door is fully closed.

3.6 Power driven doors leading from “special areas” (e.g. car decks, railway decks) in accordance with Chapter II-2, requirements 3.46 of the “1974 International Convention or the Safety of Life at Sea, SOLAS” as amended or from comparable spaces to control stations, stairwells and also to accommodation and service spaces and which are closed when the ship is at sea do not need to be equipped with indicators as described in 3.5 and alarms are described in 3.12.

3.7 Operating agents for the pneumatic control system are to be installed next to each door on both sides of the bulkhead and by their operation. A door which has been closed from the central control station can be reopened. The controls must be so designed

that, when released, they return to their original position, thereby causing the door to close again.

In an emergency situation, it should be possible to operate the controls to interrupt immediately the opening of the door and bring about its immediate closure.

A combination of the controls with the door handle may be permitted.

The controls are to be so designed that an open door can be closed locally. In addition, each door must be capable of being locked locally in such a way that it can be no longer opened by the remote control.

3.8 The control unit at the door is to be equipped with a device which will vent the pneumatic system or cut off the electric energy of the door control system, simultaneously shutting off the main supply line and thereby allowing emergency operation by hand.

3.9 The door must close automatically when the central power supply fail. The doors may not reopen automatically when the central supply is restored.

Accumulator systems are to be located in the immediate vicinity of the door being sufficient to allow the door to be completely opened and closed at least ten more times, with using the local controls in the upright condition of ship.

3.10 Measures are to be taken to ensure that the door can still be operated by hand in the event of failure of the energy supply.

3.11 Should the central energy supply fail in the local control area of a door, the capability of the other doors to function may not be adversely affected.

3.12 Doors which are closed from the central control station are to be fitted with an audible alarm. Once the door close command has been given, this alarm must start at least 5 seconds, but not more than 10 seconds before the door starts to move and continue sounding

until the door is completely closed.

3.13 Fire doors are to be fitted with safety strips such that a closing door reopens as soon as contact is made with them. Following contact with the safety strip, the opening travel of the door is to be no more than 1 meter.

3.14 Local door controls, including all components, shall be accessible for maintenance and adjustment.

3.15 The control system shall be of approved design. Their capability to operate in the event of fire must be proven in accordance with the FTP-Code **(1)** and under the supervision of **BCS**.

The control system must conform to the following minimum requirements.

3.15.1 The door must still be capable of being operated safely for 60 minutes at a minimum ambient temperature of 200°C by means of the central energy supply.

3.15.2 The central energy supply for the other doors not affected by fire may not be impaired.

3.15.3 In ambient temperature in excess of 300°C, the central energy supply must be shutoff automatically, and the local control system must be de-energized. The residual energy must be sufficient to close an open door completely during this process.

The shutoff device must be capable of shutting off the energy supply for one hour with a temperature variation corresponding to the standardized time-temperature curve specified in Section II-2, Regulation 3, 1974 International Convention for the Safety of Life at Sea, SOLAS, as amended.

3.16 The pneumatic system is to be protected against overpressure.

3.17 Drainage and venting facilities are to be provided.

(1) IMO. Res. MSC 61 (67).

3.18 Air filtering and drying facilities are to be provided.

3.19 For the details of the electrical equipment, see also Chapter 5 - Electrical Installations, Section 14, D.

4. Test in the Manufacturer's Works

The complete control system is to be subjected to a type approval test. In addition the required construction according to 2 and 3 and the operability must be proven for the complete drive.

5. Shipboard Trials

After installation, the system and its equipment are to be subjected to an operational test including emergency operation and verification of the closing times.

C. Stabilizers

1. General

1.1 Scope

The requirements in this section apply to stabilizer drive units necessary for the operation and safety of the ship.

1.2 Documents for approval

The following plans and particulars are to be submitted to **BCS** in triplicate for approval:

- Plans of all load bearing, torque transmitting components and hydraulic pressure retaining parts of the fin stabilizer system together with proposed rated torque, all relief valve settings and scantlings.
- Schematic plans of the hydraulic system(s), together with pipe material, relief valves and working pressures.
- Details of safety and control and electrical engineering arrangements.

- Material specifications for components of the fin stabilizer system.

- Details of proposed testing and sea trials.

- Details of any limits of operation for stabilisation and induced forced roll, e.g., sea states, ship speed, roll amplitude and periodicity limitations.

- For the naval ships fitted stabilizer fin, a design statement that details the stabilizer performance in terms of a specified roll angle that is not to be exceeded by more than a stated percentage of rolls in a specified wave environment at a specified ship speed and heading. This statement is to be agreed between the Designer and Owner/Operator and recognize the requirements for ship-based operations, such as flight operations and replenishment at sea (RAS) systems, in terms of sea-keeping and platform heel/trim conditions, and the requirements of continuous operation without failure under the ambient reference conditions as applicable. Details of any secondary function of the fin stabilizer to induce ship roll, for example to routinely test the fin stabilizer system (against its own induced roll), to facilitate weapon systems testing and to support CBRN Protection pre-wetting systems, are also to be included in the design statement.

2. Design and Construction

2.1 Fin stabilizer scantlings, arrangements, foundations, supporting structure and watertight integrity shall confirm the design principles and the obligatory constructional arrangement details.

2.2 Fin stabilizer actuating systems are to be consistent with the requirements of the steering gear system, as applicable.

2.3 Materials for components of fin stabilizers are to be consistent with the requirements of the steering gear system, as applicable.

2.4 Section 9, A.2.1.3 and A.2.1.4 are applicable in analogous manner to the pipe connections of hydraulic drive units.

3. Performance Characteristics

3.1 After setting to work, the fin stabilizer system is to be entirely automatic irrespective of ship speed or sea state.

3.2 Where provision is made for an automatic forced roll facility, the roll amplitude and period are to be manually adjustable. Forced induction of rolling motion is not to result in an unsafe condition for the ship, equipment or the crew. The arrangements are also to satisfy the following:

- An automatic forced roll facility is to be selectable by a switch located on the navigating bridge which is located or protected so as to prevent inadvertent operation of this function.
- Controls are to be provided on the navigating bridge to manually adjust the amplitude and periodicity of the induced rolling.

3.3 Failure of any part of the fin stabilizer unit or its control system is not to result in an unsafe condition which will have detrimental effect on the ship's operating or sea-keeping capability.

3.4 In the event of failure of the fin actuating system, a hand pump is to be provided, mounted in a readily accessible position, which is capable of centralising the fin in the absence of electrical power, and being operated by no more than two men when the ship is stopped.

4. Shipboard Trials and Testing

4.1 After installation on board the fin stabilizer unit is to be subject to hydrostatic and running tests.

4.2 Testing and trials are to be carried out in accordance with procedures that have been agreed between the Shipyard, Owner /Operator and **BCS**. The testing is to demonstrate:

- The stabilizer system including the functional performances specified in the design statement required by 1.2,
- Extending and retracting the fins,
- Alternative electrical power supply arrangements where provided and functional capability of the emergency hand pump arrangements,
- Stabilizer controls,
- The alarms and indicators,
- Where the stabilizer system is designed to avoid hydraulic locking, this feature is to be demonstrated.

4.3 Section 9, A.5.4 is applicable in and analogous manner.

SECTION 11**WINDLASS AND WINCHES**

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A. Windlasses

1. General

1.1 Application

A windlass used for handling anchors, suitable for the size of chain cable and complying with the following criteria is to be fitted to the ship. For anchors and chains, see Chapter 1 - Hull, Section 17.

1.2 Documents for approval

The following plans showing the design specifications, the standard of compliance, engineering analyses and details of construction, as applicable, are to be submitted to BCS for evaluation:

- For each type of anchor windlass and chain stopper, general arrangement and sectional drawings, circuit diagrams of the hydraulic, electrical and steam systems and detail drawings of the main shaft, cable lifter, brake, stopper bar, chain pulley and axle are to be submitted in triplicate for approval
- One copy of a description of the anchor windlass including the proposed overload protection and other safety devices is likewise to be submitted.
- Windlass design specifications; anchor and chain cable particulars; anchorage depth, performance criteria; standard of compliance,
- Windlass arrangement plan showing all of the components of the anchoring/mooring system such as the prime mover, shafting, cable lifter, anchors and chain cables; mooring winches, wires and fairleads, if they form part of the windlass machinery; brakes; controls; etc,
- One copy of the strength calculations to verify dimensions, materials, welding details, as applicable, of all torque-transmitting (shafts, gears, clutches, couplings, coupling bolts, etc.) and all load bearing (shaft bearings, cable lifter, sheaves, drums, bed-frames, etc.) components of the windlass and of the winch, where applicable, including brakes, chain stopper (if fitted) and foundation. This calculation is to consider forces acting on the windlass caused by the loads specified in 4.1 to 4.3.
- Hydraulic piping system diagram along with system design pressure, safety valves arrangement and setting, material specification for pipes and equipment, typical pipe joints, as applicable, and technical data and details for hydraulic motors.
- Electric one line diagram along with cable specification and size; motor controller; protective device rating or setting; as applicable,
- Control, monitoring and instrumentation arrangements,
- Engineering analyses for torque-transmitting and load-bearing components demonstrating their compliance with recognized standards or codes of practice. Analyses for gears are to be in accordance with a recognized standard,
- Windlass foundation structure, including under deck supporting structures, and holding down arrangements,
- Plans and data for windlass electric motors with associated gears rated 100 kW and over,
- Where an anchor windlass is to be approved for several strengths and types of chain cable, the calculation relating to the maximum braking torque is to be submitted and proof furnished of the power and hauling-in speed in accordance with 4.1.2 corresponding to all the relevant types of anchor and chain cable.
- Calculations demonstrating that the windlass prime mover is capable of attaining the hoisting speed, the required continuous duty pull, and the overload capacity are to be submitted if the "load testing" including "overload" capacity of the entire windlass unit

is not carried out at the shop

- Operation and maintenance procedures for the anchor windlass are to be incorporated in the vessel operations manual
- Regarding seating of deck machinery see Sec. 2. K , driving engine alignment and seating

1.3 Confirmed standards of compliance

The design, construction and testing of windlasses are to conform to an acceptable standard or code of practice. To be considered acceptable, the standard or code of practice is to specify criteria for stresses, performance and testing.

Essential standards presently recognized by **BCS** are follows:

- ISO 7825 (2017) : Deck machinery general requirements
- ISO 4568 (2006) : Shipbuilding - Sea-going vessels -Windlasses and anchor capstans
- SNAME T & R Bulletin 3-15 (2018): Guide to the Design and Testing of Anchor Windlasses for Merchant Ships
- JIS F6714 (1995): Windlasses

2. Materials and Fabrication

2.1 Materials

Materials used in the construction of torque-transmitting and load-bearing parts of windlasses are to comply with the requirements for materials mentioned herein or of a national or international material standard. The proposed materials are to be indicated in the construction plans and are to be approved in connection with the design. All such materials are to be certified by the material manufacturers and are to be traceable to the manufacturers' certificates.

2.1.1 Approved materials

2.1.1.1 Ram cylinders; pressure housings of rotary vane type actuators; hydraulic power piping valves, flanges and fittings; and all reduction gears and components transmitting mechanical forces to the main shaft, drums , chain sprockets and the like should be of steel or other approved ductile material, duly tested in accordance with the requirements of **BCS** Chapter 2 - Material . In general , such material should not have an elongation of less than 12 % nor a tensile strength in excess of 650 N/mm².

Pressure vessels should be generally made of steel, cast steel or nodular cast iron (with a predominantly ferritic matrix).

With the consent of the **BCS**, cast iron may be used for certain components. Gray cast iron may be accepted for redundant parts with low stress level , excluding cylinders , upon special consideration . Gray cast iron or other material having an elongation ($L_0/d = 4$) less than 12% in 50 mm. is not to be used for these parts.

2.1.1.2 Cable lifters and chain pulleys are generally to be made of cast steel. Nodular cast iron is permitted for stud link chain cables of

- Up to 50 mm. diameter for grade K 1 (ordinary quality)
- Up to 42 mm. diameter for grade K 2 (special quality)
- Up to 35 mm. diameter for grade K 3 (extra special quality).

In special cases, nodular cast iron may also be used for larger chain diameters by arrangement with **BCS**.

Grey cast iron is permitted for stud link chain cables of

- Up to 30 mm. diameter for grade K 1 (ordinary quality)
- Up to 25 mm. diameter for grade K 2 (special quality)
- Up to 21 mm. diameter for grade K 3 (extra special quality).

2.1.2 Testing of materials

2.1.2.1 The materials for forged, rolled and cast parts which are stressed by the pull of the chain when the cable lifter is disengaged (main shaft, cable lifter, brake bands, brake spindles, brake bolts, tension straps, stopper bar, chain pulley and axle) are to be tested under the supervision of **BCS** in accordance with Chapter 2 - Material.

In the case of anchor windlasses for chains up to 14 mm. in diameter, a Manufacturer Inspection Certificate issued by the producer may be accepted as proof.

In the case of housing and frame of anchor windlasses a Manufacturer Inspection Certificate issued by the producer may be accepted as proof.

2.1.2.2 In the case of hydraulic systems, the material used for pipes (see Section 16, Table 16.6) as well as for pressure vessels is also to be tested.

2.2 Welded fabrication

Weld joint designs are to be shown in the construction plans and are to be approved in association with the approval of the windlass design. Welding procedures and welders are to be qualified in accordance with **BCS** Rules, Chapter 3, Welding. Welding consumables are to be approved by **BCS** in the case their type and grade fall within the scope of BCS - R W 17 and R W 23 ; when their type and grade fall outside the scope of BCS - R W17 and R W23, the welding consumables are to comply with the **BCS** Rules , Chapter 3, Section 5 or to national or international standards . The degree of non -destructive examination of welds and post -weld heat treatment, if any, are to be specified and submitted for consideration

3. Windlass Components and Design Principles

3.1 Type of drive

3.1.1 Windlasses are normally to be driven by an engine which is independent of other deck machinery. The piping systems of hydraulic and steam-driven

windlass engines may be connected to other hydraulic or steam systems provided that this is permissible for the latter. The windlasses must, however, be capable of being operated independently from other connected systems.

3.1.2 Manual operation as the main driving power can be allowed for anchors weighing up to 250 kg.

3.1.3 In case of hydraulic drives with a piping system connected to other hydraulic systems, a secondary pump unit is recommended to be a standby pump.

3.1.4 In the case of windlasses with two cable lifters both cable lifters must be engageable simultaneously.

3.2 Reversing mechanism

Power-driven windlasses must be reversible. On windlasses for ships with a Range of Service up to "K" (or RSA 50) and on those powered by internal combustion engines a reversing mechanism may be dispensed with.

3.3 Overload protection

For the protection of the mechanical parts in the event of the windlass jamming, an overload protection (e.g. slip coupling, relief valve) is to be fitted to limit the maximum torque of the drive engine (cf. 4.1.4). The setting of the overload protection is to be specified (e.g. in the operating instructions).

3.4 Couplings

Windlasses are to be fitted with disengageable couplings between the cable lifter and the drive shaft.

Hydraulic or electrically operated couplings must be capable of being disengaged manually.

3.5 Braking equipment

Windlasses must be fitted with cable lifter brakes which are capable of holding a load in accordance with 4.2.3 with the cable lifter disengaged. In addition, where the gear mechanism is not of self-

locking type, a device (e.g. gearing brake, lowering brake, oil hydraulic brake) is to be fitted to prevent paying out of the chain should the power unit fail while the cable lifter is engaged.

If brakes are power operated, additional means are to be provided for manual operation. Manual operation shall be possible under all working conditions, including failure of the power drive.

3.6 Pipes

For the design and dimensions of pipes, valves, fittings, pressure vessels, etc. see Section 14 (Pressure Vessels) and Section 16 (Pipes, Valves, Fittings and Pumps) A, B, C, D, E and U.

3.7 Cable lifters

Cable lifters shall have at least five snugs.

3.8 Windlass as warping winch

Combined windlasses and warping or mooring winches may not be subject to excessive loads even when the maximum pull is exerted on the warping rope.

3.9 Electrical equipment

3.9.1 The electrical equipment is to comply with the Chapter 5 - Electric, Section 7, E.2.

3.9.2 Electric motors

Electric motors are to meet the requirements of **BCS** and those rated 100 kW and over are to be certified. Motors exposed to weather are to have enclosures suitable for their location as provided for in the requirements of **BCS**. Where gears are fitted, they are to meet the requirements of **BCS** and those rated 100 kW and over are to be certified.

3.9.3 Electrical circuits

Motor branch circuits are to be protected in accordance with the provisions of **BCS** and cable sizing is to be in accordance with the requirements of **BCS**.
Electrical

cables installed in locations subject to sea are to be provided with effective mechanical protection.

3.10 Hydraulic equipment

For oil level indicators see the requirements of section 9, A.3.12. For filters see the requirements of section 10, A.3.2.2.

3.11 Protection of mechanical components

To protect mechanical parts included component housing, a suitable protection system is to be fitted to limit the speed and torque at the prime mover. Consideration is to be given to a means to contain debris consequent to a severe damage of the prime mover due to over-speed in the event of uncontrolled rendering of the cable, particularly when an axial piston type hydraulic motor forms the prime mover.

4. Performance Criteria and Design

Along with and notwithstanding the requirements of the chosen standard of compliance, the following requirements are also to be complied with. In lieu of conducting engineering analyses and submitting them for review, approval of the windlass mechanical design may be based on a type test, in which case the testing procedure is to be submitted for consideration.

4.1 Mechanical design

4.1.1 Design loads

4.1.1.1 Holding loads

Calculations are to be made to show that, in the holding condition (single anchor, brake fully applied and chain cable lifter declutched), and under a load equal to 80% of the specified minimum breaking strength of the chain cable (see the requirements for the Construction of the Chapter 1 - Hull, Section 17), the maximum stress in each load bearing component will not exceed yield strength (or 0.2% proof stress) of the material. For installations fitted with a chain cable stopper, 45% of the specified minimum breaking strength of the chain cable may instead be used for the calculation.

4.1.1.2 Inertia loads

The design of the drive train, including prime mover, reduction gears, bearings, and clutches, shafts, wildcat and bolting is to consider the dynamic effects of sudden stopping and starting of the prime mover or chain cable so as to limit inertial load.

4.1.2 Continuous duty pull

The windlass prime mover is to be able to exert for at least 30 minutes a continuous duty pull, (e.g., 30-minute short time rating corresponding to S2-30 min. of IEC 60034-1), Z_{cont1} , corresponding to the grade and diameter, d , of the chain cables as follows:

Table 11.1 Z_{cont1} corresponding to the grade of chain

Grade of chain	Z_{cont1}	
	N	kgf
K1	$37,5 d^2$	$3,82 d^2$
K2	$42,5 d^2$	$4,33 d^2$
K3	$47,5 d^2$	$4,84 d^2$
Unit of d	mm	mm

The values of the above table are applicable when using ordinary stockless anchors for anchorage depth down to 82.5 m.

For anchorage depth deeper than 82.5 m, a continuous duty pull Z_{cont2} is:

$$Z_{cont2}[N] = Z_{cont1}[N] + (D - 82.5) \times 0.27d^2$$

or

$$Z_{cont2}[kgf] = Z_{cont1}[kgf] + (D - 82.5) \times 0.0275d^2$$

where

D is the anchor depth, in metres.

The anchor masses are assumed to be the masses as given BCS Rules, Chapter 1, Section 17. Also, the value of Z_{cont} is based on the hoisting of one anchor at a time, and that the effects of buoyancy and hawse pipe efficiency (assumed to be 70%) have been accounted

for. In general, stresses in each torque-transmitting component are not to exceed 40% of yield strength (or 0.2% proof stress) of the material under these loading conditions.

4.1.3 Hoisting speed

The mean speed of the chain cable during hoisting of the anchor and cable is to be at least 0,15 m/sec. For testing purposes, the speed is to be measured over two shots of chain cable and initially with at least three shots of chain (82.5 m in length) and the anchor submerged and hanging free.

4.1.4 Overload capability

The windlass prime mover is to be able to provide the necessary temporary overload capacity for breaking out the anchor. This temporary overload capacity or "short term pull" is to be at least 1.5 times the continuous duty pull applied for at least 2 minutes. The speed in this period may be lower than normal.

4.1.5 Brake capacity

The capacity of the windlass brake is to be sufficient to stop the anchor and chain cable when paying out the chain cable. Where a chain cable stopper is not fitted, the brake is to produce a torque capable of withstanding a pull equal to 80% of the specified minimum breaking strength of the chain cable without any permanent deformation of strength members and without brake slip. Where a chain cable stopper is fitted, 45% of the breaking strength may instead be applied.

4.1.6 Chain cable stopper

Chain cable stopper, if fitted, along with its attachments is to be designed to withstand, without any permanent deformation, 80% of the specified minimum breaking strength of the chain cable.

4.1.7 Support Structure

For hull supporting structures of windlass and chain cable stoppers, see BCS Rules, Chapter 1, Section 17, G.

4.2 Dimensioning of the load transmitting components and chain stoppers

4.2.1 The basis for the design of the load-transmitting components of windlasses and chain stoppers are the anchors and chain cables specified in the requirements for the Chapter 1 - Hull, Section 17.

4.2.2 The cable lifter brake is to be so designed that the anchor and chain can be safely stopped while paying out the chain cable.

4.2.3 The dimensional design of those parts of the windlass which are subjected to the chain pull when the cable lifter is disengaged (cable lifter, main shaft, braking equipment, bedframe and deck fastening) is to be based on a theoretical pull equal to 80% of the nominal breaking load specified in the Rules for Materials for the chain in question. The design of the main shaft is to take account of the braking forces, and the cable lifter brake shall not slip when subjected to this load.

4.2.4 The theoretical pull may be reduced to 45% of the nominal breaking load for the chain provided that a chain stopper approved by **BCS** is fitted.

4.2.5 The design of all other windlass components is to be based upon the force acting on the cable lifter pitch circle and equal to the maximum pull specified in 4.1.4.

4.2.6 At the theoretical pull specified in 4.2.3 and 4.2.4, the force exerted on the brake-handwheel shall not exceed 500 N.

4.2.7 The dimensional design of chain stoppers is to be based on a theoretical pull equal to 80% of the nominal breaking load of the chain.

4.2.8 The total stresses applied to components must be below the minimum yield point of the materials used.

4.2.9 The foundations and pedestals of windlasses and chain stoppers are governed by the requirements for the Chapter 1 - Hull, Section 8 and 17.

4.3 Strength requirements to resist green sea forces

4.3.1 For ships of length 80 m or more, where the height of the exposed deck in way of the item is less than 10 percent of ship's length between perpendicular (0.1L) or 22 m above the summer load waterline, whichever is the lesser, the attachment of the windlass located within the forward quarter length of the ship are to resist the green sea forces. The following pressures and associated areas are to be applied (Figure 11.1):

- 200 kN/m² normal to the shaft axis and away from the forward perpendicular, over the projected area in this direction
- 150 kN/m² parallel to the shaft axis and acting both inboard and outboard separately, over the multiple of f times the projected area in this direction

f = 1 + B/H, but not greater than 2.5,

B = Width of windlass measured parallel to the shaft axis [m],

H = Overall height of the windlass [m].

Where mooring winches are integral with the anchor windlass, they are to be considered as part of the windlass.

4.3.2 Forces in the bolts, chocks and stoppers securing the windlass to the deck, caused by green sea forces specified in 4.3.1, are to be calculated.

The windlass is supported by N bolt groups, each containing one or more bolts (Figure 11.2)

The axial forces R_i in bolt group (or bolt) i, positive in tension, is to be obtained from:

$$R_{xi} = \frac{P_x \cdot h \cdot x_i \cdot A_i}{I_x} \quad [\text{kN}] \quad (4)$$

$$R_{yi} = \frac{P_y \cdot h \cdot y_i \cdot A_i}{I_y} \quad [\text{kN}] \quad (5)$$

$$R_i = R_{xi} + R_{yi} - R_{si} \quad [\text{kN}] \quad (6)$$

P_x = Force acting normal to the shaft axis [kN],

P_y = Force acting parallel to the shaft axis, either inboard or outboard whichever gives the greater force in bolt group i [kN],

h = Shaft height above the windlass mounting [cm],

x_i, y_i = x and y coordinates of bolt group i from the centroid of all N bolt groups, positive in the direction opposite to that of the applied force [cm],

A_i = Cross sectional area of bolts in group i [cm²],

I_x = $\sum A_i x_i^2$ for N bolt groups [cm⁴],

I_y = $\sum A_i y_i^2$ for N bolt groups [cm⁴],

R_{si} = Static reaction at bolt group i, due to weight of windlass [kN].

4.3.3 Shear forces F_{xi} and F_{yi} applied to the bolt group i, and the resultant combined force F_i are to be obtained from:

$$F_{xi} = \frac{P_x - \alpha \cdot m_w}{N} \quad [\text{kN}] \quad (7)$$

$$F_{yi} = \frac{P_y - \alpha \cdot m_w}{N} \quad [\text{kN}] \quad (8)$$

$$F_i = \sqrt{F_{xi}^2 + F_{yi}^2} \quad [\text{kN}] \quad (9)$$

α = Friction coefficient, to be taken as 0.5 [-],

m_w = Weight-force of windlass [kN],

N = Number of bolt groups [-].

Axial tensile and compressive forces and lateral forces calculated in 4.3.1, 4.3.2 and 4.3.3 are also to be considered in the design of the supporting structure.

4.3.4 Tensile axial stresses in the individual bolts in each bolt group i are to be calculated. The horizontal forces F_{xi} and F_{yi} are normally to be reacted by shear chocks.

Where “fitted” bolts are designed to support these shear forces in one or both directions, the von Mises’ equivalent stresses in the individual bolts are to be calculated, and compared to the stress under proof load.

Where pourable resins are incorporated in the holing down arrangement, due account is to be taken in the calculations.

The safety factor against bolt proof strength should be greater than 2.0.

5. Tests in the Manufacturer's Works

5.1 Testing of driving engines

The requirements of Section 9, A.5.3 are applicable as appropriate.

5.2 Pressure and tightness tests

The requirements of Section 9, A.5.4 are applicable as appropriate. The set pressure of the relief valves shall be taken as p_c .

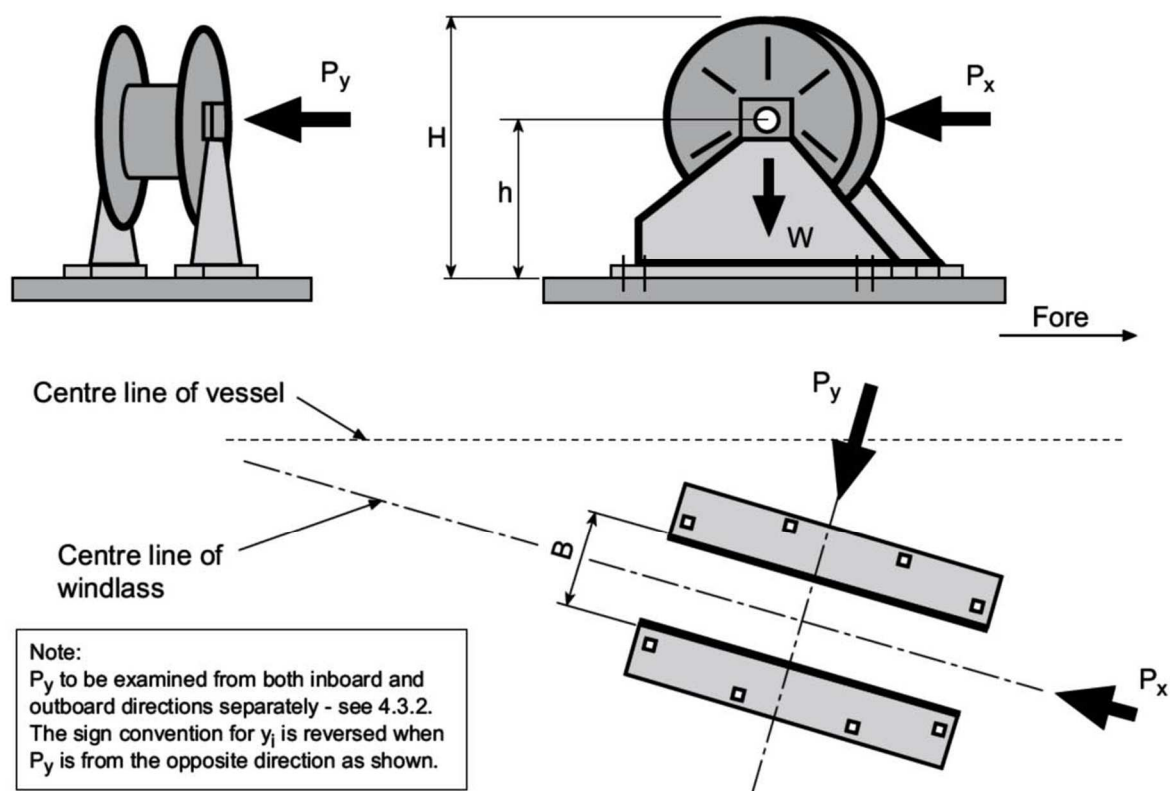


Figure 11.1 Windlass loading

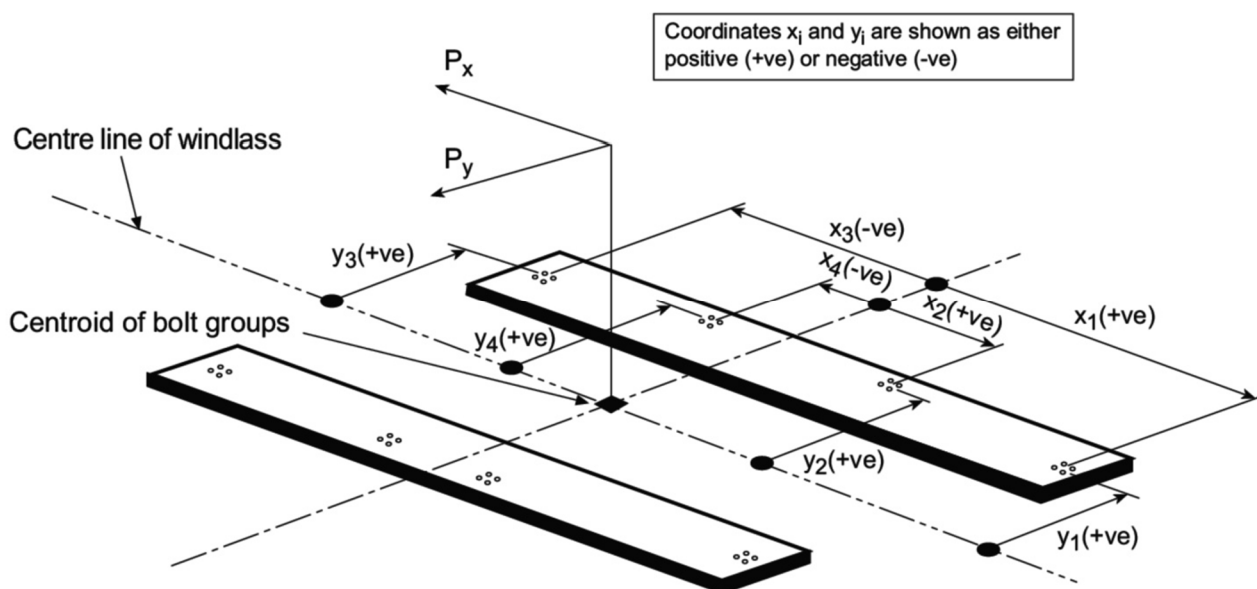


Figure 11.2 Direction of forces and weight and sign convention

5.3 Final inspection and operational testing

5.3.1 All anchors and chain cables are to be tested at establishments and on machines recognized by **BCS** and under the supervision of **BCS's** Surveyors or other Officers recognized by **BCS**, and in accordance with the requirements for Materials.

5.3.2 Test certificates showing particulars of weights of anchors, or size and weight of cable and of the test loads applied are to be furnished. These certificates are to be examined by **BCS's** Surveyors when the anchors and cables are placed on board the ship.

5.3.3 Steel wire and fibre ropes are to be tested as required by the requirements for Materials.

5.3.4 For holding power testing requirements relating to high holding power anchors, see the requirements for Chapter 2 - Material.

5.3.5 The windlasses should undergo the final inspection and operational testing at the maximum pull. The hauling-in speed is to be verified with continuous application of the nominal pull. During the tests, particular attention is to be given to the testing and, wherever necessary, to the setting of braking and to the safety equipment.

In the case of anchor windlasses for chains >14 mm. in diameter, this test should be performed in the presence of the **BCS** Surveyor.

In the case of anchor windlasses for chains ≤14 mm. diameter, the Manufacturer's Inspection Certificate will be accepted.

5.3.6 Shop inspection and testing

Windlasses are to be inspected during fabrication at the manufacturer's facilities by a surveyor for conformance with the approved plans. Acceptance tests, as specified in the specified standard of compliance, are to be witnessed by the surveyor and include the following tests as a minimum:

5.3.6.1 No-load test. The windlass is to be run without load at nominal speed in each direction for a total of 30 minutes. If the windlass is provided with a gear change, additional run in each direction for 5 minutes at each gear change is required.

5.3.6.2 Load test. The windlass is to be tested to verify that the continuous duty pull, overload capacity and hoisting speed as specified in 4.1 can be attained.

Where the manufacturing works does not have adequate facilities, the aforementioned tests including the adjustment of the overload protection can be carried out on board ship. In these cases, functional testing in the manufacturer's works is to be performed under no-load conditions.

5.3.6.3 Brake capacity test. The holding power of the brake is to be verified either through testing or by calculation.

5.3.7 After manufacturing, the chain stoppers are required to undergo final inspection and operational testing in the presence of **BCS** surveyor.

5.3.8 The design of the windlass is to be such that the following requirements or equivalent arrangements will minimize the probability of the chain locker or forecastle being flooded in bad weather:

- A watertight connection can be made between the windlass bedplate, or its equivalent, and the upper end of the chain pipe, and,
- Access to the chain pipe is adequate to permit the fitting of a cover or seal, of sufficient strength and proper design, over the chain pipe while the ship is at sea.

6. Shipboard Trials

6.1 Each windlass is to be tested under working conditions after installation onboard to demonstrate satisfactory operation.

6.2 Each unit is to be independently tested for braking, clutch functioning, lowering and hoisting of chain cable and anchor, proper riding of the chain over the chain lifter, proper transit of the chain through the hawse pipe and the chain pipe, and effecting proper stowage of the chain and the anchor.

6.3 It is to be confirmed that anchors properly seat in the stored position and that chain stoppers function as designed if fitted.

6.4 The mean hoisting speed, as specified in 4.4, is to be measured and verified, with each anchor and at least 82.5 m length of chain submerged and hanging free.

6.5 During trials on board ship, the windlass is to be shown to be capable of:

- For all specified design anchorage depths: raising the anchor from a depth of 82.5 m to a depth of 27.5 m at a mean speed of 9 meters per minute; and
- For specified design anchorage depths greater than 82.5 m: in addition to above item, raising the anchor from the specified design anchorage depth to a depth of 82.5 m at a mean speed of 3 meters per minute.

6.6 Where the depth of water in the trial area is inadequate, suitable equivalent simulating conditions will be considered as an alternative.

6.7 The braking capacity is to be tested by intermittently paying out and holding the chain cable by means of the application of the brake.

7. Marking

Windlass shall be permanently marked with the following information:

- a) Nominal size of the windlass (e.g. 100/3/45 is the size designation of a windlass for 100 mm diameter chain cable of BCS-K3 Grade, with a holding load of 45 % of the breaking load of the chain cable)

- b) Maximum anchorage depth [m].

B. Winches

1. Towing Winches

1.1 Design and testing of the towing winches are to comply with the requirements for the Construction and Testing of Towing Gears, in Chapter 1 - Hull, Section 29, D.

1.2 Where automatic devices are used for governing the tension of the towline, provision shall be made to enable checking the value of tension at every moment. The tension indicators shall be installed at the towing winch and on the bridge.

1.3 Sound warning alarm operating when the maximum permissible length of the towline is veered out shall be provided. It is recommended to install a towline length indicator.

1.4 The drums of the towing winches having the multilayer rope winding with the ropes that can be subjected to the load in several layers shall have flanges protruding above the upper layer of winding by not less than 2.5 times the rope diameter. The drums shall also be provided with fairleads. If two or more drums are provided, the fairleads shall be independent. Rope drum shall be fitted with a coupling to ensure its disconnection from the driving machinery.

Geometrical dimensions of the winch heads shall provide the possibility for paying out the towline.

1.5 The design of the winch shall provide for quick releasing of the drum in order to ensure free paying-out of the towing line.

1.6 The towing winches shall be provided with an automatic brake ensuring holding of a line at a pull equal to at least 1.25 times the rated one when the driving energy disappears or is switched off.

1.7 The rope drum of the winch shall be provided with the brake capable of holding the drum, when the effort in the rope is not less than the breaking load of the towline without slipping and when the drum is

disconnected from the drive. The drum brake controlled by any type of energy shall be provided with manual control as well. The brake design shall ensure the possibility of quick releasing for the purpose of loosing paying out of the towline.

1.8 The towing winch elements situated in lines of force flow shall be checked for strength under the rated rope pull applied to the middle layer of winding. The reference stresses in the elements shall not exceed $0.4 R_{eH}$ of the element material in this case.

1.9 The elements shall be checked for strength when the drum is affected by efforts corresponding to the maximum torque of the drive, as well as when the drum is affected by an effort equal to the towline breaking force on the upper layer of winding. The reference stresses in elements, which may be subjected to efforts caused by the above-mentioned loads, shall not exceed $0.95 R_{eH}$ of the element material.

2. Winches for Cargo Handling Gear and Other Lifting Equipment

The design and testing of these winches are to comply with the Chapter 50 - Lifting Appliances.

3. Lifeboat Winches

The design and testing of life boat winches are to comply with LSA – Life Saving Appliance Code.

4. Winches for Special Equipment

The winches for special equipment such as ramps, hoisting gear and hatch covers, shall comply with the relevant requirements Chapter 50, Lifting Appliances and LSA – Life Saving Appliance Code.

5. Towing Winch Emergency Release Systems

5.1 Scope

5.1.1 This item defines minimum safety standards for winch emergency release systems provided on towing winches that are used on towing ships within close quarters, ports or terminals, **including those ships**

normally not intended for towing operation in transverse direction.

5.1.2 This item is not intended to cover towing winches on board ships used solely for long distance ocean towage, anchor handling or similar offshore activities.

5.2 Purpose

5.2.1 The purpose of this item is to provide requirements to prevent the capsize of a tug when in the act of towage as a result of the towline force acting transversely to the tug (in beam direction) as a consequence of an unexpected event (could be loss of propulsion/steering or otherwise), whereby the resulting couple generated by offset and opposing transverse forces (towline force is opposed by thrust or hull resistance force) causes the tug to heel and, ultimately, to capsize. This capsize may be referred to as “girting”, “girthing”, “girding” or “tripping”. See Figure 11.3 which shows the forces acting during towage operations.

5.3 Definitions

5.3.1 ‘Emergency release system’ refers to the mechanism and associated control arrangements that are used to release the load on the towline in a controlled manner under both normal and **black out** conditions.

5.3.2 ‘Maximum design load’ is the maximum load that can be held by the winch as defined by the manufacturer (the manufacturer’s rating).

5.3.3 ‘Fleet angle’ is the angle between the applied load (towline force) and the towline as it is wound onto the winch drum, see Figure 11.4.

5.4 General requirements

5.4.1 The in-board end of the towline is to be attached to the winch drum with a weak link or similar arrangement that is designed to release the towline at low load.

5.4.2 All towing winches are to be fitted with an emergency release system.

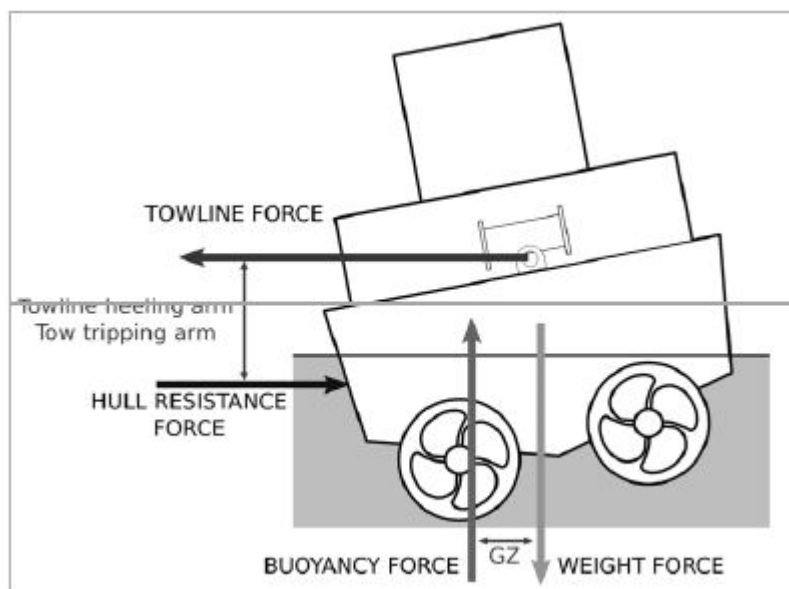


Figure 11.3 Forces during towing

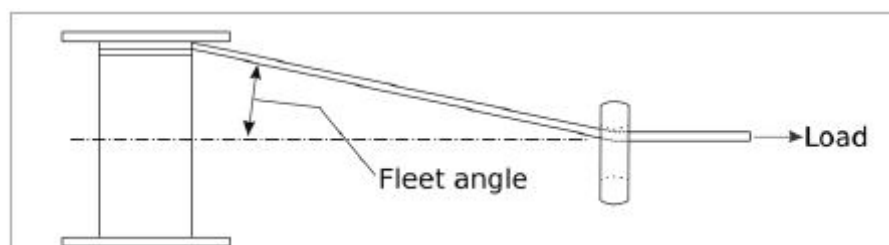


Figure 11.4 Towline 'fleet angle'

5.5 Emergency release system requirements

5.5.1 Performance requirements

5.5.1.1 The emergency release system is to operate across the full range of towline load, fleet angle and ship heel angle under all normal and reasonably foreseeable abnormal conditions (these may include, but are not limited to, the following: vessel electrical failure, variable towline load (for example due to heavy weather), etc.).

5.5.1.2 The emergency release system shall be capable of operating with towline loads up to at least 100 per cent of the maximum design load.

5.5.1.3 The emergency release system is to function as quickly as is reasonably practicable and within a maximum of three seconds after activation.

5.5.1.4 The emergency release system is to allow the winch drum to rotate and the towline to pay out in a controlled manner such that, when the emergency release system is activated, there is sufficient resistance to rotation to avoid uncontrolled unwinding of the towline from the drum. Spinning (free, uncontrolled rotation) of the winch drum is to be avoided, as this could cause the towline to get stuck and disable the release function of the winch.

5.5.1.5 Once the emergency release is activated, the towline load required to rotate the winch drum is to be no greater than:

- a) the lesser of five tonnes or five per cent of the maximum design load when two layers of towline are on the drum, or
- b) 15 per cent of the maximum design load where it is demonstrated that this resistance to rotation does not exceed 25 per cent of the force that will result in listing sufficient for the immersion of the lowest unprotected opening.

5.5.1.6 Emergency release of the towline is to be possible in the event of a blackout. For this purpose, where additional sources of energy are required, such sources are to comply with 5.5.1.7.

5.5.1.7 The sources of energy required by 5.5.1.6 are to be sufficient to achieve the most onerous of the following conditions (as applicable):

- a) Sufficient for at least three attempts to release the towline (i.e. three activations of the emergency release system). Where the system provides energy for more than one winch it is to be sufficient for three activations of the most demanding winch connected to it.
- (b) Where the winch design is such that the drum release mechanism requires continuous application of power (e.g. where the brake is applied by spring tension and released using hydraulic or pneumatic power) sufficient power is to be provided to operate the emergency release system (e.g. hold the brake open and allow release of the towline)

in the event of a blackout for a minimum of five minutes. This may be reduced to the time required for the full length of the towline to feed off the winch drum at the load specified in 5.5.1.5 if this is less than five minutes.

5.5.2 Operational requirements

5.5.2.1 Emergency release operation must be possible from the bridge and from the winch control station on deck. The winch control station on deck is to be in a safe location. A position in close proximity to the winch is not regarded as "safe location", unless it is documented that the position is at least protected against towline break or winch failure.

5.5.2.2 The emergency release control is to be located close to an emergency stop button for winch operation, if provided, and shall be clearly identifiable, clearly visible, easily accessible and positioned to allow safe operability.

5.5.2.3 The emergency release function is to take priority over any emergency stop function. Activation of the winch emergency stop from any location is not to inhibit operation of the emergency release system from any location.

5.5.2.4 Emergency release system control buttons are to require positive action to cancel, the positive action may be made at a different control position from the one where the emergency release was activated. It must always be possible to cancel the emergency release from the bridge regardless of the activation location and without manual intervention on the working deck.

5.5.2.5 Controls for emergency use are to be protected against accidental use.

5.5.2.6 Indications are to be provided on the bridge for all power supply and/or pressure levels related to the normal operation of the emergency release system.

Alarms are to activate automatically if any level falls outside of the limits within which the emergency release system is fully operational.

5.5.2.7 Wherever practicable, control of the emergency release system is to be provided by a hard-wired system, fully independent of programmable electronic systems.

5.5.2.8 Computer based systems that operate or may affect the control of emergency release systems are to meet the requirements for Category III systems of BCS- R E22.

5.5.2.9 Components critical for the safe operation of the emergency release system are to be identified by the manufacturer.

5.6 Test requirements

5.6.1 General

5.6.1.1 All testing defined within item 5.5 is to be witnessed by a **BCS** surveyor.

5.6.1.2 For each emergency release system or type thereof, the performance requirements of item 5.5.1 are to be verified either at the manufacturer's works or as part of the commissioning of the towing winch when it is installed on board. Where verification solely through testing is impracticable (e.g. due to health and safety), testing may be combined with inspection, analysis or demonstration in agreement with **BCS**.

5.6.1.3 The performance capabilities, as well as instructions for operation, of the emergency release system are to be documented by the manufacturer and made available on board the ship on which the winch has been installed.

5.6.1.4 Instructions for surveys of the emergency release system are to be documented by the manufacturer, agreed by the Society and made available on board the ship on which the winch has been installed.

5.6.1.5 Where necessary for conducting the annual and special surveys of the winch, adequately sized strong points are to be provided on deck.

5.6.2 Installation trials

5.6.2.1 The full functionality of the emergency release system is to be tested as part of the shipboard commissioning trials to the satisfaction of the surveyor. Testing may be conducted either during a bollard pull test or by applying the towline load against a strong point on the deck of the tug that is certified to the appropriate load.

5.6.2.2 Where the performance of the winch in accordance with item 5.5.1 has previously been verified, the load applied for the installation trials is to be at least the lesser of 30% of the maximum design load or 80% of vessel bollard pull.

Table 11. 2 Anchor, Chain Cable and Ropes

Equipment Numeral		Stockless bower anchor		Chain cable stud link bower chain				Stream wire or stream chain		Towline Ropes		Mooring ropes		
Incl.	Excl.	Number	Mass per anchor (kg)	Total length (m)	Diameter (mm)			Length (m)	Breaking Load (kN)	Length (m)	Breaking Load (kN)	Number	Length (m)	Breaking Load (kN)
					Gr-1	Gr-2	Gr-3							
≤ 50		2	120	165	12.5	12.5	12.5	80	65	180	100	3	80	35
50 – 70		2	180	220	14	12.5	12.5	80	65	180	100	3	80	35
70 – 90		2	240	220	16	14	14	85	75	180	100	3	100	40
90 – 110		2	300	247.5	17.5	16	16	85	80	180	100	3	110	40
110 – 130		2	360	247.5	19	17.5	17.5	90	90	180	100	3	110	45
130 – 150		2	420	275	20.5	17.5	17.5	90	100	180	100	3	120	50
150 – 175		2	480	275	22	19	19	90	110	180	100	3	120	55
175 – 205		2	570	302.5	24	20.5	20.5	90	120	180	110	3	120	60
205 – 240		3	660	302.5	26	22	20.5			180	130	4	120	65
240 – 280		3	780	330	28	24	22			180	150	4	120	70
280 – 320		3	900	357.5	30	26	24			180	175	4	140	80
320 – 360		3	1020	357.5	32	28	24			180	200	4	140	85
360 – 400		3	1140	385	34	30	26			180	225	4	140	95
400 – 450		3	1290	385	36	32	28			180	250	4	140	100
450 – 500		3	1440	412.5	38	34	30			180	275	4	140	110
500 – 550		3	1590	412.5	40	34	30			190	305	4	160	120
550 – 600		3	1740	440	42	36	32			190	340	4	160	130
600 – 660		3	1920	440	44	38	34			190	370	4	160	145
660 – 720		3	2100	440	46	40	36			190	405	4	160	160
720 – 780		3	2280	467.5	48	42	36			190	440	4	170	170
780 – 840		3	2460	467.5	50	44	38			190	480	4	170	185
840 – 910		3	2640	467.5	52	46	40			190	520	4	170	200
910 – 980		3	2850	495	54	48	42			190	560	4	170	215
980 – 1060		3	3060	495	56	50	44			200	600	4	180	230
1060 – 1140		3	3300	495	58	50	46			200	645	4	180	250
1140 – 1220		3	3540	522.5	60	52	46			200	690	4	180	270
1220 – 1300		3	3780	522.5	62	54	48			200	740	4	180	285
1300 – 1390		3	4050	522.5	64	56	50			200	785	4	180	305
1390 – 1480		3	4320	550	66	58	50			200	835	4	180	325
1480 – 1570		3	4590	550	68	60	52			220	890	5	190	325
1570 – 1670		3	4890	550	70	62	54			220	940	5	190	335
1670 – 1790		3	5250	577.5	73	64	56			220	1025	5	190	350
1790 – 1930		3	5610	577.5	76	66	58			220	1110	5	190	375
1930 – 2080		3	6000	577.5	78	68	60			220	1170	5	190	400
2080 – 2230		3	6450	605	81	70	62			240	1260	5	200	425
2230 – 2380		3	6900	605	84	73	64			240	1355	5	200	450
2380 – 2530		3	7350	605	87	76	66			240	1455	5	200	480
2530 – 2700		3	7800	632.5	90	78	68			260	1470	6	200	480
2700 – 2870		3	8300	632.5	92	81	70			260	1470	6	200	490
2870 – 3040		3	8700	632.5	95	84	73			260	1470	6	200	500
3040 – 3210		3	9300	660	97	84	76			280	1470	6	200	520
3210 – 3400		3	9900	660	100	87	78			280	1470	6	200	555
3400 – 3600		3	10500	660	102	90	78			280	1470	6	200	590
3600 – 3800		3	11100	687.5	105	92	81			300	1470	6	200	620
3800 – 4000		3	11700	687.5	107	95	84			300	1470	6	200	650
4000 – 4200		3	12300	687.5	111	97	87			300	1470	7	200	650
4200 – 4400		3	12900	715	114	100	87			300	1470	7	200	660
4400 – 4600		3	13500	715	117	102	90			300	1470	7	200	670
4600 – 4800		3	14100	715	120	105	92			300	1470	7	200	680
4800 – 5000		3	14700	742.5	122	107	95			300	1470	7	200	685
5000 – 5200		3	15400	742.5	124	111	97			300	1470	8	200	685
5200 – 5500		3	16100	742.5	127	111	97			300	1470	8	200	695
5500 – 5800		3	16900	742.5	130	114	100			300	1470	8	200	705
5800 – 6100		3	17800	742.5	132	117	102			300	1470	9	200	705
6100 – 6500		3	18800	742.5		120	107			300	1470	9	200	715
6500 – 6900		3	20000	770		124	111			300	1470	9	200	725
6900 – 7400		3	21500	770		127	114			300	1470	10	200	725
7400 – 7900		3	23000	770		132	117			300	1470	11	200	725
7900 – 8400		3	24500	770		137	122			300	1470	11	200	735
8400 – 8900		3	26000	770		142	127			300	1470	12	200	735
8900 – 9400		3	27500	770		147	132			300	1470	13	200	735
9400 – 10000		3	29000	770		152	132			300	1470	14	200	735
10000 – 10700		3	31000	770			137			300	1470	15	200	735
10700 – 11500		3	33000	770			142			300	1470	16	200	735
11500 – 12400		3	35500	770			147			300	1470	17	200	735
12400 – 13400		3	38500	770			152			300	1470	18	200	735
13400 – 14600		3	42000	770			157			300	1470	19	200	735
14600 – 16000		3	46000	770			162			300	1470	21	200	735

SECTION 12

STEAM BOILERS

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A. General**1. Scope**

1.1 The boiler is a kind of pressure vessel, associated piping systems and fittings.

The boilers are to be of a design and construction adequate for the service for which they are intended.

For the purpose of these requirements, boiler includes all closed vessels and piping systems used for:

- Generating steam at pressure above atmospheric (steam generators), or
- Raising the temperature of water above the boiling point corresponding to atmospheric pressure (hot water generators).

The boilers are to be so installed and protected as to reduce to a minimum any danger to persons on board, due regard being paid to moving parts, hot surfaces and other hazards.

The design is to have regard to materials used in construction, the purpose for which the equipment is intended, the working conditions to which it will be subjected and the environmental conditions on board

1.2 The steam generator also includes any equipment directly connected to the aforementioned vessels or piping systems in which the steam is superheated or cooled, external drums, the circulating line and the casings of circulating pumps serving forced-circulation boilers.

1.3 Hot water generators with an allowable discharge temperature of not more than 120°C and all systems incorporating steam or hot water generators which are heated solely by steam or hot liquids are not subject to these requirements, but come under Section 14-Pressure Vessels.

Raising the temperature of water above the boiling point corresponding to atmospheric pressure (discharge temperature > 120°C) – the generated hot water is to be used in a system outside of the hot water generators.

1.4 Steam and hot water generators as defined in 1.2 and 1.3 are subject to the requirements set out in B to F, for hot water generators the requirements set out in G. apply additionally.

Flue gas economizers are subject to the special requirements set out in H. In respect of materials, manufacture and design, the requirements specified in B, C and D apply as appropriate.

2. Additional Requirements

2.1 As regards their construction equipment and operation, steam boiler plants are also required to comply with the international and national standards, rules or codes approved by **BCS**.

3. Documents for Approval

Drawings of boilers containing all the data necessary for their safety assessment are to be submitted to **BCS** in triplicate.

The following details, in particular, are to be specified:

- General arrangement plan,
- Design data: heating surface, evaporative capacity, design and working pressure and temperature, superheater header and tube mean wall temperatures, estimated pressure drop through the superheaters, steam conditions, heating surfaces, allowable steam output, feed, firing system, safety valves, controllers and limiters, draft requirements at design conditions, number and capacity of forced draft fans,
- Materials of all pressurized parts and their welded attachments and full details of welds including filler materials,
- Sectional assembly,
- Seating arrangements,
- Steam and water drums, and header details,
- Waterwall details,

- Steam and superheater tubing including the maximum expected mean wall temperature of the tube wall, and the tube support arrangements,
- Economizer arrangement, header details, and element details,
- Casing arrangement,
- Typical weld joint designs,
- Post-weld heat treatment and non destructive examination,
- Boiler mountings including safety valves and relieving capacities, blow-off arrangements water gauges and try cocks, etc.
- Integral piping,
- Reheat section (when fitted),
- Fuel oil burning arrangements including burners and registers,
- Forced draft system,
- Boiler instrumentation, monitoring and control systems.

4. Definitions

Basic concept and definitions applied in this section are described in the following item:

- **Fired pressure vessel**
Fired pressure vessel is a pressure vessel which is completely or partially exposed to fire from burners or combustion gases.
- **Unfired pressure vessel**
Any pressure vessel not to be exposed firing from any burner or flame source.
- **Boiler**
Boiler is one or more fired pressure vessels and associated piping systems used for generating steam or hot water at a

temperature above 120°C by means of heat resulting from combustion of fuel or from combustion gases.

Any equipment directly connected to the boiler, such as economizers, superheaters, and safety valves, is considered as part of the boiler, if it is not separated from the steam generator by means of any isolating valve. Piping connected to the boiler is considered part of the boiler upstream of the isolating valve and part of the associated piping system downstream of the isolating valve.

- **Automatic boiler oil burner unit**
It is a device for combustion of fuel oil, the operation of which is controlled automatically, without any direct attendance of the operating personnel.
- **Auxiliary boilers for essential services**
Auxiliary boilers supply steam to the auxiliary machinery, systems and equipment providing propulsion of the ship, safety of navigation and proper carriage of goods, if no other sources of power being available on board the ship for operating the mentioned machinery, equipment and systems in case the boilers fail to operate.
- **Steam generator**
Steam generator is a heat exchanger and associated piping used for generating steam. In general, in these requirements, the requirements for boilers are also applicable for steam generators, unless otherwise indicated.
- **Superheaters, economizers, reheaters, de-superheaters**
They are the heat exchangers associated with a boiler.
- **Incinerator**
Incinerator is a shipboard facility for incinerating solid garbage approximating in composition to household garbage and liquid garbage deriving from the operation of the ship (e.g. domestic

garbage, cargo-associated garbage, maintenance garbage, operational garbage, cargo residue, and fishing gear), as well as for burning sludge with a flash point above 60°C. These facilities may be designed to use the heat energy produced.

- Design pressure, PR
Design pressure PR is the approved steam pressure in bar (gauge pressure) in the saturated steam space prior to entry into the superheater. In once - through forced flow boilers, the maximum allowable working pressure is the pressure at the superheater outlet or, in the case of continuous boilers without a superheater, the steam pressure at the steam generator outlet.
- Maximum permissible working pressure, PB
Maximum permissible working pressure PB is the maximum pressure permissible at the top of the boiler or pressure vessel in its normal operating condition and at the designated coincidental temperature specified for that pressure. It is the least of the values found for PB for any pressure-bearing parts, adjusted for the difference in static head that may exist between the part considered and the top of the boiler or pressure vessel. PB is not to exceed the design pressure PR.
- Design temperature,
The maximum temperature used in design is not to be less than the mean metal temperature (through the thickness) expected under operating conditions.
- Design boiler capacity
It is the maximum amount of steam that can be generated by the boiler at design parameters during 1 hour on continuous running.
- Steam boiler walls
Steam boiler walls are the walls of the steam and water spaces located between the boiler isolating devices. The bodies of these isolating devices form part of the boiler walls.

- The allowable steam output
The allowable steam output is the maximum quantity steam which can be produced continuously by the steam generator operating under the design steam conditions.

- The heating surface
The heating surface is that part of the boiler walls through which heat is supplied to the system, i.e:

- The area in m² measured on the side exposed to fire or exhaust gas, or
- In the case of electrical heating, the equivalent heating surface is:

$$H = \frac{860}{18000} P$$

Where P is the electric power in kW and H in m².

5. Lowest water level - highest flue- dropping time

5.1 The lowest water level (LWL) has to be located at least 150 mm above the highest flue also when the ship heels 4° to either side.

The highest flue (HF) shall remain wetted even when the ship is at the static heeling angles laid down in Section 1, Table 1.1.

The height of the water level is crucial to the response of the water level limiters.

5.2 The "dropping time" is the time taken by the water level under conditions of interrupted feed and allowable steam production, to drop from the lowest water level to the level of the highest flue.

$$T = \frac{60 \cdot V}{D \cdot v'}$$

T = Dropping time [min]

V = Volume of water in steam boiler between the lowest water level and the highest flue [m³]

D = Allowable steam output [kg/h]

v' = Specific volume of water at saturation temperature [m³/kg]

The lowest water level is to be set so that the dropping time is not less than 5 minutes.

5.3 The highest flue (HF)

- Is the highest point on the side of the heating surface which is in contact with the water and which is exposed to flame radiation and
- Is to be defined by the boiler manufacturer in such a way that, after shut-down of the burner from full-load condition or reduction of the heat supply from the engine, the flue gas temperature or exhaust gas temperature respectively is reduced to a value below 400 °C at the level of the highest flue. This shall be achieved before, under the condition of interrupted feed water supply, the water level has dropped from the lowest water level to a level 50 mm above HF.

The highest flue on water tube boilers with an upper steam drum is the top edge of the highest gravity tubes.

5.4 The requirements relating the highest flue do not apply to

- Water tube boiler risers up to 102 mm outer diameter
- Once-through forced flow boilers
- Superheaters
- Flues and exhaust gas heated parts in which the temperature of the heating gases does not exceed 400 °C at maximum continuous power

5.5 The heat accumulated in furnaces and other heated boiler parts may not lead to any inadmissible lowering of the water level due to subsequent evaporation when the oil burner is switched-off.

This requirement to an inadmissible lowering of the water level is met for example, if it has been demonstrated by calculation or trial that, after shut-down of the burner from full-load condition or reduction of the heat supply from the engine, the flue gas temperature or exhaust gas temperature respectively is reduced to a value below 400 °C at the level of the highest flue, before, under the condition of interrupted feed water supply, the water level has dropped from the lowest water level LWL to a level 50 mm above the highest flue HF.

The water level indicators have to be arranged in such a way that the distance 50 mm above HF could be identified.

5.6 The lowest specified water level is to be indicated permanently on the boiler shell by means of a water level pointer. The location of the pointer is to be included in the documentation for the operator.

Reference plates are to be attached additionally beside or behind the water level gauges pointing at the lowest water level.

B. Materials

1. General Requirements

1.1 The materials used for manufacturing of steam boilers shall satisfy the **BCS** technical requirements and comply with the ASME Boiler and Pressure Vessel Code Section I or TRD (Technical Rules for Steam Boilers).

1.2 Pressure parts of boilers are to be constructed of materials conforming to specifications permitted by the applicable boiler or pressure vessel code.

Table 12.1 Approved materials

Material and product form	Limits of application	Material grades in accordance with the Rules Chapter 2 - Material
Steel plates and steel strips	-	Plates and strip of high-temperature steels to Section 3
Steel pipes	-	Seamless and welded pipes of ferritic steels to Section 4, B and 4, C
Forgings and formed parts: - drums, headers and similar hollow components without longitudinal seam - covers, flanges, branch pipes, end plates	-	Forgings for boilers, vessels and pipeline to Section 5
Nuts and bolts	-	Bolts and nuts to Section 4. High-temperature bolts, e.g. to EN 10269
	$\leq 300^{\circ}\text{C}$ $\leq 4 \text{ MPa}$ $\leq \text{M } 30$	EN ISO 898 Part 1 and 2 or equivalent standards
Steel castings	-	Cast steel for boilers, pressure vessels and pipelines to Section 6, D.
	$\leq 300^{\circ}\text{C}$	Also GS 38 and GS 45 to EN 10293 and GS 16 Mn5 and GS 20 Mn5 to EN 10293
Nodular cast iron	$\leq 300^{\circ}\text{C}$ $\leq 4 \text{ MPa}$ $\leq \text{DN } 175$ for valves and fittings	Nodular cast iron to Section 7
Lamellar (grey) cast iron: - boiler parts (only for unheated surfaces and not for heaters in thermal oil systems) - valves and fittings (except valves subject to dynamic loads) - exhaust gas economizers	$\leq 200^{\circ}\text{C}$ $\leq 1 \text{ MPa}$ $\leq 200 \text{ mm diameter}$	Grey cast iron grades to Section 7
	$\leq 200^{\circ}\text{C}$ $\leq 1 \text{ MPa}$ $\leq \text{DN } 175$ $\leq 5.2 \text{ MPa}$ smoke gas temperature $\leq 600^{\circ}\text{C}$ water outlet temperature $\leq 245^{\circ}\text{C}$	
	$\leq 10 \text{ MPa}$ smoke gas temperature $\leq 700^{\circ}\text{C}$ water outlet temperature $\leq 260^{\circ}\text{C}$	Grey cast iron of at least GG-25 grade to Section 7
Valves and fittings of cast copper alloy	$\leq 225^{\circ}\text{C}$ $\leq 2.5 \text{ MPa}$	Cast copper alloys to Section 9.

1.3 Materials for non-pressure parts are to be of a weldable grade (to be verified by welding procedure qualification, for example) if such parts are to be welded to pressure parts.

1.4 Materials exposed to high temperature

Materials of pressure parts subjected to service temperatures higher than room temperature are to have mechanical and metallurgical properties suitable for operating under stress at such temperatures. Material specifications concerned are to have specified mechanical properties at elevated temperatures, or alternatively, the application of the materials is to be limited by allowable stresses at elevated temperatures as specified in the applicable boiler or pressure vessel standard.

1.5 Materials exposed to low temperature

Materials of pressure parts subjected to low service temperatures are to have suitable notch toughness properties. Permissible materials, the allowable operating temperatures, the tests that need be conducted and the corresponding toughness criteria are to be as specified in the applicable pressure vessel standard.

2. Approved Materials

The requirements specified in 1 are recognized as having been complied with if the materials shown in Table 12.1 are used.

Materials not specified in the **BCS** 's Rules Chapter 2 - Material may be used provided that proof is supplied of their suitability and material properties.

3. Material testing

3.1 Materials, including welding consumables, entered into the construction of boilers and pressure vessels are to be certified by the material manufacturers as meeting the material specifications concerned. Certified mill test reports, traceable to the material concerned, are to be presented to **BCS** Surveyor for information and verification in all cases.

3.2 The materials of boiler parts subject to pressure, i.e. steam and water drums, shell and heads, headers, shell flange, tubes, tubesheets, etc. including flue gas economizer tubes are required to have their materials tested in the presence of **BCS** Surveyor to verify their compliance with the Rules Chapter 2 - Material (cf. Table 12 .1). Welding consumables, in these instances, are to have their mechanical strength verified by the testing of production test pieces.

3.3 Material testing by **BCS** may be dispensed with in the case of:

3.3.1 Small boiler parts made of unalloyed steels, such as stay bolts, stays of ≤ 100 mm. diameter, reinforcing plates, handhole and manhole covers, forged flanges and nozzles up to DN 150 and

3.3.2 Smoke tubes (tubes subject to external pressure).

For the parts mentioned in 3.3.1 and 3.3.2, the properties of the materials are to be attested by material certificates in accordance with EN 10204- 3.1.B.

3.4 Special agreements may be made regarding the testing of unalloyed steels to recognized standards.

3.5 The materials of valves and fittings must be tested by **BCS** in accordance with Table 12.2.

Table 12.2 Testing of materials for valves and fittings

Type of material (1)	Service temperature [°C]	Testing required for: PB [MPa] DN [mm]
Steel, cast steel	> 300	DN > 32
Steel, cast steel nodular, cast iron	≤ 300	PBxDN > 250 (2) or DN > 250
Copper alloys	≤ 225	PBxDN > 150 (2)
(1) No tests are required for grey cast iron. (2) Testing may be dispensed with if the nominal DN ≤ 32 mm.		

3.6 Parts not subject to material testing, such as external supports, lifting brackets, pedestals etc. must be designed for the intended purpose and must be made of suitable materials.

C. Manufacturing Principles

1. Manufacturing Processes Applied to Boiler Materials

Materials are to be checked for defects during the manufacturing process. Care is to be taken to ensure that different materials cannot be confused. During the course of manufacture care is likewise required to ensure that marks and inspection stamps on the materials remain intact or are transferred in the prescribed manner.

Boiler parts whose structure has been adversely affected by hot or cold forming are to be subjected to heat treatment in accordance with the Rules for Materials.

2. Welding

Boilers are to be manufactured by welding. The execution of welds, welding procedure specifications and procedure qualification records, post-weld heat treatment procedure, nondestructive examination plan and the approval of welding shops are to be in accordance with the Chapter 3 - Section 13, Welding of Steam Boilers.

Welder qualification records are to be submitted to the Surveyor.

3. Riveting

Where, in special, unusual but obligatory cases, boiler parts have to be riveted, relevant requirements are to be obtained from **BCS**.

4. Tube Expansion

Tube holes must be carefully drilled and deburred.

Sharp edges are to be chamfered. Tube holes should be as close as possible to the radial direction, particularly in the case of small wall thicknesses.

Tube ends to be expanded are to be cleaned and checked for size and possible defects. Where necessary, tube ends are to be annealed before being expanded.

Smoke tubes with welded connection between tube and tube plate at the entry of the second path shall be roller expanded before and after welding.

5. Stays, Stay Tubes and Stay Bolts

5.1 Stays, stay tubes and stay bolts are to be so arranged that they are not subjected to undue bending or shear forces.

Stress concentrations at changes in cross-section, in screw threads and at welds are to be minimized by suitable component geometry.

5.2 Stay and stay bolts are to be welded by full penetration preferably. Any vibrational stresses are to be considered for long stays.

5.3 Stays are to be drilled at both ends in such a way that the holes extend at least 25 mm. into the water or steam space. Where the ends have been upset, the continuous shank must be drilled to a distance of at least 25 mm. See Fig. 12.22.

5.4 Wherever possible, the angle made by gusset stays and the longitudinal axis of the boiler shall not exceed 30°. Stress concentrations at the welds of gusset stays are to be minimized by suitable component geometry. Welds are to be executed as full-strength welds. In firetube boilers, corner stays are to be located at least 200 mm. from the fire tubes.

5.5 Where flat surfaces exposed to flames are stiffened by stay bolts, the distance between centres of the stay bolts shall not generally exceed 200 mm.

6. Stiffeners, Straps and Lifting Eyes

6.1 Where flat and surfaces are stiffened by profile sections or ribs, the latter shall transmit their load directly (i.e. without welded-on straps) to the boilershell.

6.2 Doubling plates may not be fitted at the pressure parts subject to flame radiation.

Where necessary to protect the walls of the boiler, strengthening plates are to be fitted below supports and lifting brackets.

7. Welding of Flat Unrimmed Ends to Boiler Shells

Flat unrimmed ends (disc ends) on shell boilers are only permitted as socket-welded ends with a shell projection of ≥ 15 mm. The end/shell, S_B/S_M , wall thickness ratio shall not be greater than 1.8. The end is to be welded to the shell with a full penetration weld.

8. Nozzles and Flanges

Nozzles and flanges are to be of rugged design and properly welded to the shell. The wall thickness of nozzles must be sufficiently large safely to withstand additional external loads. The wall thickness of welded-in nozzles shall be appropriate to the wall thickness of the part into which they are welded.

Welding-neck flanges must be made of forged material with favourable grain orientation.

9. Cleaning and Inspection Openings, Cutouts and Covers

9.1 Boilers are to be provided with openings for inspection and cleaning of all internal surfaces. Especially critical and high-stress welds, parts subjected to flame radiation and areas of varying water level shall be sufficiently accessible to inspection.

9.2 The manholes are to be main concerned types of openings. Where the provision of manholes is not possible, arrangements shall be made for head holes and hand holes.

9.3 Boiler vessels with an inside diameter of more than 1200 mm. and those measuring over 800 mm. in diameter and 2000 mm. in length are to be provided with means of access. Parts inside drums must not obstruct inner inspection or must be capable of being removed.

9.4 Inspection and access openings are required to have the following minimum dimensions:

Manholes 300 x 400 mm, for oval openings,
400 mm for round openings,

In separate cases, if specially approved by **BCS**, the dimensions of manhole openings may be reduced to 280 mm x

380 mm and to 380 mm for oval and round openings, respectively. The oval manholes in cylindrical shells are to be so positioned that the minor axis of the manhole is longitudinally arranged, where the annular height is >150 mm, the opening is to measure 320x420 mm.

Headholes 220x320 mm, for oval openings,
or 320 mm for round openings.

Handholes 90x120 mm, for oval openings or 120 mm for round openings. Where, due to size or interior arrangement of a boiler, it is impractical to provide a manhole or other suitable opening for direct access, there are to be two or more handholes or other suitable openings through which the interior can be inspected. Considerations shall be given to alternative provisions in other boiler standards or codes.

Sight holes are required to have a diameter of at least 50 mm; they should, however, be provided only when the design makes a handhole impracticable.

9.5 Vertical gas-tube boilers shall have at least two hand holes arranged in the shell opposite to each other in the area of the raw (working) water level.

9.6 All boiler parts such as may prevent or hinder free access to, and inspection of, internal surfaces are to be of a removable type.

9.7 The edges of manholes and other openings, e.g. for domes, are to be effectively strengthened if the plate has been unacceptably weakened by the cutouts. The edges of openings closed with covers are to be reinforced by flanging or by welding on edge-stiffeners if it is likely that the tightening of the crossbars etc. would otherwise cause undue distortion of the edge of the opening.

9.8 Cover plates, manhole stiffeners and crossbars must be made of ductile material (not grey or malleable cast iron). Grey cast iron (at least GG-20) may be used for handhole cover crossbars of headers and sectional headers, provided that the crossbars are not located in the heating gas flow. Unless metal packings are used, cover plates must be provided on the external side with a rim or spigot to prevent the packing from being forced out. The gap between this rim or spigot and the edge of the opening is to be uniform round the periphery and may not exceed 2 mm. for boilers with a working pressure of less than 3.2 MPa, or 1 mm. where the pressure is 3.2 MPa or over. The height of the rim or spigot must be at least 5 mm. greater than the thickness of the packing.

9.9 Only continuous rings may be used as packing. The materials used must be suitable for the given operating conditions.

10. Boiler Drums, Shell Sections, Headers And Firetubes

See Chapter 3 - Welding, Section 13.

11. Manual Operation

11.1 For steam boilers which are operated automatically means for operation and supervision are to be provided which allow a manual operation with the following minimum requirements by using an additional control level:

11.1.1 At boilers with a defined highest flue at their heating surface (e.g. oil fired steam boilers and exhaust gas boilers with temperature of the exhaust gas > 400 °C) at least the water level limiters and at hot water generators the temperature limiters have to remain active.

11.1.2 Exhaust gas boilers with temperatures of the exhaust gas < 400 °C may be operated without water level limiters.

11.1.3 The monitoring of the oil content of the condensate or of the ingress of foreign matters into the feeding water may not lead to a shut-down of the feeding pumps during manual operation.

11.1.4 The safety equipment not required for manual operation may only be deactivated by means of a key-operated switch. The actuation of the keyoperated switch is to be indicated.

11.1.5 For detailed requirements in respect of manual operation of the oil firing system, see Section 15.

11.2 Manual operation demands constant and direct supervision of the steam boiler plant.

12. Power of Steam Propulsion Plants

On ships propelled by steam, the plant is to be so designed that, should one main boiler fail, sufficient propulsive capacity will remain to maintain adequate manoeuvrability and to supply the auxiliary machinery.

D. Design Calculation

1. Design Principles

1.1 Range of applicability of design formulae

1.1.1 The following strength calculations represent the minimum requirements for normal operating conditions with mainly static loading. Separate allowance must be made for additional forces and moments of significant magnitude.

1.1.2 The wall thicknesses arrived at by applying the formulae are the minima required. The undersize tolerances permitted by the Rules Chapter 2 - Material are to be added to the calculated values.

1.2 Design pressure, P_c

1.2.1 In general, the design pressure is to be at least the maximum allowable working pressure. Additional allowance is to be made for static pressures of more than 5 kPa.

1.2.2 In designing once-through forced flow boilers, the pressure to be applied is the maximum working pressure anticipated in main boiler sections at maximum allowable continuous load.

1.2.3 The design pressure applicable to the superheated steam lines from the boiler is the maximum working pressure values which adequate safety devices prevent from being exceeded.

1.2.4 In the case of boiler parts which are subject in operation to both internal and external pressure, e.g. desuperheaters in boiler drums, the design may be based on the differential pressure, provided that it is certain that in service both pressures will invariably occur simultaneously. However, the design pressure of these parts is to be at least 1.7 MPa. The design is also required to take account of the loads imposed during the hydrostatic pressure test.

1.3 Design temperature, t

Strength calculations are based on the temperature at the centre of the wall thickness of the component in question. The maximum temperature obtained from calculation of the most stressed cross-sections of the steam superheater is to be taken as design temperature. The design temperature is made up of the reference temperature and a temperature allowance in accordance with Table 12.3. The minimum value is to be taken as 250°C.

Table 12.3 Design temperatures

Reference temperature	Allowance to be added		
	Unheated parts	Heated parts heated mainly by	
		Contact	Radiation
Saturation temperature at max. allowable working pressure	0°C	25°C	50°C
Superheated steam temperature	15°C (1)	35°C	50°C
(1) The temperature allowance may be reduced 7°C provided that special measures are taken to ensure that the design temperature cannot be exceeded.			

1.4 Allowable stresses

The design of structural components is to be based on the allowable stress σ_{perm} [N/mm²]. In each case, the minimum value produced by the following relations is applicable:

1.4.1 Rolled and forged steels

For design temperatures up to 350°C

$\frac{R_{m,20^0}}{2.7}$ where $R_{m,20^0}$ Guaranteed minimum tensile strength at room temperature, [N/mm²]

$\frac{R_{eH,t}}{1.6}$ where $R_{eH,t}$ Guaranteed yield point or minimum 0.2% proof stress at design temperature t , [N/mm²]

For design temperature over 350°C

$\frac{R_{m,100000,t}}{1.5}$ where $R_{m,10^5,t}$ Average 100,000 hours creep strength at design temperature t , [N/mm²]

$\frac{R_{eH,t}}{1.6}$ where $R_{eH,t}$ Guaranteed yield point or minimum 0.2% proof stress at design temperature t , [N/mm²]

1.4.2 Cast materials

- Cast steel

$$\frac{R_{m,20^{\circ}}}{3.2} \quad \frac{R_{eH,t}}{2.0} \quad \frac{R_{m,100000,t}}{2.0}$$

- Nodular cast iron

$$\frac{R_{m,20^{\circ}}}{4.8} \quad \frac{R_{eH,t}}{3.0}$$

- Grey cast iron

$$\frac{R_{m,20^{\circ}}}{11.0}$$

For further details and explanations, see Section 14.

1.4.3 Special arrangements may be agreed for high-ductility austenitic steels.

1.4.4 In the case of cylinder shells with cutouts and in contact with water, a nominal load of 170 N/mm² shall not be exceeded in view of the protective magnetite layer.

1.4.5 Mechanical characteristic are to be taken from the Rules Chapter 2 - Material or from the standards specified therein.

1.5 Allowance for corrosion and wear

The allowance for corrosion and wear, *c*, is to be 1 mm. For plate thicknesses of 30 mm. and over for stainless materials, this allowance may be dispensed with.

1.6 Special cases

Where boiler parts cannot be designed in accordance with the following requirements or on general engineering principles, the dimensions in each individual case must be determined by tests, e.g. by strain measurements.

2. Cylindrical Shells Under Internal Pressure

2.1 Scope

The following design requirements apply to drums, shell rings and headers up to a diameter ratio D_a/D_i of ≤ 1.7 . Diameter ratios of up to $D_a/D_i \leq 2$ may be permitted provided that the wall thickness is ≤ 80 mm.

2.2 Symbols

p_c = Design pressure [bar],

s = Wall thickness [mm],

D_i = Inside diameter [mm],

D_a = Outside diameter, [mm],

c = Allowance for corrosion and wear [mm],

d = Diameter of opening or cutout [mm].

Hole diameter for expanded tubes and for expanded and seal-welded tubes (see Figure 12.1a and 12.1b),

Inside tube diameter for welded-in pipe nipples and sockets (Figure 12.1c),

t, t_r, t_u = Pitch of tube holes (measured at centre of wall thickness for circumferential seams) [mm],

v = Weakening factor [-],

for welds: The qualitative ratio of the welded joints to the plate (weld factor),

for holes: Drilled in the plate: the ratio of the weakened to the unweakened plate section,

σ_{perm} = Allowable stress (see 1.4) [N/mm²],

s_A = Necessary wall thickness at edge of opening or cutout [mm],

s_s = Wall thickness of branch pipe [mm],

b = Supporting length of parent component [mm],

ℓ = Width of ligament between two branch pipes [mm],

ℓ_s = Supporting length of branch pipe [mm],

ℓ'_s = Internal projection of branch pipe [mm],

A_p = Area under pressure [mm²],

A_σ = Supporting cross-sectional area [mm²].

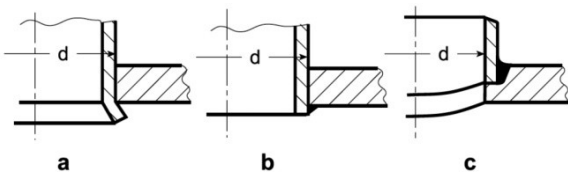


Figure 12.1 Hole diameter and tube inside diameter

2.3 Design calculations

2.3.1 The necessary wall thickness s is given by the expression:

$$S = c + \frac{D_a \cdot p_c}{20 \cdot \sigma_{perm} \cdot v + p_c} \quad (1)$$

2.3.2 In the case of heated drums and headers with a maximum allowable working pressure of more than 2.5 N/mm², special attention is to be given to thermal stresses. For heated drums not located in the first pass (gas temperature up to 1000°C max.), special certification in respect of thermal stresses may be waived subject to the following provisos: Wall thickness up to 30 mm. and adequate cooling of the walls by virtue of close tube arrangement.

The description "close tube arrangement" is applicable if the ligament perpendicular to the direction of gas flow and parallel to the direction of gas flow does not exceed 50 mm and 100 mm respectively.

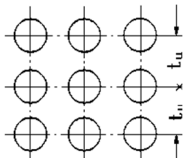
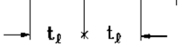
2.3.3 Weakening factor v

The weakening factor v is shown in Table 12.4

2.3.4 Weakening effects due to cut-outs or individual branch pieces are to be taken into account by area compensation in accordance with the expression:

$$\frac{p_c}{10} \left(\frac{A_p}{A_\sigma} + \frac{1}{2} \right) \leq \sigma_{perm} \quad (2)$$

Table 12.4 Weakening factor, v

Construction	Weakening factor v
Seamless shell rings and drums	1.0
Shell rings and drums with longitudinal weld	Weld factor see Chapter 3 - Welding
Rows of holes (1) in: longitudinal direction	$(t_t - d)/t_t$ 
Circumferential direction	$2 \cdot (t_u - d)/t_u$ 
(1) The value of v for rows of holes may not be made greater than 1.0 in the calculation. For staggered pitches, see Figure 12.27. Refer also to Figures 12.1a ÷ 12.1c under item 2.2.	

The area under pressure A_p and the supporting cross-sectional area A_σ are defined in Figure 12.2.

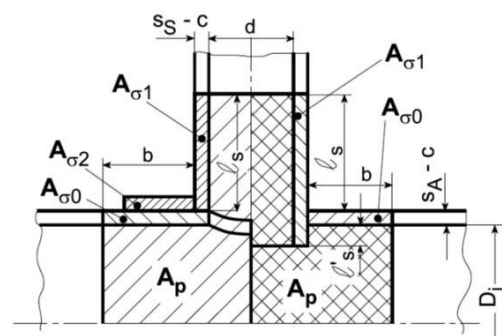


Figure 12.2 Opening in cylindrical shells

Supporting lengths may not exceed the values from following formula.

For the parent component:

$$b = \sqrt{(D_i + s_A - c) \cdot (s_A - c)}$$

For the branch pipe:

$$\ell_s = 1.25 \cdot \sqrt{(d + s_s - c) \cdot (s_s - c)}$$

Where a branch projects into the interior, the value introduced into the calculation as having a supporting function may not exceed $\ell_s \leq 0.5 \ell_s$.

Where materials with different mechanical strengths are used for the parent component and the branch or reinforcing plate, this fact is to be taken into account in the calculation. However, the allowable stress in the reinforcement may not be greater than that for the parent material in the calculation.

Disk-shaped reinforcements should not be thicker than the actual parent component thickness, and this thickness is the maximum which may be allowed for in the calculation and the width of the reinforcement should be more than three times the as-built wall thickness at the edge of the opening / cut-out (s_A)

Disk-shaped reinforcements are to be fitted on the outside.

The wall thickness of the branch pipe should not be more than twice the as-build wall thickness at the edge of the cut-out (s_A).

Cut-outs exert a mutual effect if the ligament is

$$\ell \leq 2 \cdot \sqrt{(D_i + s_A - c) \cdot (s_A - c)}$$

The area compensation is then as shown in Figure 12.3.

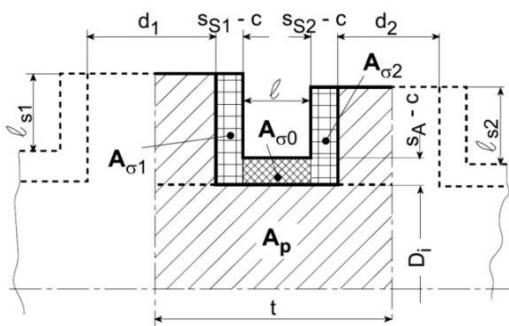


Figure 12.3 Mutual effect on openings

For cut-outs which exert a mutual effect the reinforcement by internal branch pipe projections or reinforcement plates has also to be taken into account.

2.4 Minimum allowable wall thickness

For welded and seamless shell rings the minimum allowable wall thickness is 5 mm. For non-ferrous metals, stainless steels and cylinders diameters up to 200 mm, smaller wall thicknesses may be permitted. The wall thickness of drums into which tubes is expanded is to be such as to provide a cylindrical expansion length of at least 16 mm.

3. Cylindrical Shells and Tubes With an Outside Diameter of More than 200 mm Subject to External Pressure

3.1 Scope

The following requirements apply to the design plain and corrugated cylindrical shells and tubes with an outside diameter of more than 200 mm. which are subjected to external pressure. These will be designated in the following as fire tubes if they are exposed to flame radiation.

3.2 Symbols

- p_c = Design pressure [bar],
- s = Wall thickness [mm],
- d = Mean diameter of plain tube [mm],
- d_a = Outside diameter of plain tube [mm],
- d_i = Minimum inside diameter of corrugated firetube [mm],
- ℓ = Length of tube distance between two effective stiffeners [mm],
- h = Height of stiffening ring [mm],
- b = Thickness of stiffening ring [mm],
- u = Percentage out-of-roundness of tube [%],
- a = Greatest deviation from cylindrical shape (see Figure 12.5) [mm],

σ_{perm} = Allowable stress [N/mm²],

E_t = Modules of elasticity at design temperature
[N/mm²],

S_k = Safety factor against elastic buckling[-],

v = Transverse elongation factor (0.3 for steel)[-],

c = Allowance for corrosion and wear in [mm].

3.3 Design calculations

3.3.1 Cylindrical shells and plain firetubes

Calculation of resistance to plastic deformation:

$$p_c \leq 10 \cdot \sigma_{perm} \cdot \frac{2 \cdot (s-c)}{d} \cdot \frac{1 + 0.1 \cdot \frac{d}{\ell}}{1 + 0.03 \cdot \frac{d}{s-c} \cdot \frac{u}{1 + 5 \cdot \frac{d}{\ell}}} \quad (3)$$

Calculation of resistance to elastic buckling:

$$p_c \leq 20 \cdot \frac{E_t}{S_k} \cdot \left[\frac{(s-c)^3}{(n^2-1) \left(1 + \left(\frac{d_a}{Z} \right)^2 \right)} + \frac{\left(\frac{d_a}{3(1-v^2)} \right)^2}{n^2-1 + \frac{2n^2-1-v}{1 + \left(\frac{d_a}{Z} \right)^2}} \right] \quad (4)$$

Where

$$Z = \frac{\pi \cdot d_a}{2 \cdot \ell}$$

under condition of $n \geq 2$ and $n > Z$

The integer factor of n is to be so chosen as to reduce P_c to its minimum value. The integer factor of n represents the number of buckled folds occurring round the periphery in the event of failure. The integer factor of n can be estimated by applying the following approximation formula:

$$n = 1.63 \cdot \sqrt[4]{\left(\frac{d_a}{\ell} \right)^2 \frac{d_a}{s-c}}$$

3.3.2 In the case of corrugated tubes of Fox and Morrison types, the necessary wall thickness s is given by the expression:

$$s = \frac{p_c}{20 \sigma_{perm}} \cdot \frac{d_i}{1} + 1 \quad [\text{mm}] \quad (5)$$

3.4 Allowable stress

Contrary to 1.4, the values for the allowable stress of firetubes used in the calculations are to be as follows:

Plain firetubes, horizontal	$\frac{R_{eH,t}}{2.5}$
Plain firetubes, vertical	$\frac{R_{eH,t}}{2.0}$
Corrugated firetubes	$\frac{R_{eH,t}}{2.8}$
Tubes heated by exhaust gases	$\frac{R_{eH,t}}{2.0}$

3.5 Design temperature

Contrary to 1.3, the design temperature to be used for firetubes is that shown in Table 12.5.

3.6 Stiffening

Apart from the firetube and firebox end plates, the types of structure shown in Figure 12.4 can also be regarded as providing effective stiffening.

Table 12.5 Design temperatures for heated components under external pressure

For tubes exposed to fire (firetubes):	but at least 250°C
Plain tubes $t [C^\circ] = \text{saturation temperature} + 4s + 30^\circ C$	
Corrugated tubes $t [C^\circ] = \text{saturation temperature} + 3s + 30^\circ C$	
For tubes heated by exhaust gases: $t [C^\circ] = \text{saturation temperature} + 2s + 15^\circ C$	

3.7 Safety factor, S_k

The safety factor, S_k of 3.0 is to be used in the calculation of resistance to elastic buckling. This value

is applicable where the out-of-roundness is more than 1.5% or less. Where the out-of-roundness is more than 1.5% and up to 2%, the safety factor S_k to be applied is 4.0.

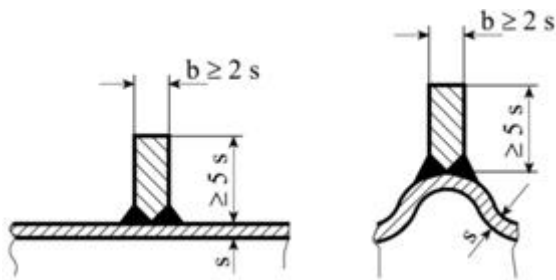


Figure 12.4 Effective stiffening

3.8 Modulus of elasticity

Table 12.6 shows the modules of elasticity for steel in relation to the design temperature.

Table 12.6 Elasticity modulus for steel

Design temperature [°C]	E_t (1) [N/mm ²]
20	206000
250	186400
300	181500
400	171700
500	161900
600	152100
(1) Intermediate values should be interpolated.	

3.9 Allowance for corrosion and wear

An allowance of 1 mm. for corrosion and wear is to be added to the wall thickness s . In the case of corrugated tubes, s is the wall thickness of the finished tube.

3.10 Minimum allowable wall thickness and maximum wall thickness

The wall thickness of plain firetubes shall be at least 7 mm, that of corrugated firetubes at least 10 mm. For small boilers, non-ferrous metals and stainless steels, smaller wall thicknesses are permitted. The maximum wall thickness may not exceed 20 mm. Tubes which are heated by flue gases <1000°C may have a maximum wall thickness of up to 30 mm.

3.11 Maximum unstiffened length

For firetubes, the length between two stiffeners may not exceed $6d$. The greatest unsupported length shall not exceed 6 meters or, in the first pass from the front end-plate, 5 meters. Stiffening of the type of shown in Figure 12.4 is to be avoided in the flame zone, i.e. up to approximately $2d$ behind the lining.

The plain portion of corrugated firetubes need not be separately calculated provided that its stressed length, measured from the middle of the end-plate attachment to the beginning of the first corrugation, does not exceed 250 mm.

3.12 Out-of-roundness

The out-of-roundness [%]

$$u = \frac{2(d_{\max} - d_{\min})}{d_{\max} + d_{\min}} \cdot 100$$

for new plain tubes is to be given the value $u=1.5\%$ in the design formula.

In the case of used firetubes, the out-of-roundness is to be determined by measurements of the diameters according to Figure 12.5.

$$u = \frac{4a}{d} \cdot 100$$

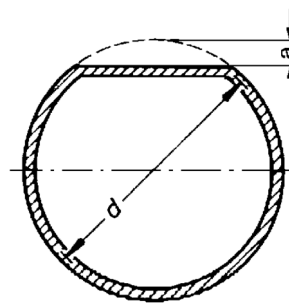


Figure 12.5 Parameters of out-of-roundness

3.1.3 Firetube spacing

The clear distance between the firetube and boiler shell at the closest point shall be at least 100 mm. The distance between any two firetubes shall be at least 120 mm.

4. Dished end-plates Under Internal and External Pressure

4.1 Scope

4.1.1 The following requirements apply to the design of unstayed, dished end-plates under internal or external pressure (see Figure 12.6). The following requirements are to be complied with:

The radius R of the dished end may not exceed the outside end-plate diameter D_a , and the knuckle radius r may not be less than $0.1 \cdot D_a$.

The height H may not be less than $0.18 D_a$.

The height of the cylindrical portion, with the exception of hemispherical end-plates, shall be $3.5 s$, s being taken as the thickness of the unpierced plate even if the end-plate is provided with a manhole. The height of the cylindrical portion need not, however, exceed the values in Table 12.7.

Table 12.7 Height h of cylindrical portion

Wall thickness, s [mm]	h [mm]
up to 50	150
over 50 up to 80	120
over 80 up to 100	100
over 100 up to 120	75
over 120	50

4.1.2 These requirements also apply to welded dished end plates. Due account is to be taken of the weakening factor of the weld. (See 2.3.3)

4.2 Symbols

p_c = Design pressure [bar],

s = Wall thickness of end-plate [mm],

D_a = Outside diameter of end-plate [mm],

H = Height of end-plate curvature [mm],

h = Height of cylindrical portion in [mm],

R = Inside radius of dished end [mm],

d = Diameter of opening measured along a line passing through the centres of the end-plate and the opening. In the case of openings concentric with the end-plate, the maximum opening diameter [mm],

σ_{perm} = Allowable stress (cf. 1.4) [N/mm²],

β = Coefficient of stress in flange [-],

β_o = Coefficient of stress in spherical section [-],

v = Weakening factor [-],

c = Allowance for corrosion and wear [mm],

E_t = Modules of elasticity at design temperature [N/mm²],

s_A = Necessary wall thickness at edge of opening [mm],

s_s = Wall thickness of branch pipe [mm],

b = Supporting length of parent component [mm],

ℓ = Width of ligament between two branch pipes [mm],

ℓ_s = Supporting length of branch pipe [mm],

ℓ'_s = Internal projection of branch pipe [mm],

A_p = Area subject to pressure [mm²],

A_σ = Supporting cross-sectional area [mm²],

S_k = Safety factor against elastic buckling [-],

S'_k = Safety factor against elastic buckling at test pressure [-].

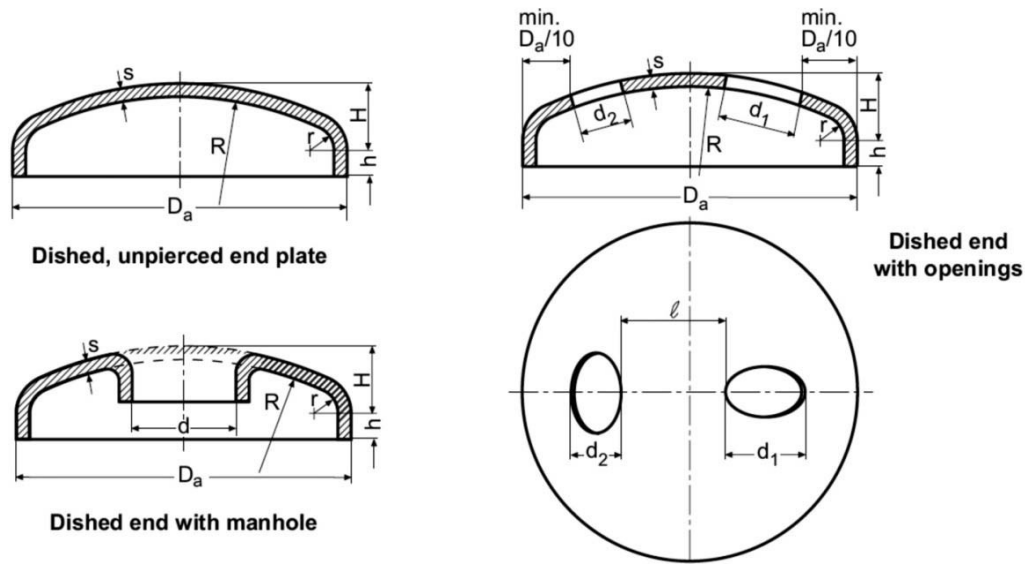


Figure 12.6 Parameters for unstayed dished end plates

4.3 Design calculation for internal pressure

4.3.1 The necessary wall thickness is given by the expression:

$$s = \frac{D_a \cdot p_c \cdot \beta}{40 \cdot \sigma_{perm} \cdot v} + c \quad (6)$$

The finished wall thickness of the cylindrical portion must be at least equal to the required wall thickness of a cylindrical shell without weakening.

4.3.2 Design coefficients β and β_0

The design coefficients are shown in Figure 12.7 in relation to the ratio H/D_a and parameters $d/(D_a s)^{1/2}$ and s/D_a .

For dished ends of the usual shapes, the height H can be determined as follows:

Shallow dished end ($R = D_a$):

$$H \approx 0,1935 \cdot D_a + 0,55 \cdot s$$

Deep dished end, ellipsoidal shape ($R = 0,8D_a$):

$$H \approx 0,255 \cdot D_a + 0,36 \cdot s$$

The values of β for unpierced end-plates also apply to dished ends with openings whose edges are located inside the spherical section and whose maximum opening diameter is $d \leq 4s$, or whose edges are adequately reinforced. The width of the ligament between two adjacent, non-reinforced openings must be at least equal to the sum of the opening radii measured along the line connecting the centres of the openings. Where the width of the ligament is less than that defined above, the wall thickness is to be dimensioned as though no ligaments were present, or the edges of the openings are to be adequately reinforced.

4.3.3 Reinforcement of openings in the spherical section

Openings in the spherical are deemed to be adequately reinforced if the following expression relating to the relevant areas is satisfied.

$$\frac{p_c}{10} \left(\frac{A_p}{A_\sigma} + \frac{1}{2} \right) \leq \sigma_{perm} \quad (7)$$

The area under pressure A_p and the supporting cross-sectional area A_σ are shown in Figure 12.8.

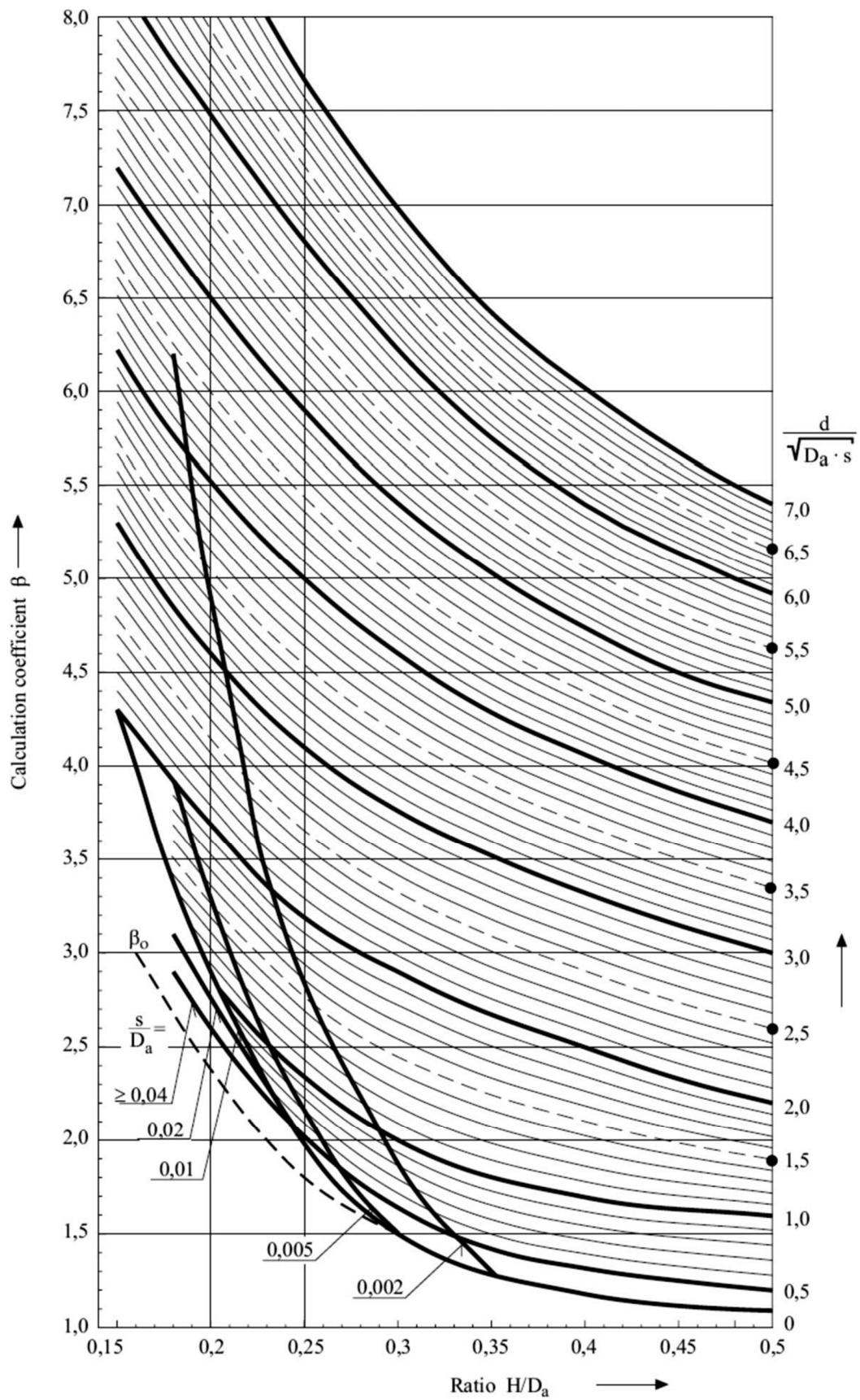


Figure 12.7 Values of coefficient β for the design of dished ends

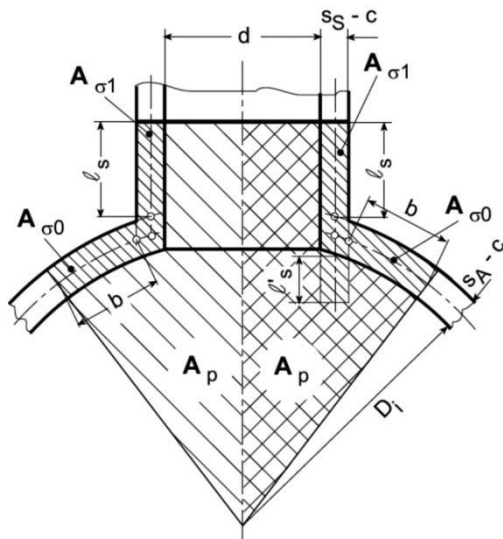


Figure 12.8 Opening in dished end plates

For calculation of reinforcements and supporting lengths the formulae and prerequisites in 2.3.4 are applicable.

The relationship between respective areas of cutouts exerting a mutual effect is shown in Figure 12.9.

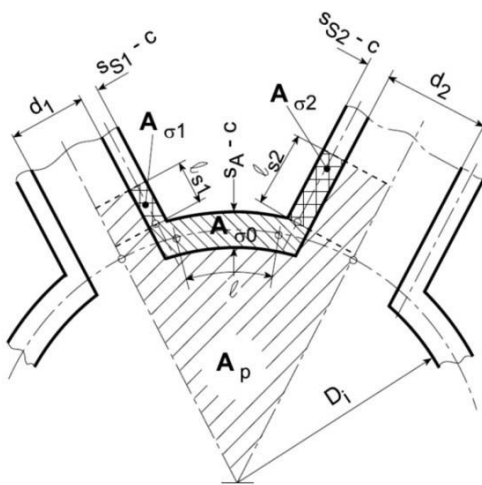


Figure 12.9 Mutual effect on openings

The edge of disk-shaped reinforcements may not extend beyond $0.8 D_a$

In the case of tubular reinforcements, the following wall thickness ratio is applicable:

$$\frac{s_s - c}{s_A - c} \leq 2.0$$

4.4 Design calculation for external pressure

4.4.1 The same formulae are to be applied to

dished end-plates under external pressure as to those subject to internal pressure. However, the safety factor used to determine the allowable stress in accordance with 1.4.1 is to be increased by 20%.

4.4.2 A check is also required to determine whether the spherical section of the end-plate is safe against elastic buckling.

The following relationship is to be applied:

$$p_c \leq 3.66 \frac{E_t (s - c)^2}{S_k \left(\frac{R}{R} \right)} \quad (8)$$

The modulus of elasticity, E_t for steel can be taken from Table 12.6. The coefficient S_k against elastic buckling and the required safety coefficient S'_k at the test pressure are shown in Table 12.8.

Table 12.8 Safety coefficients against elastic buckling

$(s-c)/R$	$S_k(1)$	$S'_k(1)$
0.001	5.5	4.0
0.003	4.0	2.9
0.005	3.7	2.7
0.010	3.5	2.6
0.100	3.0	2.2
(1) Intermediate values should be interpolated.		

4.5 Weakening factor

The weakening factor can be taken from Table 12.4 in 2.3.3. Apart from this, with welded dished ends - except for hemispherical ends - a value of $v=1$ may be applied irrespective of the scope of the test provided that the welded seam impinges on the area within the apex defined by $0.6 D_a$ (cf. Figure 12.10).

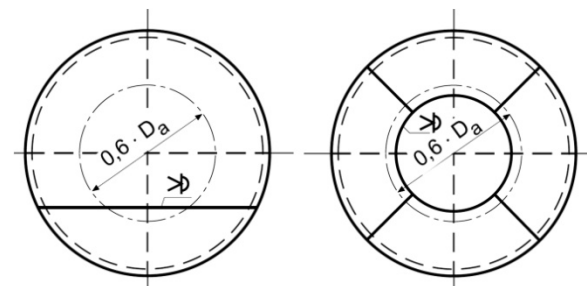


Figure 12.10 Welding seam within the apex area

4.6 Minimum allowable wall thickness

The minimum allowable wall thickness for welding neck end-plate is to be 5 mm. The smaller values for the permissible wall thickness as a minimum for non - ferrous metals and stainless steels need to be approved by **BCS**.

5. Flat surfaces

5.1 Scope

The following requirements apply to stayed and unstayed flat, flanged end-plates and to flat surfaces which are simply supported, or bolted, or welded at their periphery and which are subjected to internal or external pressure.

5.2 Symbols

- p_c = Design pressure [bar],
- s = Wall thickness [mm],
- s_1 = Wall thickness in a stress relieving groove [mm],
- s_2 = Wall thickness of a cylindrical or square header at the connection to a flat end-plate with a stress relieving groove [mm],
- D_b = Inside diameter of a flat, flanged end-plate or design diameter of an opening to be provided with means of closure [mm],
- D_1, D_2 = Diameter of circular plates [mm],
- D_t = Bolt-hole circle diameter of a plate subject additionally to a bending moment [mm],
- d_e = Diameter of the largest circle which can be described on a flat plate inside at least three anchorage points [mm],
- d_a = Outside diameter of expanded tubes [mm],
- a, b = Clear supporting or design widths of

rectangular or elliptical plates, b always designating the shorter side or axis [mm],

- t_1, t_2 = Pitch of uniformly spaced stays or stay bolts [mm],
- e_1, e_2 = Distances between centres of non-uniformly spaced stays and stay bolts [mm],
- f = Cross-sectional area of ligament [mm²],
- r_K = Inner corner radius of a flange, or radius of a stress relieving groove [mm],
- h = Inner depth of a flat, welding-neck end-plate [mm],
- C = Design coefficient, (for unstayed surfaces see Table 12.11 and for stayed surfaces see Table 12.12) [-],
- y = Ratio [-],
- σ_{perm} = Allowable stress (see 1.4) [N/mm²],
- c = Allowance for corrosion and wear [mm].

5.3 Design calculation of unstayed surfaces

5.3.1 Flat, circular, flanged, unpierced end-plates

Curvature of corner round of unstayed surfaces and inside diameter of flanged endplate are shown in Figure 12.11.

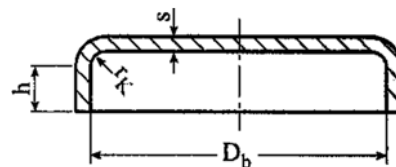


Figure 12.11 Flat, circular and flanged end plate

The necessary wall thickness s is given by the expression:

$$s = C \cdot (D_b - r_K) \cdot \sqrt{\frac{p_c}{10 \cdot \sigma_{perm}}} + c \quad (9)$$

The height of the cylindrical portion h shall be at least 3.5 s .

5.3.2 Circular plates

The necessary wall thickness s considering the Figures 12.12 to 12.14 is given by the expression:

$$s = C \cdot D_b \cdot \sqrt{\frac{p_c}{10 \cdot \sigma_{perm}}} + c \quad (10)$$

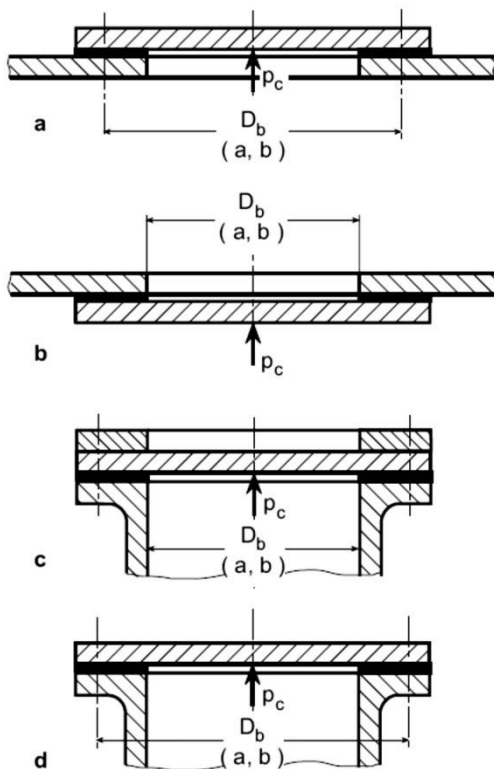


Figure 12.12 Circular plates with flat sealing

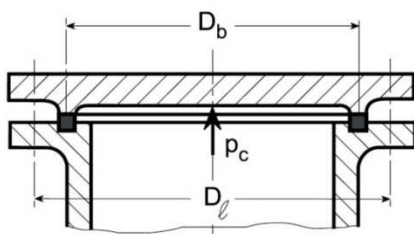


Figure 12.13 Circular plates with sealing ring

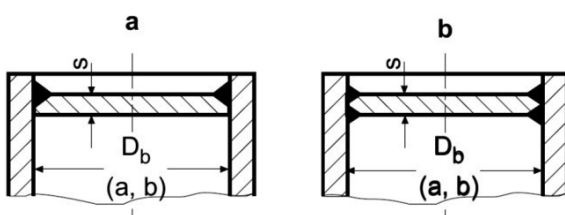


Figure 12.14 Circular welded-in endplates

5.3.3 Rectangular and elliptical plates

The required wall thickness s considering Figure 12.15 is given by the expression:

$$s = C \cdot b \cdot y \cdot \sqrt{\frac{p_c}{10 \cdot \sigma_{perm}}} + c \quad (11)$$

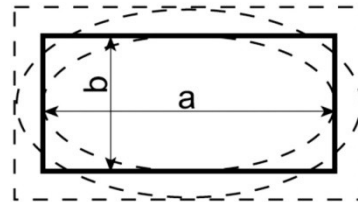


Figure 12.15 Parameters of rectangular and elliptical plates

5.3.4 Welding-neck end-plates

For welding-neck endplates of headers additional requirements are to be found in 5.5.2.

The thickness of the plated s is determined by applying formula (10) or (11) as appropriate.

In the case of end-plates with a stress relieving groove, provision must be made for the effective relieving of the welded seams. The wall thickness s_1 in the stress relieving groove must therefore satisfy the following conditions, cf. Figure 12.17:

For round end-plates: $s_1 \leq 0.77 \cdot s_2$

For rectangular end-plates: $s_1 \leq 0.55 \cdot s_2$

Here s_2 represents the wall thickness of the cylindrical or rectangular header, in mm. In addition, provision must be made to ensure that shear forces occurring in the cross-section of the groove can be safely absorbed.

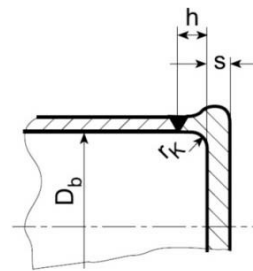


Figure 12.16

Welded-neck endplates

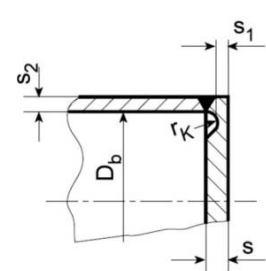


Figure 12.17

Welded-neck endplates with relieving groove

It is therefore necessary that

for round end-plates:

$$s \geq \frac{p_c \left(\frac{D_b - r}{2} \right) 1.3}{10 \left(\frac{1}{K} \right) \sigma_{perm}} \quad (12)$$

for rectangular end-plates:

$$s \geq \frac{p_c \left(\frac{a \cdot b}{a + b} \right) 1.3}{10 \left(\frac{1}{K} \right) \sigma_{perm}} \quad (13)$$

Radius r_K shall be at least 0.2 s and not less than 5 mm.

Wall thickness s_1 must be at least 5 mm.

Where welding-neck end-plates in accordance with Figures 12.16 or Figures 12.17 are manufactured from plates, the area of the connection to the shell is to be tested for laminations, e.g. ultrasonically.

5.4 Design calculation of stayed surfaces

5.4.1 For flat surfaces which are uniformly braced by stay bolts, circular stays or stay tubes, cf. Figure 12.18.

The required wall thickness s inside the stayed areas is given by the expression:

$$s = c + C \cdot \sqrt{\frac{p_c (t_1^2 + t_2^2)}{10 \cdot \sigma_{perm}}} \quad (14)$$

5.4.2 For flat plates which are non-uniformly braced by stay bolts, circular stays and stay tubes, cf. Figures 12.19.

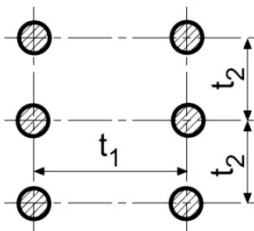


Figure 12.18
Uniformly braced plates

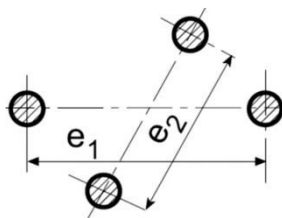


Figure 12.19
Non-uniformly braced plates

The required wall thickness s inside the stayed areas is given by the expression:

$$s = C \cdot \frac{e_1 + e_2}{2} \cdot \sqrt{\frac{p_c}{10 \cdot \sigma_{perm}}} + c \quad (15)$$

5.4.3 For flat plates which are braced by corner stays, supports or other means and flat plates between arrays of stays and tubes, cf. Figure 12.20.

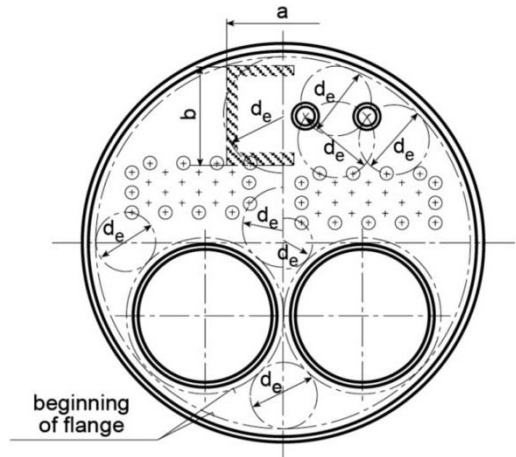


Figure 12.20 Braced flat plates

The design calculation is to be based on the diameter d_e of a circle, or on the length of the shorter side b of a rectangle which can be inscribed in the free unstiffened area, the least favorable position from the point of view of stress being decisive in each case.

The required wall thickness s is given by the expression:

$$s = C \cdot d_e \cdot \sqrt{\frac{p_c}{10 \cdot \sigma_{perm}}} + c \quad (16)$$

or

$$s = C \cdot b \cdot y \cdot \sqrt{\frac{p_c}{10 \cdot \sigma_{perm}}} + c \quad (17)$$

The higher of the values determined by the formulae is applicable.

5.4.4 Flat annular plates with central longitudinal staying, see Figure 12.21.

The required wall thickness s is given by the expression:

$$s = 0.25 \cdot (D_1 - D_2 - r_{K1} - r_{K2}) \cdot \sqrt{\frac{p_c}{10 \cdot \sigma_{perm}}} + c \quad (18)$$

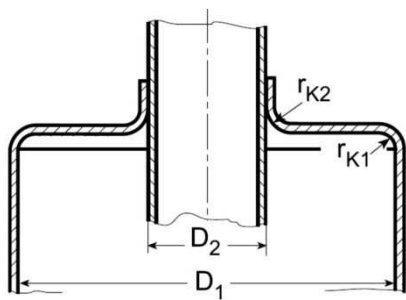


Figure 12.21 Flat annular plate with central longitudinal staying

5.5 Requirements for flanges

5.5.1 Application of the above formulae to flanged end-plate and to flanges as a means of staying is subject to the proviso that the corner radii of the flanges should have the following minimum values in relation to the outside diameter of the end-plate (cf. Table 12.9).

In addition, the flange radii r_K (Figures 12.11, 12.20 and 12.21) must be equal to at least 1.3 times the wall thickness.

Table 12.9 Minimum corner radii of flanges

Outside diameter of end plate, D_a [mm]	Corner radius of flanges, r_K [mm]
up to 500	30
over 500 up to 1400	35
over 1400 up to 1600	40
over 1600 up to 1900	45
over 1900	50

5.5.2 In the case of welding-neck end-plates without a stress relieving groove for headers, the flange radius must be $r_K \geq 1/3 s$, subject to a minimum of 8 mm., and the inside depth of the end-plate must be $h \geq s$, s for end-plates with openings being the thickness of an unpierced end-plate of the same dimensions, cf. Figure 12.16.

5.6 Ratio y

The ratio y takes account of the increase in stress, as compared with round plates, as a function of the ratio of the sides b/a of unstayed, rectangular and elliptical plates and of the rectangles inscribed in the free, unstayed areas of stayed, flat surfaces, cf. Table 12.10.

Table 12.10 Values of ratio y

Shape	Ratio b/a (1)				
	1.0	0.75	0.5	0.25	≤ 0.1
Rectangle	1.10	1.26	1.40	1.52	1.56
Ellipse	1.00	1.15	1.30	-	-
(1) Intermediate values are to be interpolated linearly.					

5.7 Calculation coefficient C

The calculation coefficient C takes account of the type of support, the edge connection and the type of stiffening. The value of C to be used in the calculation is shown in Tables 12.11 and 12.12.

Where different values of coefficient C are applicable to parts of a plate due to different kinds of stiffening according to Table 12.12, coefficient C is to be determined by the arithmetical mean value.

5.8 Minimum ligament with expanded tubes

The minimum ligament width depends on the expansion technique used. The cross-section f of the ligament between two tube holes for expanded tubes should be for:

Steel $f = 15 + 3.4 \cdot d_a \text{ [mm}^2\text{]}$

Copper $f = 25 + 9.5 \cdot d_a \text{ [mm}^2\text{]}$

5.9 Minimum and maximum wall thickness

5.9.1 With expanded tubes, the minimum plate thickness is 12 mm concerning safeguards against the dislodging of expanded tubes, see 6.3.2.

Table 12.11 Values of coefficient C for unstayed flat surfaces

Type of end-plate or cover	C
Flat, forged end-plates or end-plates with machined recesses for headers and flat, flanged end-plates	0.35
Encased plates tightly supported and bolted at their circumference	
Inserted, flat plates welded on both sided	
Welding-neck end-plates with stress relieving groove	0.40
Loosely supported plates, such as manhole covers; in the case of closing appliances, in addition to the working pressure, allowance is also to be made for the additional force which can be exerted when the bolts are tightened (the permitted loading of the bolt or bolts distributed over the cover area).	0.45
Inserted, flat plates welded on one side	
Plates which are bolted at their circumference and are thereby subjected to an additional bending moment according to the ratio: $D_i/D_b = 1.0$ $= 1.1$ $= 1.2$ $= 1.3$ Intermediate values are to be interpolated linearly.	0.45 0.50 0.55 0.60

Table 12.12 Values of coefficient C for stayed surfaces

Type of stiffening and/or end-plate	C
Boiler shell, header or combustion chamber wall, stay plate or tube area	0.35
Stay bolts in arrays with maximum stay bolt center distance of 200 mm.	0.40
Round stays and tubes outside tube arrays irrespective of whether they are welded-in, bolted or expanded	0.45

5.9.2 The wall thickness of flat end-plates should not exceed 30 mm. in the heated portion.

5.10 Reinforcement of openings

Where the edges of the openings are not reinforced, special allowance is to be made when calculating thickness for cutouts, branches etc. in flat surfaces which lead to undue weakening of the plate.

6. Stays, Stay Tubes and Stay Bolts

6.1 Scope

The following requirements apply to longitudinal stays, gusset stays, stay tubes, stay bolts and stiffening girders of steel or copper and are subject to the requirements set out in 5.

6.2 Symbols

p_c = Design pressure [bar],

F = Load on a stay, stay tube or stay bolt [N],

A_1 = Calculated required cross-sectional area of stays, stay bolts and stay tubes [mm²],

A_2 = Supported area of expanded tubes [mm²],

A_p = Plate area supported by one stay, stay bolt or stay tube [mm²],

d_a = Outside diameter of tube, stay or stay bolt [mm],

d_i = Inside diameter of stay tube [mm],

l_o = Length of expanded section of tube [mm],

a_1 = Weld height in direction of load according to Figure 12.22 to Fig 12.24 [mm],

σ_{perm} = Allowable stress [N/mm²].

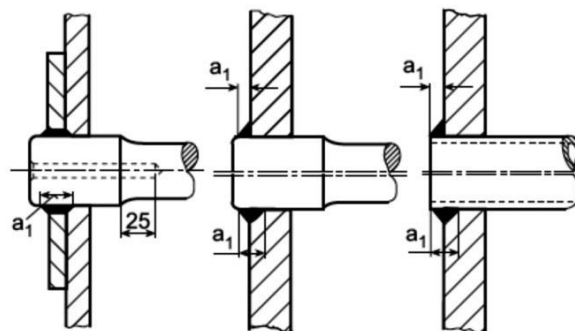


Figure 12.22 Figure 12.23 Figure 12.24
Parameters for welding of stays, stay tubes and stay bolts

6.3 Design calculation

The supporting action of other boiler parts may be taken into consideration when calculating the size of stays, stay tubes and stay bolts. Where the boundary areas of flanged end-plates are concerned, calculation of the plate area A_p is to be based on the flat surface extending to the beginning of the end-plate flange.

In the case of flat end-plates, up to half the load may be assumed to be supported by the directly adjacent boiler wall.

6.3.1 For stays, stay bolts or stay tubes, the necessary cross-sectional area is given by the expression:

$$A_1 = \frac{F}{\sigma_{\text{perm}}} \quad (19)$$

6.3.2 Where expanded tubes are used, a sufficient safety margin must be additionally applied to prevent the tubes from being pulled out of the tube plate. Such a safety margin is deemed to be achieved if the allowable load on the supporting area does not exceed the values specified in Table 12.13.

Table 12.13 Loading of expanded tube connections

Type of expanded connection	Allowable load on supporting area [N/mm ²]
Plain	$(F / A_2) \leq 150$
With groove	$(F / A_2) \leq 300$
With flange	$(F / A_2) \leq 400$

For the purpose of the calculation, the supporting area is given

by the expression: $A_2 = (d_a - d_i) \cdot \ell_o$

subject to a maximum of: $A_2 = 0.1 \cdot d_a \cdot \ell_o$

For calculating the supporting area, the length of the expanded section of tube (ℓ_o) may not be taken as exceeding 40 mm.

6.3.3 Where longitudinal stays, stay tubes or stay bolts are welded in, the cross-section of the fillet weld subject to shear shall be at least 1.25 times the required bolt or stay tube cross-section:

$$d_a \cdot \pi \cdot a_1 \geq 1.25 A_1 \quad (20)$$

6.4 Allowable stress

The allowable stress is to be determined in accordance with 1.4.1. In departure from this, however, a value of $R_{eH,t}/1.8$ is to be expected in the area of the weld in the case of stays, stay tubes and stay bolts made of rolled and forged steels.

6.5 Allowances for wall thickness

For the calculation of the necessary cross-section of stays, stay tubes and stay bolts according to formula (19) the allowance for corrosion and wear is to be considered.

7. Boiler and Superheater Tubes

7.1 Scope

The design calculation applies to tubes under internal pressure and, up to an outside tube diameter of 200 mm, also to tubes subject to external pressure.

7.2 Symbols

p_c = Design pressure [bar],

s = Wall thickness [mm],

d_a = Outside diameter of tube [mm],

σ_{perm} = Allowable stress [N/mm²],

v = Weld quality rating of longitudinally welded tubes [-].

7.3 Calculation of wall thickness

The necessary wall thickness s is given by the expression:

$$s = \frac{d \cdot p}{20 \cdot \sigma_{\text{perm}} \cdot v + p_c} \quad (21)$$

7.4 Design temperature t

The design temperature is to be determined in accordance with 1.3.

In the case of once through forced flow boilers, the calculation of the tube wall thicknesses is to be based on the maximum temperature excepted in the individual main sections of the boiler under operating conditions plus the necessary added temperature allowances.

7.5 Allowable stress

The allowable stress is to be determined in accordance with 1.4.1.

For tubes subject to external pressure, a value of $R_{eH,t}/2.0$ is to be applied.

7.6 Welding factor v

For longitudinally welded tubes, the value of v to be applied shall correspond to the approval test.

7.7 Wall thickness allowances

In the case of tubes subject to relatively severe mechanical or chemical attack an appropriate wall thickness allowance shall be agreed which shall be added to the wall thickness calculated by applying formula (21). The allowable minus tolerance on the wall thickness (see 1.1.2) need only be taken into consideration for tubes whose outside diameter exceeds 76.1 mm.

7.8 Maximum wall thickness of boiler tubes

The wall thickness of intensely heated boiler tube (e.g. where the temperature of the heating gas exceeds 800°C) shall not be greater than 6.3 mm. This requirement may be dispensed with in special cases, e.g. for superheater support tubes.

8. Plain Rectangular Tubes and Sectional Headers

8.1 Symbols

p_c = Design pressure [bar],

s = Wall thickness [mm],

$2 \cdot m$ = Clear width of the rectangular tube parallel to the wall in question [mm],

$2 \cdot n$ = Clear width of the rectangular tube perpendicular to the wall in question [mm],

Z = Coefficient according to formula (23) [mm²],

a = Distance of relevant line of holes from centre line of side [mm],

t = Pitch of holes [mm],

d = Hole diameter [mm],

v = Weakening (ligament) factor for rows of holes under tensile stress [-],

v' = Weakening factor for rows of holes under bending stress [-],

r = Inner radius at corners [mm],

σ_{perm} = Allowable stress [N/mm²].

8.2 Design calculation

8.2.1 The wall thickness is to be calculated for the centre of the side and for the ligaments between the holes. The maximum calculated wall thickness shall govern the wall thickness of the entire rectangular tube.

The following method of calculation is based on the assumption that the tube connection stubs have been properly mounted, so that the wall is adequately stiffened.

8.2.2 The required wall thickness is given by the expression:

$$s = \frac{p_c \cdot n}{20 \cdot \sigma_{perm} \cdot v} + \sqrt{\frac{4.5 \cdot p_c \cdot Z}{10 \cdot \sigma_{perm} \cdot v'}} \quad (22)$$

If there are several different rows of holes, the necessary wall thickness is to be determined for each row.

8.2.3 Z is calculated by applying the formula:

$$Z = \left| \frac{1}{3} \left(\frac{m^3 + n^3}{m + n} \right) - \frac{1}{2} (m^2 - a^2) \right| \quad (23)$$

8.3 Weakening factor, ligament efficiency factor

8.3.1 If there is only one row of holes, or if there are several parallel rows not staggered in relation to each other, the weakening factors v and v' are to be determined as follows:

$$v = \frac{t - d}{t}$$

$$v' = v = \frac{t - d}{t} \quad \text{for holes where } d < 0.6 \cdot m$$

$$v' = \frac{t - 0.6m}{t} \quad \text{for holes where } d \geq 0.6 \cdot m$$

8.3.2 In determining the values of v and v' for elliptical holes, d is to be taken as the clear width of the holes in the longitudinal direction of the rectangular tube. However, for the purpose of deciding which formula is to be used for determining v' , the value of d in the expressions $d \geq 0.6 \cdot m$ and $d < 0.6 \cdot m$ is to be the inner diameter of the hole perpendicular to the longitudinal axis.

8.3.3 In calculating the weakening factor for staggered rows of holes, t is to be substituted in the formula by t_1 for the oblique ligaments (Figure 12.25).

8.3.4 For oblique ligaments, Z is calculated by applying the formula:

$$Z = \left| \frac{1}{3} \left(\frac{m^3 + n^3}{m + n} \right) - \frac{1}{2} m^2 \cos \alpha \right|$$

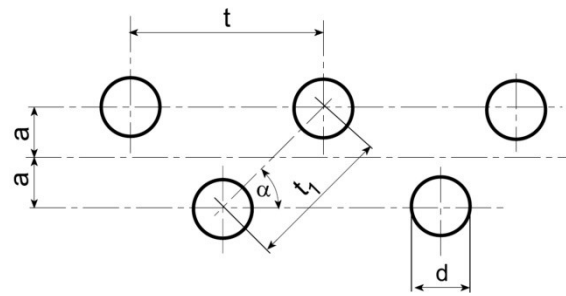


Figure 12.25 Length of ligament for staggered rows of holes

8.4 Stress at corners

In order to avoid undue stresses at corners, the following conditions are to be satisfied for the higher values of r than $s/2$ ($r \geq s/2$), subjected to a minimum of:

- 3 mm for rectangular tubes with a clear width of up to 50 mm.
- 8 mm for rectangular tubes with a clear width of 80 mm or over.

Intermediate values are to be interpolated linearly. The radius shall be governed by the arithmetical mean value of the nominal wall thicknesses on both sides of the corner. The wall thickness at corners may not be less than the wall thickness determined by applying formula (22).

8.5 Minimum wall thickness and ligament width

8.5.1 The minimum wall thickness for expanded tubes shall be 14 mm.

8.5.2 The width of a ligament between two openings or tube holes may not be less than 1/4 of the distance between the tube centres.

9. Straps and Girders

9.1 Scope

The following requirements apply to steel girders used for stiffening of flat plates.

9.2 General

The supporting girders are to be properly welded to the combustion chamber crown at all points. They are to be arranged in such a way that the welds can be competently executed and the circulation of water is not obstructed.

9.3 Symbols

p_c = Design pressure [bar],

F = Load carried by one girder [N],

e = Distance between centre lines of girders [mm],

ℓ = Free length between girder supports [mm],

b = Thickness of girder [mm],

h = Depth of girder [mm],

W = Section modules of one girder [mm³],

M = Bending moment acting on girder at given load [Nmm],

z = Coefficient for section modules [-],

σ_{perm} = Allowable stress (see 1.4) [N/mm²].

9.4 Design calculation

9.4.1 The simply supported girder shown in Figure 12.26 is to be treated as a simply supported beam of length ℓ . The support afforded by the plate material may also be taken into consideration.

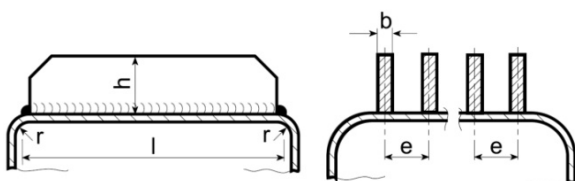


Figure 12.26 Unsupported girder

9.4.2 The required section modules of a girder is given by:

$$W = \frac{M_{max}}{1.3 \cdot \sigma_{perm} \cdot z} \leq \frac{b \cdot h^2}{6} \quad (24)$$

The coefficient z for the section modules takes account of the increase in the section modules due to the flat plate forming part of the girder. It may in general be taken as $z = 5/3$.

For the height h , a value not exceeding $8 \cdot b$ is to be inserted in the formula.

9.4.3 The maximum bending moment is given by the expression:

$$M_{max} = \frac{F \cdot \ell}{8} \quad (25)$$

where

$$F = \frac{p_c}{10} \ell \cdot e \quad (26)$$

10. Bolts

10.1 Scope

The following requirements related to bolts which, as force-transmitting connecting elements, are subjected to tensile stresses due to the internal pressure. Normal operating conditions are assumed.

10.2 General

Necked-down bolts should be used for elastic bolted connections, particularly where the bolts are highly stressed, or are exposed to service temperatures of over 300°C, or have to withstand internal pressures of 8 N/mm² or over. All bolts > M30 (30 mm diameter metric thread) must be necked-down bolts. Necked-down bolts are bolts to DIN 2510 (TS 1709) with a shank diameter $d_s = 0.9 \cdot d_k$ (d_k being the root diameter). In the calculation special allowance is to be made for shank diameters < 0.9 d_k .

Bolts with a shank diameter of less than 10 mm. are not allowed.

Bolts may not be located in the path of heating gases. At least 4 bolts must be used to form a connection.

To achieve small sealing forces, the jointing material should be made as narrow as possible.

Where standard pipe flanges are used, the strength requirements for the bolts are considered to be satisfied if the bolts used comply with EN 1515-1 and EN 1515-2, conform to the specifications contained therein in respect of the materials used, the maximum allowable working pressure and the service temperature.

10.3 Symbols

p_c = Design pressure [bar],

p' = Test pressure [bar],

F_s = Total load on bolted connection in service [N],

F'_s = Total load on bolted connection at test pressure [N],

F_{s0} = Total load on bolted connection in assembled condition with no pressure exerted [N],

F_B = Load imposed on bolted connection by the working pressure [N],

F_D = Force to close joint under service condition [N],

F_{D0} = Force to close joint in assembled condition [N],

F_Z = Additional force due to stresses in connecting piping [N],

D_b = Mean sealing or bolt pitch circle diameter [mm],

d_i = Inside diameter of connected pipe [mm],

d_s = Shank diameter of necked-down bolt [mm],

d_k = Root diameter of thread [mm],

n = Number of bolts forming connection [-],

σ_{perm} = Allowable stress [N/mm²],

ϕ = Surface finish coefficient [-],

c = Additional allowance [mm],

k_1 = Sealing factor for service condition [mm],

k_0 = Sealing factor for assembled condition [mm],

K_D = Sealing material deformation factor [N/mm²].

10.4 Design Calculation

10.4.1 Bolted joints are to be designed for the following load conditions:

10.4.1.1 Service conditions (design pressure p_c and design temperature t),

10.4.1.2 Load at test pressure (test pressure p' , $t=20^\circ\text{C}$) and,

10.4.1.3 Assembled condition at zero pressure ($p = 0$ bar, $t = 20^\circ\text{C}$).

10.4.2 The necessary root diameter of a bolt in a bolted joint comprising n bolts is given by:

$$d_k = \sqrt{\frac{4 \cdot F_s}{\pi \cdot \sigma_{perm} \cdot \phi \cdot n}} + c \quad (27)$$

10.4.3 The total load on a bolted joint is to be calculated as follows:

10.4.3.1 For service conditions:

$$F_s = F_B + F_D + F_Z \quad (28)$$

$$F_B = \frac{\pi}{4} D_b^2 \cdot \frac{p_c}{10} \quad (29)$$

$$F_D = 1.2 \cdot k_1 \cdot \pi \cdot D_b \cdot \frac{p_c}{10} \quad (30)$$

(Where the arrangement of the bolts deviates widely from the circular, due allowance is to be made for the special stresses occurring).

The additional force F_Z due to connected piping must be calculated from the stresses present in these pipes. F_Z is 0 in the case of bolted joints with no connected pipes. Where connecting pipes are installed in the normal manner and the service temperatures are $< 400^\circ\text{C}$, F_Z may be determined, as an approximation, by applying the expression:

$$F_Z \approx \frac{\pi}{4} \cdot d_i^2 \cdot \frac{p_c}{10}$$

10.4.3.2 For the test pressure:

$$F'_s = \frac{p_p}{p_c} \left(F_D + 1.2 \right) + F_Z \quad (31)$$

For calculating the root diameter of the thread, F_s is to be substituted by F'_s in formula (27).

10.4.3.3 For the zero pressure, assembled condition:

$$F_{S0} = F_{D0} + F_Z \quad (32)$$

$$F_{D0} = k_0 \cdot K_D \cdot \pi \cdot D_b \quad (33)$$

For calculating root diameter of the thread, F_s is to be substituted by F_{S0} in formula (27).

In the zero pressure, assembled condition, the force F_{D0} is to be exerted on the bolts during assembly to affect an intimate union with the sealing material and to close the gap at the flange bearing surfaces.

If the force exerted on assembly $F_{D0} > F_s$ this value may be replaced by the following where malleable sealing materials with or without metal elements are used:

$$F'_{D0} = 0.2 \cdot F_{D0} + 0.8 \cdot \sqrt{F_s \cdot F_{D0}} \quad (34)$$

Factors k_0 , k_1 and K_D depend on the type, design and shape of the joint and the kind of fluid.

The relevant values are shown in the Tables 12.16 and 12.17.

10.4.4 The bolt design is to be based on the greatest root diameter of the thread determined in accordance with the three load conditions specified in items 10.4.1.1 to 10.4.1.3.

10.5 Design temperature t

The design temperatures of the bolts depend on the type of joint and the insulation. In the absence of special proof as to temperature, the following design temperatures are to be applied:

Loose flange	
+ loose flange	steam temperature -30°C
Fixed flange	
+ loose flange	steam temperature -25°C
Fixed flange	
+ fixed flange	steam temperature -15°C

The temperature reductions allow for the drop in temperature at insulated, bolted connections. For non-insulated bolted joints, a further temperature reduction is not permitted because of the higher thermal stresses imposed on the entire bolted joint.

10.6 Allowable stress

The values of the allowable stress σ_{perm} are shown in Table 12.14.

Table 12.14 Allowable stress σ_{perm}

Condition	For necked-down bolts	For full-shank bolts
Service condition	$\frac{R_{eH,t}}{1.5}$	$\frac{R_{eH,t}}{1.6}$
Test pressure and zero-pressure assembled condition	$\frac{R_{eH,20}}{1.1}$	$\frac{R_{eH,20}}{1.2}$

10.7 Surface finish coefficient, ϕ

10.7.1 Full-shank bolts are required to have a surface finish of at least grade mg to EN ISO 898. Necked-down bolts must be machined all over.

10.7.2 In the case of unmachined, plane-parallel bearing surfaces, $\phi = 0.75$. Where the bearing surfaces of the mating parts are machined, a value of $\phi = 1.0$ may be used. Bearing surfaces which are not plane-parallel (e.g. on angle sections) are not permitted.

10.8 Additional allowance c

The additional allowance c [mm] shall be as shown in Table 12.15.

Table 12.15 Allowance c

Condition	c [mm]
For service conditions:	
up to M 24	3
M 27 up to M 45	$5 - 0.1 d_k$
M 48 and over	1
For test pressure	0
For assembled condition	0

Table 12.16 Deformation factors

Material	Deformation factor K_D [N/mm ²]
Aluminium, soft	92
Copper, soft	185
Soft iron	343
Steel, St 35	392
Alloy steel, 13 Cr Mo 44	441
Austenitic steel	491
<i>Note: At room temperature K_D is to be substituted by the deformation factor at 10% compression δ_{10} or alternatively by the tensile strength R_m.</i>	

E. Equipment and Installation**1. General**

1.1 The following requirements apply to steam boilers which are not constantly and directly monitored during operation. Note is also to be taken of the official regulations of the flag country of the vessel, where appropriate.

1.2 In the case of steam boilers which are monitored constantly and directly during operation, some easing of the following requirements may be permitted, while maintaining the operational safety of the vessels.

1.3 In the case of steam boilers which have a maximum water volume of 150 litres, a maximum allowable working pressure of 1 MPa and where the product of water volume and maximum allowable water pressure is less than 50 (MPa x litres), an easing of the following requirements may be permitted.

1.4 With regard to the electrical installation and equipment also the Rules for Classification and Construction, Chapter 5 - Electrical Installations and Chapter 4-1 - Automation are to be observed.

2. Safety Valves

2.1 Each steam generator which has its own steam space is to be equipped with at least two type approved, spring-loaded safety valves. At least one safety valve is to be set to respond if the maximum allowable working pressure is exceeded.

In combination, the safety valves are to be capable of discharging the maximum quantity of steam which can be produced by the steam generator during continuous operation without the maximum allowable working pressure being exceeded by more than 10 %.

2.2 Each steam generator which has a shut-off but which does not have its own steam space is to have at least one type approved, spring-loaded safety valve fitted at its outlet. At least one safety valve is to be set to respond if the maximum allowable working pressure is

exceeded. The safety valve or safety valves are to be designed so that the maximum quantity of steam which can be produced by the steam boiler during continuous operation can be discharged without the maximum allowable working pressure being exceeded by more than 10 %.

2.2.1 Steam generators with a great water space which are exhaust gas heated and can be shut-off having a heating surface up to 50 m² are to be equipped with one, with a heating surface above 50 m² with at least two, suitable type-approved, springloaded safety valves. The safety valve resp. the safety valves have to be so designed that their activation is also guaranteed with compact sediments between spindle and bushing. Otherwise their design may be established in a way that compact sediments in the valve and between spindle and bushing are avoided (e.g. bellows valves).

2.3 External steam drums are to be fitted with at least two type approved, spring-loaded safety valves. At least one safety valve is to be set to respond if the maximum allowable working pressure is exceeded. In combination, the safety valves shall be capable of discharging the maximum quantity of steam which can be produced in continuous operation by all connected steam generators without the maximum allowable working pressure of the steam drum being exceeded by more than 10 %.

2.4 Each hot water generator is to be equipped with at least two type approved, spring-loaded safety valves. At least one safety valve is to be set to respond if the maximum allowable working pressure is exceeded.

For the size of the safety valves steam blow-off at saturated steam condition corresponding to the set pressure of the safety valves has to be supposed also for safety valves which are normally under water

pressure. In combination, the safety valves are to be capable of discharging the maximum quantity of steam which corresponds to the allowable heating power of the hot water generator during continuous operation without the maximum allowable working pressure being exceeded by more than 10 %.

2.5 The closing pressure of the safety valves shall be not more than 10 % below the response pressure.

2.6 The minimum flow diameter of the safety valves shall be at least 15 mm.

2.7 Servo-controlled safety valves are permitted wherever they are reliably operated without any external energy source.

2.8 The safety valves are to be fitted to the saturated steam part or, in the case of steam boilers which do not have their own steam space, to the highest point of the boiler or in the immediate vicinity respectively.

At hot water generators the safety valves could also be arranged at the discharge line in the immediate vicinity of the generator. At once-through hot water generators the safety valves are to be located in the immediate vicinity of the connection of the discharge line to the generator.

2.9 In the case of steam generators which are fitted with superheaters with no shut-off capability, one safety valve is to be located at the discharge from the superheater. The safety valve at the superheater discharge has to be designed for at least 25 % of the necessary exhaust capacity.

Superheaters with shut-off capability are to be fitted with at least one safety valve designed for the full steam capacity of the superheater.

When designing the capacity of safety valves, allowance is to be made for the increase in the volume of steam caused by superheating.

2.10 Steam may not be supplied to the safety valves through pipes in which water may collect.

2.11 Safety valves are to be easily accessible and capable of being released safely during operation.

2.12 Safety valves are to be designed so that no binding or jamming of moving parts is possible even when heated to different temperatures. Seals which may prevent the operation of the safety valve due to frictional forces are not permitted.

2.13 Safety valves are to be set in such a way as to prevent unauthorized alteration.

2.14 Pipes or valve housings are to have a drain facility fitted at the lowest point on the blow-off side which has no shut-off capability.

2.15 Combined blow-off lines from several safety valves shall not unduly impair the blow-off capability. The discharging media are to be drained away safely.

3. Water Level Indicators

3.1 Steam generators which have their own steam chamber are to be fitted with two devices giving a direct reading of the water level.

3.2 Steam generators which have their own steam space heated by exhaust gases and where the temperature does not exceed 400 °C, are to be fitted with at least one device giving a direct reading of the water level.

3.3 External steam drums of steam generators which do not have their own steam space are to be fitted with two devices giving a direct reading of the water level.

3.4 In place of water level indicators, once through forced flow boilers are to be fitted with two mutually

independent devices which trip an alarm as soon as water flow shortage is detected. An automatic device to shut down the oil burner may be provided in place of the second warning device.

3.5 Hot water generators are to be equipped with a test cock at the highest point of the generator or in the immediate vicinity.

3.5.1 Additionally a water level indicator shall be provided. This water level indicator is to be located at the hot water generator or at the discharge line.

3.5.2 This water level indicator at the generator can be dispensed with in hot water generation plants with membrane expansion vessel if a low pressure limiter is installed (at the membrane expansion vessel or in the system) which trips in case the water level falls below the specified lowest water level in the membrane expansion vessel.

3.5.3 A low flow limiter is to be installed at once through hot water generators instead of the water level indicator (see 8.8.5).

3.6 Cylindrical glass water level gauges are not permitted.

3.7 The water level indicators are to be fitted so that a reading of the water level is possible when the ship is heeling and during the motion of the ship when it is at sea. The limit for the lower visual range shall be at least 30 mm above the highest flue, but at least 30 mm below the lowest water level. The lowest water level shall not be above the centre of the visual range. The water level indicators have to be illuminated and visible from the steam boiler control station resp. from the station for control of the water level.

3.8 The connection pipes between steam boiler and water level indicators are to have an inner diameter of at least 20 mm. They shall be run in such a way that there are no sharp bends in order to avoid water and steam traps, and have to be protected from the effects of the heated gases and against cooling.

Where water level indicators are linked by means of common connection lines or where the connection pipes on the water side are longer than 750 mm, the connection pipes on the water side are to have an inner diameter of at least 40 mm.

3.9 Water level indicators are to be connected to the water and steam space of the steam boiler by means of easily accessible, simple to control and quick-acting shut-off devices.

3.10 The devices used for blowing through the water level indicators are to be designed so that they are safe to operate and so that blow-through can be monitored.

The discharging media are to be drained away safely.

3.11 Remote water level indicators and display equipment of a suitable type to give an indirect reading may be allowed as additional display devices.

3.12 The cocks and valves of the water level indicators which cannot be directly reached by hand from floor plates or a control platform are to have a control facility using pull rods or chain pulls.

4. Pressure Gauges

4.1 At least one pressure gauge directly connected to the steam space is to be fitted on each boiler. The allowable maximum working pressure is to be marked on the dial by means of a permanent and easily visible red mark.

4.2 At least one additional pressure indicator having a sensor independent from the pressure gauge has to be located at the machinery control station or at some other appropriate site.

4.3 Where several steam boilers are incorporated on one ship, the steam chambers of which are linked together, one pressure gauge is sufficient at the machinery control station or at some other suitable location, in addition to the pressure gauges on each boiler.

4.4 The pipe to the pressure gauge must have a water trap and must be of a blow-off type. A connection for a test gauge must be installed close to the pressure gauge. In the case of pressure gauges which are set off at a lower position the test connection must be provided close to the pressure gauge and also close to the connection piece of the pressure gauge pipe.

4.5 Pressure gauges are to be protected against radiant heat and must be well illuminated.

4.6 Pressure gauges are to be located where they can be easily seen.

4.7 The double-ended boilers are to have one pressure gauge at each end.

5. Temperature Gauges

5.1 A temperature gauge is to be fitted to the flue gas outlets of fired steam boilers.

5.2 Temperature gauges are to be fitted to the exhaust gas inlet and outlet of steam boilers heated by exhaust gas.

5.3 Temperature gauges must be fitted at the outlets from superheaters or superheater sections, at the inlet and outlet of economizers, and also at the outlet of once-through forced flow boilers, where this is necessary to assess the behaviour of the materials used.

5.4 A temperature indicator is to be fitted to the flue gas outlet of oil fired steam boilers.

5.5 Temperature indicators are to be installed in the discharge and return line of each hot water generator in such a way that they indicate the actual outlet and inlet temperature.

6. Regulating Devices (Controllers)

6.1 With the exception of boilers which are heated by exhaust gas, steam boilers are to be operated with rapid-control, automatic firing systems. In main boilers, the control facility must be capable of

safely controlling all rates of speed and manoeuvres so that the steam pressure and the temperature of the superheated steam stay within safe limits and the supply of feed water is guaranteed. Auxiliary boilers are subject to the same requirements within the scope of potential load changes.

6.2 Steam pressure must be automatically regulated by controlling the supply of heat. The steam pressure of boilers heated by exhaust gas may also be regulated by condensing the excess steam.

6.3 In the case of boilers which have a specified minimum water level, the water level must be regulated automatically by controlling the supply of feed water.

6.4 In the case of forced-circulation boilers whose heating surface consists of a steam coil and once through forced flow boilers, the supply of feed water may be regulated as a function of fuel supply.

6.5 In the case of steam boilers which are fitted with superheaters, the temperature of the superheated steam must be automatically regulated unless the calculated temperature is higher than the maximum attainable temperature of the superheater walls.

6.6 The discharge temperature of each hot water generator shall be automatically regulated by controlling the supply of heat. The control of the discharge temperature of exhaust gas heated hot water generators may also be carried out by a dumping cooler

7. Monitoring Devices (Alarms)

7.1 A warning device is to be fitted which is tripped when the specified maximum water level is exceeded.

7.2 In exhaust-gas heated boilers, a warning device is to be fitted which is tripped before the maximum allowable working pressure is reached.

7.3 In exhaust-gas heated boilers with specified minimum water level, a warning device is to be fitted which is tripped when the water falls below this level.

7.4 Exhaust gas boilers with finned tubes are to have a temperature monitor fitted in the exhaust gas pipe which trips an alarm in the event of fire. See Automation.

7.5 Where there is a possibility of oil or grease getting into the steam or condensate system, a suitable automatic and continuously operating unit is to be installed which trips an alarm and cuts off the feed water supply if the concentration at which boiler operation is put at risk is exceeded.

7.6 Where there is a possibility of acid, lye or seawater getting into the steam or condensate system, a suitable automatic and continuously operating unit is to be installed which trips an alarm and cuts off the feed water supply if the concentration at which boiler operation is put at risk is exceeded.

7.7 It must be possible to carry out function testing of the monitoring devices, even during operation, if an equivalent degree of safety is not attained by self-monitoring of the equipment.

7.8 The monitoring devices must trip visual and audible fault warnings in the boiler room or in the machinery control room or any other suitable site. See Automation.

8. Safety Devices (Limiters)

8.1 The suitability of safety devices for marine use is to be proven by type testing.

The safety devices must be suitable for the use on steam boilers.

8.2 Fired boilers are to be equipped with a reliable pressure limiter which cuts out and interlocks the firing system before the maximum allowable working pressure is reached.

8.3 In steam boilers on whose heating surfaces a highest flue is specified, two reliable, mutually independent water level limiters must respond to cut out and interlock the firing system when the water falls

below the specified minimum water level. The water level limiter must also be independent of the water level control devices.

8.4 The receptacles for water level limiters located outside the boiler must be connected to the boiler by means of lines which have a minimum inner diameter of 20 mm. Shut-off devices in these lines must have a nominal diameter of at least 20 mm. and must indicate their open or closed position. Where water level limiters are connected by means of common connection lines, the connection pipes on the water side must have an inner diameter of at least 40 mm.

Operation of the firing system may only be possible when the shut-off devices are open or else, after closure, the shut-off devices must reopen automatically and in a reliable manner.

Water level limiter receptacles which are located outside the boiler are to be designed in such a way that a compulsory and periodic blow-through of the receptacles and lines can be carried out.

8.5 In the case of forced-circulation boilers with a specified lowest water level, two reliable, mutually independent safety devices must be fitted in addition to the requisite water level limiters, which will cut out and interlock the heating system in the event of any unacceptable reduction in water circulation.

8.6 In the case of forced-circulation boilers whose heating surface consists of a single coil and once-through forced flow boilers, two reliable, mutually independent safety devices must be fitted in place of the water level limiters in order to provide a sure means of preventing any excessive heating of the heating surfaces by cutting out and interlocking the firing system.

8.7 In steam boilers with superheaters, a temperature limiter is to be fitted which cuts out and interlocks the heating system if the allowable superheated steam temperature is exceeded. In the case of boiler parts which carry superheated steam and which have been designed to long-term resistance values; one temperature recording device is adequate.

8.8 The safety devices must trip visual and audible alarms in the boiler room or in the machinery control room or any other appropriate site. See Automation.

8.9 The electrical devices associated with the limiters are to be designed in accordance with the closed-circuit principle so that, even in the event of a power failure, the limiters will cut out and interlock the systems unless an equivalent degree of safety is achieved by other means.

8.10 To reduce the effects due to swell, water level limiters can be fitted with a delay function provided that this does not cause a dangerous drop in the water level.

8.11 The electrical interlocking of the firing system following tripping by the safety devices may only be cancelled out at the firing system control panel itself.

8.12 If an equivalent degree of safety cannot be achieved by the self-monitoring of the equipment, the safety devices must be subjected to operational testing even during operation. In this case, the operational testing of water level limiters must be carried out without the surface of the water dropping below the lowest water level.

8.13 For details of additional requirements relating to once-through forced flow boilers, see 3.10.

8.14 Hot water generators are to be equipped with the following safety equipment:

8.14.1 A pressure limiter, which shuts-down and interlocks the oil burner resp. triggers an alarm at an exhaust gas heated hot water generator in case the maximum allowable working pressure is exceeded (high pressure limiter), shall be provided at each hot water generator equipped with external pressure generation. It has to be defined for each special plant if apart from shutting-down the oil burner the circulating pumps have to be shut-down also.

8.14.2 A pressure limiter, which shuts-down and interlocks the oil burner in case the system pressure

falls below the system related minimum pressure (low pressure limiter), shall be provided in systems with external pressure generation.

8.14.3 A water level limiter, which shuts-down and interlocks the oil burner and the circulating pumps in case the water level falls below the allowable lowest level, shall be provided at the hot water generator. This water level limiter is to be installed at the hot water generator or at the discharge line. The installation of the low water level limiter can be dispensed with for systems with membrane expansion vessel in case a low pressure limiter is set to a value that trips in case the water level at the membrane expansion vessel falls below the lowest specified level.

8.14.4 At hot water generators with natural circulation the low water level limiter has to be replaced by a low flow limiter in case the temperature limiter or low water level limiter could not switch-off the oil burner as early as to prevent unacceptable evaporation.

8.14.5 At once-through hot water generators a low flow limiter has to be installed instead of the low water level limiter, which shuts-down and interlocks the oil burner in case the water flow is reduced below the specified lowest value.

8.14.6 Each hot water generator is to be equipped with a temperature limiter. The place of installation of the sensor of the temperature limiter shall be so that in every case the highest temperature at the hot water generator will be detected under all operating conditions, even when the circulating pumps are stopped.

An immersion pipe has to be provided close to the sensor of the temperature limiter for checking the set temperature.

9. Feed and Circulation Devices

9.1 For details of boiler feed and circulation devices, see Section 16, F. The following requirements are also to be noted:

9.2 The feed devices are to be fitted to the steam boiler in such a way that it cannot be drained lower than 50 mm. above the highest flue when the non-return valve is not tight.

9.3 The feed water is to be fed into the steam generator in such a way as to prevent damaging effects to the boiler walls and to heated surfaces.

9.4 A proper treatment and adequate monitoring of the feed and boiler water are to be carried out.

9.5 At hot water generators the discharge line has to be arranged at the highest point of the generator.

9.6 In the hot water return line leading to the generator a check-valve has to be installed. This check valve can be dispensed with if the return line is connected to the generator at least 50 mm above the highest flue.

10. Shut-off Devices

10.1 Each steam boiler shall be capable of being shut off from all connected pipes. The shut-off devices are to be installed as close as possible to the boiler walls and are to be operated without risk.

10.2 Where several steam boilers which have different maximum allowable working pressures give off their steam or hot water resp. into common lines, it has to be ensured that the maximum working pressure allowable for each steam boiler cannot be exceeded in any of the boilers.

10.3 Where there are several steam boilers which are connected by common pipes and the shut-off devices for the steam, feed and drain lines are welded to the steam boilers, for safety reasons during internal inspection, two shut-off devices in series which are to be protected against unauthorised operation are each to be fitted with an interposed venting device.

10.4 For plants consisting of steam generators without own steam space, which are using an oil fired steam generator or a steam drum for steam separation, the shut-off devices in the circulation lines are to be sealed in the open position.

10.5 The shut-off devices in the discharge and return line at the hot water generator are to be sealed in open position.

11. Scum Removal, Sludge Removal, Drain, Venting and Sampling Devices

11.1 Boilers and external steam drums are to be fitted with devices to allow them to be drained and the sludge removed. Where necessary, boilers are to be fitted with a scum removal device.

11.2 Drain devices and their connections must be protected from the effects of the heating gases and capable of being operated without risk. Self-closing sludge removal valves must be lockable when closed or alternatively an additional shut-off device is to be fitted in the pipe.

11.3 Where the scum removal, sludge removal or drain lines from several boilers are combined, a non-return valve is to be fitted in the individual boiler lines.

11.4 The scum removal, sludge removal or drain lines, plus valves and fittings, are to be designed to allow for maximum allowable working pressure of the boiler.

11.5 With the exception of once-through forced flow boilers, devices for taking samples from the water contained in the boiler are to be fitted to steam boilers.

11.6 Scum removal, sludge removal, drain, venting and sampling devices must be capable of safe operation. The mediums being discharged are to be drained away safely.

12. Name Plate

12.1 A name plate is to be permanently affixed to each steam boiler, displaying the following information:

- Manufacturer's name and address
- Serial number and year of construction
- Maximum allowable working pressure [bar]

Allowable steam production [kg/h] or [t/h] for steam generators

- Maximum allowable temperature of superheated steam in °C provided that the steam generator is fitted with a super-heater with no shutoff capability
- Maximum allowable discharge temperature [°C] for hot water generators
- Maximum allowable heating power [kW or MW] for hot water generators

12.2 The name plate must be permanently attached to the largest part of the boiler or to the boiler frame so that it is visible.

13. Valves and Fittings

13.1 Materials

Valves and fittings for boilers must be made of ductile materials as specified in Table 12.1 and all their components must be able to withstand the loads imposed in operation, in particular thermal loads and possible stresses due to vibration. Grey cast iron may be used within the limits specified in Table 12.1, but may not be employed for valves and fittings which are subjected to dynamic loads, e.g. safety valves and blow-off valves.

Testing of material for valves and fittings is to be carried out as specified in Table 12.2.

13.2 Design

Care is to be taken to ensure that the bodies of shut-off gate valves cannot be subjected to unduly high pressure due to heating of the enclosed water. Valves with screw-on bonnets must be safeguarded to prevent unintentional loosening of the bonnet.

13.3 Pressure and tightness tests

13.3.1 All valves and fittings are to be subjected to a hydrostatic pressure test at 1.5 times the nominal

pressure before they are fitted. Valves and fittings for which no nominal pressure has been specified are to be tested at twice the working pressure. In this operation, the safety factor in respect of the 20°C yield point may not fall below 1.1.

13.3.2 The sealing efficiency of the closed valve is to be tested at the nominal pressure or at 1.1 times the working pressure, as applicable.

Valves and fittings made of castings and subject to operating temperatures over 300°C are required to undergo one of the following tightness tests:

- Tightness test with air (test pressure approximately 0.1 x working pressure; maximum 200 kPa);
- Tightness test with saturated or superheated steam (test pressure may not exceed the maximum allowable working pressure);
- A separate tightness test may be dispensed with if the pressure test is performed with petroleum or other liquid displaying similar properties.

13.3.3 Safety valves are to be subjected to a test of the set pressure. After the test the tightness of the seat is to be checked at a pressure 0.8 times the set pressure. The setting is to be secured against unauthorized alteration.

13.3.4 Pressure test and tightness test of valves and fittings and the test of the set pressure of safety valves shall be carried out in the presence of the BCS Surveyor.

14. Installation of Boilers

14.1 Mounting

Boilers must be installed in the ship with care and must be secured to ensure that they cannot be displaced by any of the circumstances arising when the ship is at sea. Means are to be provided to accommodate the thermal expansion of the boiler in service. Boilers and their seatings must be easily accessible from all sides or shall be easily made accessible.

14.2 Bottom Clearance

The distance between the boiler and the floors or inner bottom is not to be less than 200 mm at the lowest part of a cylindrical boiler. This distance is not to be less than 750 mm between the bottom of the furnace (or boiler pan) and tank top (or floor) in the case of water-tube boilers.

14.3 Side Clearance

The distance between boilers and vertical bulkheads is to be sufficient to provide access for maintenance of the structure; and, in the case of bulkheads in way of fuel oil and other oil tanks, the clearance is to be sufficient to prevent the temperature of the bulkhead from approaching the flash point of the oil. This clearance, generally, is to be at least 750 mm.

14.4 Top Clearance

Sufficient head room is to be provided at the top of boiler to allow for adequate heat dissipation. This clearance is, generally, not to be less than 1270 mm. No fuel oil or other oil tank is to be installed directly above any boiler.

14.5 Tween Deck Installation

Where boilers are located on tween decks in machinery spaces and boiler rooms are not separated from a machinery space by watertight bulkheads, the tween decks are to be provided with coamings at least 200 mm in height. This area may be drained to the bilges.

14.6 Hot Surfaces

Hot surfaces likely to come into contact with the crew during operation are to be suitably guarded or insulated. Where the temperature of hot surfaces are likely to exceed 220°C, and where any leakage, under pressure or otherwise, of fuel oil, lubricating oil or other flammable liquid is likely to come into contact with such surfaces, they are to be suitably insulated with materials impervious to such liquid. Insulation material not impervious to oil is to be encased in sheet metal or an equivalent impervious sheath.

14.7 Ventilation

The spaces in which the oil fuel burning appliances are fitted are to be well ventilated.

14.8 Fire precautions

Boiler space is to be considered a machinery space of category A and is to be provided with fixed fire extinguishing system and other fire fighting equipment, as specified in Section 18-Fire Protection and Fire Extinguishing Equipments.

F. Testing of Boilers

1. Nondestructive Testing

Radiographic examinations are to be in accordance with **BCS** Rules Chapter 2 - Material and approved standards or codes . The radiography standard and acceptance criteria , along with the degree of other nondestructive examination , such as ultra -sonic , dye penetrant , or magnetic particle , are to be in accordance with the chosen standard or code . Radiographic films are to be submitted to **BCS** surveyor for review.

2. Constructional Control and Checking

After completion, boilers are to undergo a constructional checking and test.

The constructional checking includes verification that the boiler agrees with the approved drawings and is of satisfactory construction. For this purpose, all parts of the boiler must be accessible to allow adequate inspection. If necessary, the constructional test is to be performed at separate stages of manufacture. The following documents are to be presented;

- Material test certificates covering the materials used,
- Reports on the non-destructive testing of welds and, where applicable,
- The results of tests of workmanship, and

- Proof of the heat treatment applied.

Constructional test shall be carried out by or in the presence of the **BCS** surveyor.

3. Hydrostatic Pressure Tests

3.1 A hydrostatic pressure test is to be carried out on the boiler before refractory, insulation and casing is fitted. Where only some of the component parts are sufficiently accessible to allow proper visual inspection, the hydrostatic pressure test may be performed in stages. Boiler surfaces must withstand the test pressure without leaking or suffering permanent deformation.

3.2 The test pressure is generally required to be 1.5 times the maximum allowable working pressure, see A.4. In case the maximum allowable working pressure is less than 200 kPa or 0.2 N/mm², the test pressure has to be at least 0.1 N/mm² higher than the maximum allowable working pressure.

3.3 In the case of continuous-flow boilers, the test pressure must be at least 1.1 times the water inlet pressure when operating at the maximum allowable working pressure and maximum steam output. In the event of danger that parts of the boiler might be subjected to stresses exceeding 0.9 of the yield strength, the hydrostatic test may be performed in separate sections. The maximum allowable working pressure is then deemed to be the pressure for which the particular part of the boiler has been designed.

3.4 For boiler parts subject to internal and external pressures which invariably occur simultaneously in service, the test pressure depends on the differential pressure. In these circumstances, however, the test pressure should at least be equal to 1.5 times the design pressure specified in D.1.2.4.

3.5 Hydrostatic pressure test shall be carried out by or in the presence of the **BCS** surveyor.

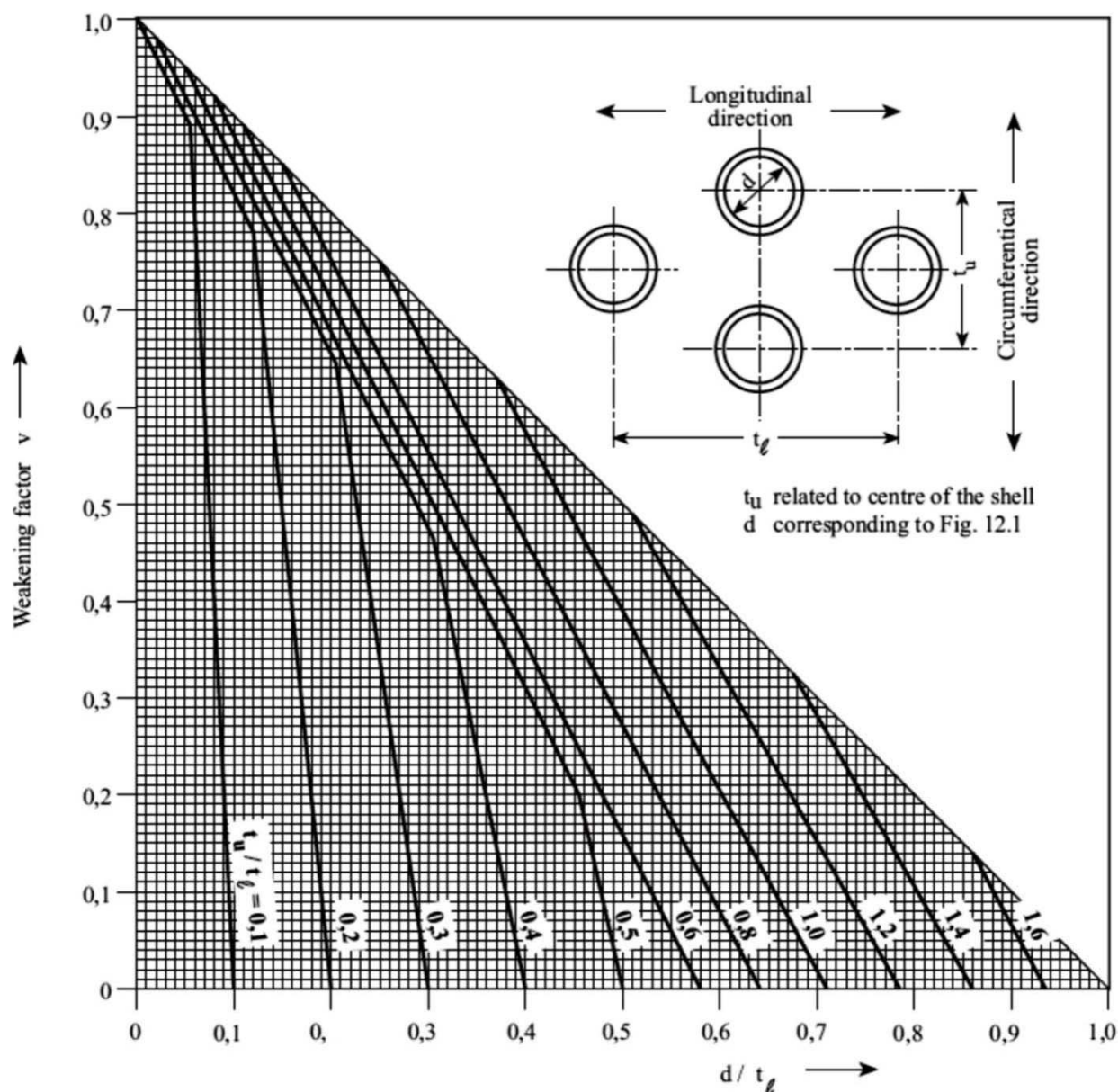


Figure 12.27 Weakening factor v for cylindrical shells with symmetrically staggered rows of holes

4. Acceptance test after installation on board

4.1 Functional test of the safety relevant equipment

The function of the safety relevant equipment is to be tested, as far as possible, at the not heated, pressureless steam boiler.

4.2 Test of safety valves

4.2.1 The actuation pressure of the safety valves is

to be proven by a blow-off test or the adjustment Certificate of the manufacturer is to be presented for the sealed valve.

4.2.2 The sufficient blow-off performance of the safety valves has to be proven by a blow-off test. For steam boilers heated with exhaust gas the blow-off test is to be performed at 100 % MCR (maximum continuous rating). For combined steam boilers and combined steam boiler plants with oil fired steam boiler and exhaust gas boiler without own steam space, it has to

be guaranteed, that the maximum allowable working pressure is not exceeded by more than 10 % for 100 % oil burner performance and the above mentioned conditions for operation of the exhaust gas boiler.

4.3 Functional test

The complete equipment of the steam boiler, including control and monitoring devices, are to be subjected to a functional test.

5. Constructional check, hydrostatic pressure test and acceptance test shall be carried out by or in the presence of **BCS** Surveyor.

G. Hot Water Generators

1. General

1.1 The materials, design calculations and manufacturing principles for hot water generators which are heated by steam or hot liquids are subject to the requirements in Section 14.

1.2 For hot water generation plants forced circulation is to be used. Plants with natural circulation are not allowed.

1.3 Hot water generation plants are to be designed with external pressure generation (e.g. with membrane expansion vessel or expansion vessel with nitrogen blanket without membrane). Plants open to the atmosphere or with internal pressure generation are not allowed.

1.4 The pressure generation has to be carried out in a way as to prevent a steam generation critical for the safety of the plant.

1.5 Each hot water generation plant shall have a sufficient volume for expansion, to accommodate the increase of volume of the water from the hot water generation plant and the heat consuming system resulting from the change of temperature. The expansion vessel and the connecting lines shall be protected against freezing.

2. Pre-Pressurized Expansion Vessel

2.1 A low water level limiter is to be provided at the expansion vessel which shuts-down and interlocks the oil burner and the circulating pumps in case the water level falls below the allowable minimum.

2.2 Shut-off devices in the connecting lines between system and expansion vessel are to be sealed in open position.

2.3 Hot water generation plants with membrane expansion vessel

2.3.1 The installation of the low water level limiter (see 2.1) at the membrane expansion vessel can be dispensed with in case the low pressure limiter of the plant is actuated at a value when the water level falls below the allowable minimum level.

2.3.2 A possibility for checking the correct filling pressure of the gas space shall be provided at the prepressurized membrane expansion vessels.

2.3.3 A safety valve and a pressure indication shall be provided at membrane expansion vessels where the gas pressure of the blanket is controlled by a pressure regulator.

2.4 Hot water generation plants with expansion vessel with nitrogen blanket without membrane

2.4.1 The lowest water level (LWL) at the expansion vessel shall be at least 50 mm above the top edge of the pipe connecting the expansion vessel with the system.

2.4.2 Each pressurized expansion vessel shall be equipped with a pressure indication.

2.4.3 Each pressurized expansion vessel shall be equipped with a safety valve which is set to a pressure below the set-pressure of the safety valves at the hot water generator. For the dimensioning of the safety valve it is sufficient to consider the power of the largest hot water generator in the plant. Additional heating appliances are to be considered if necessary.

2.4.4 The water level shall be controlled by a water level regulator, if it is necessary to drain or to feed water to the expansion vessel resulting from the change of the water volume of the system. In case of too high or too low water level an alarm shall be tripped.

2.4.5 In case of a water level above the highest water level specified for the plant the oil burner and the feed water supply shall be shut-off and interlocked. This trip can be actuated by the sensor of the water level controller.

3. Feed Water Supply

3.1 Each hot water generation plant shall be equipped with at least one feed water supply.

3.2 The flow of the feed water supply shall be such that the loss of water in the whole system can be compensated.

3.3 The feed water supply shall be able to feed the required flow to the generator at 1,1 times the maximum allowable working pressure.

4. Circulating Pumps

4.1 Hot water generation plants are to be equipped with at least two circulating pumps. A common stand-by pump is sufficient for hot water generating plants, if this pump can be connected to any hot water generator of the plant.

4.2 An alarm shall be tripped in case of a breakdown of one circulating pump. An alarm shall be tripped and a shutdown and interlock of oil burner at the oilfired hot water generator shall be carried out if the flow falls below the specified minimum value.

H. Flue Gas Economizers (1)

1. Definitions

Flue gas economizers are preheaters arranged in the flue gas duct of boilers used for preheating of feedwater without any steam being produced in service. They can be disconnected from the water side of the boiler.

The surfaces of the preheater comprise the water space walls located between the shut-off devices plus the casings of the latter. Drawing water from the economizer is only permissible if the boiler feed system is specially designed for this purpose.

2. Materials

See Section B.

3. Design Calculations

The formulae given under D are to be applied in the calculation. The design pressure is to be at least the maximum allowable working pressure of economizer.

The design temperature is the maximum feedwater temperature plus 25°C for plain tube economizers and plus 35°C for finned tube economizers.

The feedwater temperature at the economizer outlet should be 20°C below the saturation temperature corresponding to the working pressure of the boiler.

4. Equipments

4.1 Pressure gauges

The inlet side of each economizer is to be provided with a reliable pressure gauge as well as with a connection for a test pressure gauge. The maximum allowable working pressure of the economizer is to be marked by a red line on the scale of the pressure gauge.

4.2 Safety valve

Each economizer is to be equipped with a spring-loaded safety valve with an inside diameter of at least 15 mm. which is to be set that it starts to blow-off if the maximum allowable working pressure is exceeded.

(1) *For shell type exhaust gas heated economizers that are intended to be operated in a flooded condition and that may be isolated from the steam plant system, BCS- R P6 is to be applied.*

The safety valve is to be so designed that, even if shutoff devices between the economizer and the boiler are closed, the maximum allowable working pressure of the economizer is not exceeded by more than 10%.

4.3 Temperature measuring device

Each economizer is to be equipped with at least one temperature measuring device giving a reliable reading of the feedwater temperature at the outlet of the economizer. Allowable outlet temperature of the feedwater is to be marked in red on the temperature meter.

4.4 Shut-off devices

Each economizer is to be equipped with a shut-off device at the feedwater inlet and outlet. The boiler feed valve may be regarded as one of these shut-off devices.

4.5 Discharge and venting equipment

Each economizer is to be provided with means of drainage and with vents for all points where air may gather enabling it to be satisfactorily vented even when in operation.

4.6 Means for preventing the formation of steam in economizers

Suitable equipment is to be fitted to prevent steam from being generated in the economizer, e.g. when the steam supply is suddenly stopped. This may take the form of a circulating line from the economizer to a feedwater tank to enable the economizer to be cooled, or of a by-pass enabling the economizer to be completely isolated from the flue gas flow.

5. Name Plate

A name plate giving the following details is to be fitted to every economizer:

- Name and address of manufacturer,

- Serial number and year of manufacture,
- Maximum allowable working pressure of economizer in bar.

6. Tests

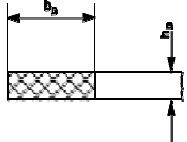
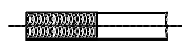
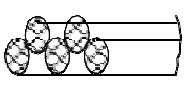
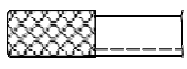
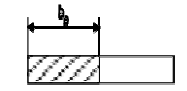
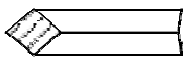


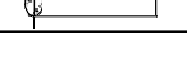
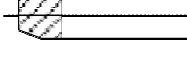
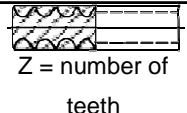
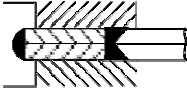
Before they are installed, finished economizers are to be subjected at the maker's works to a constructional test and a hydrostatic pressure test at 1.5 times the maximum allowable working pressure in the presence of the **BCS** surveyor.

7. Operating Instructions

The manufacturer is to provide operating instructions for each economizer which is to include reference to :

- Feed water treatment and sampling arrangements,
- Operating temperatures-exhaust gas and feed water temperatures,
- Operating pressure,
- Inspection and cleaning procedures,
- Records of maintenance and inspection,
- The need to maintain adequate water flow through the economizer under all operating conditions,
- Periodical operational checks of the safety devices to be carried out by the operating personnel and to be documented accordingly,
- Procedures for using the exhaust gas economizer in the dry condition,
- Procedures for maintenance and overhaul of safety valves.

Table 12.17 Gasket factors

Joining type	Shape	Description	Material	Gasket factor (1)					
				for liquids			for gases and vapors		
				assembly (2)		service	assembly (2)		service
				k_o	$k_o \cdot K_D$	k_1	k_o	$k_o \cdot K_D$	k_1
				[mm]	[N/mm]	[mm]	[mm]	[N/mm]	[mm]
Soft gaskets		flat gaskets acc. to DIN EN 1514-1	impregnated sealing material	-	$20b_D$	b_D	-	-	-
			rubber	-	b_D	$0.5b_D$	-	$2b_D$	$0.5b_D$
			Teflon	-	$20b_D$	$1.1b_D$	-	$25b_D$	$1.1b_D$
			lt (4)	-	$15b_D$	b_D	-	$200 \sqrt{\frac{b_D}{h_D}} \cdot b_D$ (3)	$1.3b_D$
Combined metal and soft gaskets		spirally wound gasket	unalloyed steel	-	$15b_D$	b_D	-	$50b_D$	$1.3b_D$
		corrugated gasket	Al	-	$8b_D$	$0.6b_D$	-	$30b_D$	$0.6b_D$
			Cu, Brass	-	$9b_D$	$0.6b_D$	-	$35b_D$	$0.7b_D$
			mild steel	-	$10b_D$	$0.6b_D$	-	$45b_D$	$1.0b_D$
		metal-sheathed gasket	Al	-	$10b_D$	b_D	-	$50b_D$	$1.4b_D$
			Cu, Brass	-	$20b_D$	b_D	-	$60b_D$	$1.6b_D$
			mild steel	-	$40b_D$	b_D	-	$70b_D$	$1.8b_D$
metal gaskets		flat gasket acc. to DIN EN 1514-4	-	$0.8b_D$	-	b_D+5	b_D	-	b_D+5
		diamond gasket	-	0.8	-	5	1	-	5
		oval gasket	-	1.6	-	6	2	-	6
		round gasket	-	1.2	-	6	1.5	-	6
		ring gasket	-	1.6	-	6	2	-	6
		U-shaped gasket acc. to DIN 2696	-	1.6	-	6	2	-	6
		corrugated gasket to EN 1514-6	-	$0.4\sqrt{Z}$	-	$9+0.2Z$	$0.5\sqrt{Z}$	-	$9+0.2Z$
		membrane welded gasket to DIN 2695	-	0	-	0	0	-	0

(1) Applicable to flat, machined, sound, sealing surfaces.

(2) Where k_o cannot be specified, the product of $k_o \times K_D$ is given here.

(3) Must be a gastight grade.

(4) Non asbestos compressed fibre jointing material.

SECTION 13**THERMAL OIL SYTEMS**

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2. Thermal Oil Systems	

A. General	Electrical Installations, Chapter 5,	for electrical installations.
1. Scope	Automation, Chapter 4-1	for automated machinery systems (AUT).
The following requirements apply to thermal oil systems in which organic liquids (thermal oils) are heated by oil burners, exhaust gases or electricity to temperatures below their initial boiling point at atmospheric pressure.		
The arrangements for storage, distribution and utilisation of thermal oil under pressure are to comply with the requirements detailed in this Section.		
Thermal oil systems are to be so designed as to:		
- Avoid overheating of the thermal oil and contact with air,		
- Take into account the compatibility of the thermal oil with the heated products in case of contact due to leakage of coils or heater tubes,		
- Prevent oil from coming into contact with sources of ignition.		
2. Additional Requirements	3. Definitions	
Basic concept and definitions applied in this section are described in following items:		
	-	Maximum allowable working pressure The maximum allowable working pressure is the maximum pressure which may occur in the individual parts of the equipment under service conditions.
	-	Thermal oil temperature The thermal oil temperature is the temperature of the thermal oil at the centre of the flow cross-section.
	-	Discharge temperature The discharge temperature is the temperature of the thermal oil immediately at the heater outlet.
In addition, the Rules listed below are to be applied analogously:	-	Return temperature The return temperature is the temperature of the thermal oil immediately at the heater inlet.
Section 12, B, C and D for materials, fabrication and design of the heaters	-	Film temperature The film temperature is the wall temperature on the thermal oil side. In the case of heated surfaces, this may differ considerably from the temperature of the thermal oil.
Section 14, B, C and D for materials, fabrication and design of the expansion vessel and the tanks		
Section 15, A and B for oil burners and oil firing systems (additional shutdown criteria see B.4 and C.4)	-	Thermal oil heater The thermal oil heater is the heat exchanger apparatus for heating a thermal liquid with steam, water electric power or thermal oil of another circuit.
Section 16, V for thermal oil tanks		
Section 16, A to D, H, Q and R. for pipes, valves and pumps	-	Thermal oil boiler The thermal oil boiler is the heat exchanger apparatus for heating a thermal liquid up to the required temperature using the energy of fuel oil burnt in it, of an engine exhaust gases or electric power.
Section 18 for fire protection and firefighting equipment		

4. Documents for Approval

The following documents are to be submitted for approval:

- A description of the system stating the discharge and return temperatures, the maximum allowable film temperatures, the total volume of the system and the physical and chemical characteristics of the thermal oil,
- Drawings of the heaters, the expansion and other vessel and the drainage and storage tanks and other pressure vessels,
- Piping equipment schedules (for information)
- A functional diagram with information about the proposed safety devices and valves,
- Circuit diagrams of the electrical control system, respectively monitoring and safety devices with limiting values.

If specially requested, mathematical proof of the maximum film temperature in accordance with DIN 4754 is to be submitted.

5. Thermal Oils

5.1 An approved type of thermal oil is to be used. The proposed thermal oil should be stated, giving flash point ($>55^{\circ}\text{C}$), fire point, auto-ignition temperature and maximum operating temperature.

5.2 The thermal oil must remain serviceable for at least 1 year at the specified thermal oil temperature. Its suitability for further use is to be verified at appropriate intervals, but at least once a year.

5.3 Thermal oils are to be used within the temperature ranges set by the manufacturer.

The delivery temperature is, however, to be kept 50°C below the oil distillation point.

A safety margin about 50°C is to be maintained between the discharge temperature and the maximum allowable film temperature specified by the manufacturer..

Thermal oil is not to be used for the direct heating of:

- Accommodation,
- Fresh drinking water,
- Liquid cargoes with flashpoints below 60°C .

5.4 Precautions are to be taken to protect the thermal oil from oxidation.

5.5 Copper and copper alloys are to be avoided due to their catalytic effect on the thermal oil.

6. Manual Operation

6.1 The facility is to be provided for manual operation. At least the temperature limiters on the oil side and flow monitoring must remain operative even in manual operation.

The heater heated by exhaust gas may be operated without temperature and flow monitoring if the permissible header temperature can be kept.

The safety equipment not required for manual operation may only be deactivated by means of a keyoperated switch. The actuation of the key-operated switch is to be indicated.

6.2 Manual operation demands constant and direct supervision of the system.

6.3 For details of requirements in respect of the manual operation of the oil firing system, see Section 15.

B. Heaters

1. Approved Materials

Heaters of thermal oil systems are to be fabricated from the same materials as boilers as per Section 12, B.

2. Testing of Materials

The materials of the parts of the heaters which are in contact with the thermal oil are to be tested in accordance with Section 12, B.

For coils with a maximum allowable working pressure up to 1.0 MPa and an allowable operating temperature up to 300°C Manufacturer Inspection Certificates are sufficient.

3. Design

3.1 Heaters are to be designed thermodynamically and by construction that neither the surfaces nor the thermal oil become excessively heated at any point. The flow of the thermal oil must be ensured by forced circulation.

3.2 The surfaces which come into contact with the thermal oil are to be designed for the maximum allowable working pressure subject to a minimum gauge pressure of 1 MPa.

3.3 Heaters heated by exhaust gas are to be so designed that damages by resonance resulting from oscillation of the exhaust gas column cannot occur.

3.4 The exhaust gas intake is to be so arranged that the thermal oil cannot penetrate the engine or the turbocharger in case of a leakage in the heater respectively the cleaning medium cannot penetrate during heater cleaning.

3.5 Heaters heated by exhaust gas are to be provided with manholes serving as inspection openings at the exhaust gas intake and outlet.

3.6 Oil fired heaters are to be provided with inspection openings for examination of the combustion chamber.

A thermostatic control or cut-out actuated by the circulating thermal oil temperature, failure of the circulating thermal oil pumps and 'flame out', is to be incorporated in the oil fired thermal oil heater burner system.

3.7 Sensors for the temperature measuring and monitoring devices are to be introduced into the system through welded-in immersion pipes.

3.8 Heaters are to be fitted with means enabling

them to be completely drained.

3.9 For electrically heated heaters the requirements are to be applied analogously to oil fired heaters.

3.10 Outlets of exhaust gas lines from thermal oil heaters are to be provided with spark arrestors or equivalent and are not to be led through the cargo zone. The distance between the outlet and the cargo zone is to be not less than 2 meters.

3.11 The air intakes from the thermal oil heater are to be so arranged that their openings are not less than 2 meters outside the cargo zone and not less than 6 meters from openings of cargo or slop tanks, cargo pumps on deck, openings of high velocity vents or over pressure devices and shore connections of the cargo lines. Furthermore, the air intakes are to be arranged not less than 2 meters above deck.

3.12 Thermal oil heaters are to be situated in the engine room or, alternatively, in a special space outside the cargo zone accessible from deck or from within the engine room.

3.13 In case of heating systems are provided for the cargo tanks, the spectacle flanges or spool pieces are to be provided in the heating medium supply and return pipes to the cargo heating system, at a suitable position within the cargo area, so that the lines can be blanked off in circumstances where the cargo does not require to be heated or where the heating coils have been removed from the cargo tanks. Alternatively, blanking arrangements may be provided for each tank heating circuit.

3.14 Means are to be provided for measuring the cargo temperature. Where overheating could result in a dangerous condition, an alarm system which monitors the cargo temperature is to be provided.

3.15 In any heating system a positive pressure in the coils of at least 30 kPa above the static liquid pressure of the cargo, increased with the relevant set pressure of the high velocity valve as far as applicable, shall be maintained under all conditions of service when the circulation pump is not in operation.

3.16 The heating medium supply and return lines are not to penetrate the cargo tank plating, other than at the top of the tank and the main supply lines are to be run above the deck.

Isolating shut-off valves or cocks are to be provided at the inlet and outlet connections to the heating circuit(s) of each tank and means are to be provided for regulating the flow.

In case of direct heating arrangements valves for the individual heating coils are to be provided with locking arrangements to ensure that the coils are under static pressure at all times.

For direct heating systems, isolation valves are to be provided in the cargo heating supply and return line in a readily accessible position in the cargo zone.

Where thermal oil is employed in the heating circuits, the arrangements are to be such that contamination of the thermal oil with cargo liquid cannot take place under normal operating conditions.

4. Equipments

The suitability of safety and monitoring devices (e.g. valves, limiters/alarms for temperature, flow and leakage monitoring) for marine use is to be proven by type testing.

4.1 General

4.1.1 The equipment on the heaters has to be suitable for use at thermal oil heaters and on ships. The proof of the suitability of the limiters (e.g. temperature, flow, pressure) is to be demonstrated by a type approval test according to the requirements of **BCS** requirements listed in A.2.

4.1.2 The alarms and the activation of the limiters have to create optical and acoustic fault signals in the installation space of the heater resp. in the engine control room and another suitable location.

4.2 Safety valves

Each heater is to be equipped with at least one safety

valve having a blow-off capacity at least equal to the increase in volume of the thermal oil at the maximum heating power. During blow-off the pressure shall not increase above 10% over the maximum allowable working pressure.

4.3 Temperature, pressure and flow indicators

4.3.1 Pressure measuring devices are to be fitted at the discharge and return line of both oil fired heaters and heaters heated by exhaust gas. The maximum allowable working pressure PB is to be shown on the scale by a red mark which is permanently fixed and well visible. The indication range has to include the test pressure.

4.3.2 Temperature measuring devices are also to be fitted in the flue gas or exhaust gas stream at the heaters outlet.

4.3.3 The flow of the thermal oil is to be indicated.

4.4 Temperature control

4.4.1 For automatic control of the discharge temperature, oil fired heaters are to be equipped with an automatic rapidly adjustable heat supply in accordance with Section 15, A and B.

4.4.2 The discharge temperature of heaters heated by exhaust gas is to be controlled by automatic regulation of the heat input or by re-cooling the thermal oil in a dumping cooler, but independently from the control of the engine output.

4.5 Temperature monitoring

4.5.1 If the allowable discharge temperature is exceeded, for oil fired heaters the heat supply is to be switched off and interlocked by a temperature limiter.

Parallel-connected heating surfaces are to be monitored individually at the discharge side of each coil. At the oilfired heater the oil burner is to be switched off and interlocked by a temperature limiter in case the allowable discharge temperature is exceeded in at least one coil. An additional supervision of the allowable discharge temperature of the heater is not necessary.

4.5.2 If the allowable discharge temperature is exceeded for heaters heated by exhaust gas an alarm shall be tripped.

Parallel-connected heating surfaces are to be monitored individually at the discharge side of each coil. At the heater heated by exhaust gas an alarm shall be tripped in case the allowable discharge temperature is exceeded in at least one coil. An additional supervision of the allowable discharge temperature of the heater is not necessary.

4.5.3 The discharge temperature of parallel-connected heating surfaces in the heater is to be monitored individually at the outlet of each heating surface.

With heaters heated by exhaust gas, individual monitoring of heating surfaces connected in parallel may be dispensed with if the maximum exhaust gas temperature is lower than the maximum allowable film temperature of the thermal oil.

4.5.4 If the specified maximum flue gas temperature of the oil fired heaters is exceeded, the firing system must be switched off and be interlocked.

4.5.5 Heaters heated by exhaust gases are to be equipped with a temperature switch which, when the maximum design exhaust gas temperature is exceeded, signals by means of an alarm that the heating surfaces are badly fouled.

4.6 Flow monitoring

4.6.1 Precautions must be taken to ensure that the maximum allowable film temperature of the thermal oil is not exceeded.

4.6.2 A flow monitor switched as a limiter must be provided at the oil fired heater. If the flow rate falls below a minimum value the firing system has to be switched off and be interlocked.

4.6.3 Start-up of the burner must be prevented by interlocks if the circulating pump is stationary.

4.6.4 A flow monitor switched as an alarm must be

provided at heaters heated by exhaust gas. An alarm is to be triggered in case the flow rate falls below the minimum value.

4.6.5 An alarm has to be created for the case that at an undercut of the minimum flow through the heater heated by exhaust gas (e.g. at standstill of the circulation pump, closed shut-off valves) the engine delivering the exhaust gas for heating of the heater is to be started.

4.7 Leakage monitoring

4.7.1 Oil fired heaters are to be equipped with a leakage detector which, when actuated, shuts down and interlocks the firing system. If the oil fired heater is in "stand-by" the starting of the burner has to be blocked if the leakage detector is actuated.

4.7.2 Heaters heated by exhaust gas are to be equipped with a leakage detector which, when actuated, trips an alarm, and a reference shall be provided to reduce the power of engine, which delivers exhaust gas to the heater.

4.8 Shut-off devices

4.8.1 Both oil fired heaters and heaters heated by exhaust gas are to be fitted with shut-off devices and, if necessary with by-pass valves, which can also be operated from a position outside the immediate area in which the heater is installed.

4.8.2 The heater has to be capable of being drained and ventilated as well from a position outside the immediate area in which the heater is installed.

4.9 Fire detection and fire distinguishing system

4.9.1 The temperature switch for fire detection, required according to Section 18, C.4 is to be provided additionally to the temperature switch according to 4.5.4 and shall be set to a temperature 50 to 80°C higher. If actuated alarm shall be given by group alarm.

4.9.2 Thermal oil heaters heated by exhaust gas are

to be fitted with a permanent system for extinguishing and cooling in the event of fire, e.g. a pressure water spraying system. For details see Section 18, Table 18.1.

C. Vessels

1. Approved Materials

Vessels are to be fabricated from the materials conforming to Section 14, B., in the pressure vessel class appropriate to the thermal oil system.

2. Testing of Materials

The vessel materials are to be tested in accordance with Section 14, B.

3. Design

3.1 All vessels, including those open to the atmosphere, are to be designed for a pressure of at least 200 kPa, unless provision has to be made for a higher working pressure excepted from this requirement are tanks designed and dimensioned according to the Rules for the Construction of the Hull, Section 12, B.

3.2 A positive pressure in the heating coils exceeding the external pressure is to be maintained under all conditions of service irrespective of the type of cargo to be carried. This can be achieved by means of an atmospheric expansion tank situated at sufficient height or by pressurising the expansion tank with an inert gas or compressed air.

The space provided for expansion must be such that the increase in the volume of the thermal oil at the maximum thermal oil temperature can be safely accommodated. The following are to be regarded as minimum requirements: 1.5 times the increase in volume for volumes up to 1000 liters, and 1.3 times the increase for volumes over 1000 liters. The volume is the total quantity of thermal oil contained in the equipment up to the lowest liquid level in the expansion vessel.

Arrangements for atmospheric expansion tanks are to comply with 3.3 to 3.5 and arrangements for

pressurized expansion tanks are to comply with 3.6 to 3.9.

3.3 Means of approved type are to be provided to ascertain the level in the thermal expansion tank.

3.4 The expansion/header tank is to be fitted with both high and low level alarms. At low level alarm, the circulation pump is to be stopped automatically and the thermal oil heater is to be shut down.

3.5 The vent pipe from the expansion tank is to be led to a safe position on the open deck.

3.6 For expansion tanks provided with inert gas padding, it is to be guaranteed that sufficient inert gas will be available to maintain the pressure in the expansion vessel under all conditions of service.

3.7 For expansion tanks pressurised by compressed air, it is to be guaranteed that the temperature of the thermal oil in the expansion tank is not to exceed 50°C in order to avoid oxidation of the thermal oil.

3.8 The expansion vessel is to be provided with a pressure indication and alarm for the minimum pressure. At low pressure alarm, the circulation pump is to be stopped automatically and the thermal oil boiler is to be shut down.

3.9 A pressurized expansion vessel is to be protected against over pressure by a relief valve, the discharge of which is to be led to a safe position on the open deck.

3.10 At the lowest point of the system a drainage tank is to be located, the capacity of which is sufficient to hold the volume of the largest isolatable system section.

3.11 A separate storage tank is to be provided to compensate any losses. The stock of thermal oil is to be at least 40% of the capacity of the system. Depending on the system design or the ship's geographical area of service, a smaller stock may be acceptable.

3.12 In exceptional cases, approval may be given for the drainage tank and the storage tank to be combined. Combined storage/drainage tanks are to be dimensioned that in addition to the stock of thermal oil, there is room for the contents of the largest isolatable system section.

4. Equipment of Expansion Vessel

4.1 General

4.1.1 The equipment on the expansion vessel (e.g. level indicator) has to be suitable for use at thermal oil heaters and on ships. The suitability of level indication device, safety and monitoring devices (e.g. low level limiter) for marine use is to be demonstrated by a type approval test according to the requirements of **BCS** requirements listed in A.2.

4.1.2 The alarms and the activation of the limiters have to create optical and acoustic fault signals in the installation space of the heater resp. in the engine control room and another suitable location.

4.2 Level indication device

4.2.1 The expansion vessel is to be equipped with a liquid level gauge with a mark indicating the lowest allowable liquid level.

4.2.2 Level gauges made of glass or plastic are not allowed.

4.3 Low level limiter and pre-alarm

4.3.1 A limit switch is to be fitted which shuts down and interlocks the firing system and switches off the circulating pumps if the liquid level falls below the allowable minimum.

4.3.2 Additionally an alarm for low liquid level is to be installed, e.g. by means of an adjustable level switch on the liquid level gauge which gives an early warning of a falling liquid level (e.g. in the event of a leakage).

4.3.3 An alarm is also to be provided for the maximum liquid level.

4.4 Quick drainage valve and emergency shut-off valve

4.4.1 For rapid drainage in case of danger, a quick drainage valve is to be fitted directly to the vessel with remote control from outside the space in which the equipment is installed.

4.4.2 Automatic means are to be provided to ensure a sufficient air supply to the expansion vessel when the quick drainage valve is operated.

4.4.3 Where the expansion vessel is installed outside the engine room, the quick drainage valve may be replaced by an emergency shut-off device (quick closing valve).

4.4.4 The opening of the quick drainage valve or the operation of the emergency shut-off device, as applicable, shall cause the automatic shutdown of the firing system and the circulating pumps.

4.4.5 The dimensions of the drainage and venting pipes are to be applied according to Table 13.1.

Table 13.1 Nominal diameter of drainage and venting pipes as well as of expansion and overflow pipes depending on the performance of the heater

Performance of heater [kW]	Expansion and overflow pipes DN [mm]	Drainage and venting pipes DN [mm]
≤ 600	25	32
≤ 900	32	40
≤ 1200	40	50
≤ 2400	50	65
≤ 6000	65	80

4.5 Connection lines

4.5.1 A safety expansion line has to connect the system to the expansion vessel. This shall be installed with a continuous positive gradient and is to be dimensioned that a pressure rise of more than 10% above the maximum allowable working pressure in the system is avoided.

4.5.2 The expansion vessel is to be provided with an overflow line leading to the drainage tank.

4.5.3 The quick drainage line may be routed jointly with the overflow line leading to the drainage tank.

4.5.4 All parts of the system in which thermal oil can expand due to the absorption of heat from outside are to be safeguarded against excessive pressure. Any thermal oil emitted is to be safely drained off.

4.5.5 The dimensions of the expansion and overflow pipes are to be applied according to Table 13.1.

4.6 Pre-pressurised system

4.6.1 Pre-pressurised systems are to be equipped with an expansion vessel which contents are blanketed with an inert gas. The inert gas supply to the expansion vessel has to be guaranteed.

4.6.2 The pressure in the expansion vessel is to be indicated and safeguarded against overpressure.

5. Equipment of the drainage and storage tank

For the equipment of the drainage and storage tank see, Section 16, V.

D. Design Of Circulating System And Equipment Items

1. Approved Materials

1.1 Materials for pipes, valves and pumps; see Section 16, B.

Casings of pumps, valves and fittings are to be made of steel or other ductile material.

1.3 Grey cast iron is unacceptable for equipment items in the hot thermal oil circuit and for safety valves.

2. Testing of Materials

Pipe valve and pump materials are tested in accordance

with Section 16, B.3.

3. Equipments

3.1 Pipes, valves and pumps are governed, in addition to the following specifications, by the provisions of Section 16, Q.

3.2 At least two circulating pumps are to be provided, of such a capacity as to maintain a sufficient flow in the heaters with any one pump out of action.

However, for circulating systems supplying non-essential services, one circulating pump only may be accepted.

3.3 The circulating pumps are to be locally and remotely controlled.

3.4 The outlets of the circulating pumps are to be equipped with a pressure gauge.

3.5 It must be possible to shut down the circulating pumps by an emergency switch which can also be operated from a position outside the room in which they are installed.

3.6 Devices for safe sampling are to be provided at a suitable location in the thermal oil circuit.

3.7 Means of venting are to be provided at the highest points of the isolatable sections of the thermal oil system and drains or drainage devices at the lowest points.

Venting and drainage via open funnels are to be avoided as far as possible.

3.8 A device which efficiently filters the thermal oil is to be provided in the circuit. In the case of essential services, the filters provided for this purpose are to be so arranged that they can be easily cleaned without stopping the thermal oil supply. The fineness of the filter mesh is to comply with the requirements of the thermal oil heating installation manufacturer.

3.9 Thermal oil pipes are not to pass through accommodation or public spaces or control stations.

Thermal oil pipes passing through main and auxiliary machinery spaces are to be restricted as far as possible.

3.10 For fitting and draining pumps, see Section 16, Q.1.2.

3.11 Electric equipment items are governed by Chapter 5 - Electrical Installation especially Section 9.

E. Marking

1. Heaters

The following information shall be stated on a durable manufacturer's nameplate permanently attached to the heater:

- Manufacturer's name and address,
- Serial number,
- Year of manufacture,
- Maximum allowable heating power,
- Maximum allowable working pressure,
- Maximum allowable discharge temperature,
- Minimum flow rate,
- Liquid capacity.

2. Vessels

2.1 Vessels are to be fitted with nameplates bearing the following information:

- Manufacturer's name and address,

- Serial number,
- Year of manufacture,
- Maximum allowable working pressure,
- Maximum allowable working temperature,
- Capacity.

2.2 For vessels with an open connection to the atmosphere, the maximum allowable working pressure is to be shown on the nameplate as "0" or "Atm.", even though a gauge pressure of 200 kPa is taken as the design basis in accordance with C.3.

F. Fire Precautions

1. General

The fire precautions are governed by the provisions of Section 18 - Fire Protection and Fire Extinguishing Equipments.

G. Testing

1. Heaters

The thermal oil heaters are to be subjected to a constructional check and a hydrostatic pressure test, at 1.5 times the maximum allowable working pressure, at the manufacturer's works, in the presence of the **BCS** surveyor.

2. Thermal Oil System

After completion of installation on board, the system including the associated monitoring equipment is to be subjected to pressure, tightness and operational test in the presence of the **BCS** surveyor.

SECTION 14

PRESSURE VESSELS

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A. General

1. Scope

1.1 The following requirements apply to essential pressure vessels (gauge or vacuum pressure) for the operation of the main propulsion plant and its auxiliary machinery. They also apply to vessels and equipment necessary for the operation of the ship and to independent cargo containers if these are subjected to internal or external pressure in service.

Gas cylinders are subject to the requirements in G.

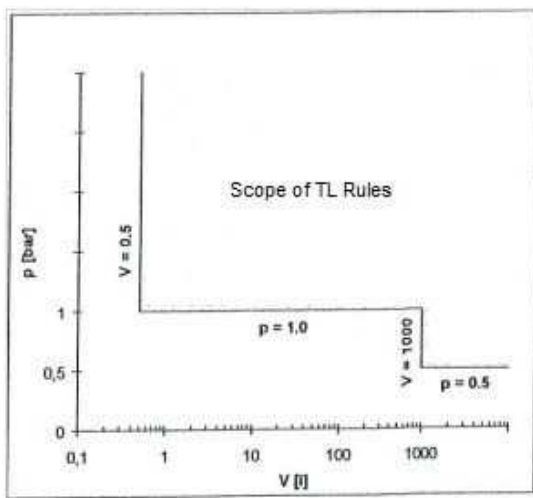


Fig . 14 .1 Scope of BCS Rules for pressure vessels and heat exchangers

1.2 The requirements do not apply to pressure vessels and equipment with

- A maximum allowable working pressure of up to 1bar gauge and a total capacity, without deducting the volume of internal fittings, of not more than 1000 litres,
- A maximum allowable working pressure of up to 0,5 bar gauge,
- A capacity of 0.5 litres and less.

1.3 Ship's service pressure vessels manufactured to the recognized standards, e.g. pressure vessels for the water supply system and calorifiers are not subject to these requirements with

respect to their wall thicknesses or the materials used.

1.4 In the case of the hydrophore tanks and the air coolers with a maximum allowable working pressure of up to 7 bar gauge and a maximum working temperature of 100°C an examination of the drawings can be dispensed with.

1.5 The pressure vessels and equipment mentioned in 1.3 and 1.4 are , demonstrated to the **BCS** Surveyor for final inspection (constructional check) and for a hydrostatic pressure test in accordance with F.1. For the materials Manufacturer Test Reports are to be presented by confirming the **BCS** Rules of Chapter 2 - Material, Section 1, F.

1.6 Hot water generators with outlet temperatures above 120°C which are heated by solid, liquid or gaseous fuels, by exhaust gases or by electrical means, as well as to economizers heated by flue gas are subject to Section 12- Boilers.

Surface condensers are additionally subject to Section 3 – Steam Turbines and 4 – Gas Turbines.

For charge air coolers, see Section 2, an examination of the drawings can be dispensed with.

Cargo containers and process pressure vessels for the transport of liquefied gases in bulk are additionally subject to the requirements for Chapter 10 - Liquefied Gas Tankers.

For reservoirs in hydraulic systems, additionally Section 10, A. is to be applied.

For filter arrangement, additionally, Section 2.G.3. (Diesel engines) as well as Section 16.G.7. (Fuel oil systems), H.2.3 (lubrication oil systems) and I.4. (Seawater cooling systems) are to be applied.

Pressure vessels and heat exchangers intended for the use in ballast, bilge, sewage or fresh water systems as well as pressure vessels for cargo handling are also subject to these rules.

1.7 For warm water generators with outlet temperature of max. 120°C, which are heated by

solid, liquid or gaseous fuels or by exhaust gases, the drawing approval can be dispensed with if the generators are manufactured according to recognized Standard or Directive. The stresses coming from the installation onboard ships have to be considered.

Warm water generators used for accommodation and sanitary water heating only are not covered by these Rules.

2. Documents for Approval

Drawings of pressure vessels and heat exchangers containing all the data necessary for their safety assessment are to be submitted to **BCS** in triplicate.

The following details, in particular, are to be specified:

- General arrangement plan,
- Intended use, substance to be contained in the vessel,
- Design data: design pressures and temperatures, fluid name, degree of radiographic examination, corrosion allowance, heat treatment (or lack of it), hydrostatic test pressure, setting of safety relief valve,
- Maximum allowable working pressures and temperatures; if necessary, secondary loads, volume of the individual pressure spaces,
- Material specifications including heat treatment, mechanical properties and details of welding techniques,
- Design details of the pressurized parts,
- Shell and head details, and shell to head joint details,
- Nozzles, openings, manways, etc., and their attachment details; flanges and covers, as applicable,

- Tubes, tube sheets, heads, shell flanges, covers, baffles, tube to tubesheet joint details, packings, as applicable
- Support structures, seating, etc.

No plan approval is required for pressure vessels of Class III as specified in Table 14.1 and 14.2. However, **BCS** reserves the right to apply all or part of the requirements of this Section to Class III heat exchangers and pressure vessels, depending on the criticality of the equipment and/or of the system of which they are part.

The validity of the drawing approval is restricted to five years and can be extended after expiration upon request for another five years provided that the product continues to conform to the current rules, having undergone no changes with regard to its characteristics or construction.

On request it can be certified separately, that the design of the pressure vessel or heat exchanger meets the specified requirements (Design Approval Certificate)

3. Definitions

Basic concept and definitions applied in this section are described in the following item:

- Pressure vessel
Pressure vessel is a welded or seamless container used for the containment of fluids at a pressure above or below the ambient pressure and at any temperature. Fluid power cylinders in hydraulic or pneumatic plants are also considered pressure vessels.
- Fired pressure vessel
Fired pressure vessel is a pressure vessel which is completely or partially exposed to fire from burners or combustion gases.
- Unfired pressure vessel
Any pressure vessel not to be exposed firing from any burner or flame source.

- Design pressure, PR, in formula p_c
Design pressure PR is the gauge pressure to be used in the design of the boiler or pressure vessel. It is to be at least the most severe condition of coincidental pressure and temperature to be expected in normal operation. For pressure vessels having more than one chamber, the design pressure of the inner chamber is to be the maximum difference between the inner and outer chambers.
- Maximum permissible working pressure, PB
Maximum permissible working pressure PB is the maximum pressure permissible at the top of the boiler or pressure vessel in its normal operating condition and at the designated coincidental temperature specified for that pressure. It is the least of the values found for PB for any pressure-bearing parts, adjusted for the difference in static head that may exist between the part considered and the top of the boiler or pressure vessel. PB is not to exceed the design pressure PR.
- Design temperature,
The maximum temperature used in design is not to be less than the mean metal temperature (through the thickness) expected under operating conditions.

B. Materials

1. General Requirements

1.1 The materials of parts subjected to pressure are to be suitable for the intended use. Materials for vessels related to pressure vessel classes I and II according to Table 14.1 have to comply with the **BCS** Rules Chapter 2 - Material.

1.2 Parts such as gussets, girders, lugs, supports, brackets etc. welded directly to pressure vessel walls are to be made of material compatible with the basic material and of guaranteed weldability.

1.3 Welded structures of pressure vessel classes I and II according to Table 14.1 are also subject to the **BCS** Rules Chapter 3 - Welding.

1.4 For corrosion protection, see C.7.

2. Pressure Vessel Classes

2.1 According to operating conditions, pressure vessels and heat exchangers are to be classed in accordance with Table 14.1

2.2 Pressure vessels filled partly with liquids and partly with air or gases or which are blown out by air or gases, such as pressure tanks in drinking water or sanitary systems and reservoirs, are to be classified as pressure vessels containing air or gas.

3. Approved Materials

The materials specified in Table 14.2 are to be used for the classes stated in 2.

4. Testing of Materials

4.1 Tests in accordance with the **BCS** Rules Chapter 2 - Material are prescribed for materials belonging to pressure vessel class I used for:

- All parts under pressure with the exception of small parts such as welded pads, reinforcing discs, branch pieces and flanges of nominal diameter \leq DN 50 mm., together with forged or rolled steel valve heads for compressed air receivers;
- Forged flanges for service temperatures $>300^\circ\text{C}$ and for service temperatures $\leq 300^\circ\text{C}$ if the product of maximum permissible working pressure and nominal diameter is greater than 250 (i.e. $PB [\text{N/mm}^2] \cdot DN [\text{mm}] > 250 [\text{N/mm}]$) or the nominal diameter DN is greater than 250 mm;
- Bolts of metric size M30 (30 mm diameter metric thread) and above made of steels with

a tensile strength of more than 500 N/mm²,
and alloyed or heat-treated steel bolts of
metric size M16 and above;

- Nuts of metric size M30 and above made of steels with a tensile strength of more than 600 N/mm²;
- Bodies of valves and fittings, see Section 16, B.

Table 14.1 Pressure vessels classes

Operating medium	Design pressure p_c [N/mm ²] Design temperature t [°C]		
	I	II	III
Pressure vessel class			
Liquefied gases (propane, butane etc.), toxic and corrosive media	all	-	-
Refrigerants	Group 2	Group 1	-
Steam, compressed air, gases,	$p_c > 1,6$ or $t > 300$	$0,7 < p_c \leq 1,6$ $170 < t \leq 300$	$p_c \leq 0,7$ $t \leq 170$
Thermal oils	$p_c > 1,6$ or $t > 300$	$0,7 < p_c \leq 1,6$ $150 < t \leq 300$	$p_c \leq 0,7$ $t \leq 150$
Liquid fuels, lubricating oils, flammable hydraulic fluids	$p_c > 1,6$ or $t > 150$	$0,7 < p_c \leq 1,6$ $60 < t \leq 150$	$p_c \leq 0,7$ $t \leq 60$
Water, non-flammable hydraulic fluids	$p_c > 4$ or $t > 300$	$1,6 < p_c \leq 4$ $200 < t \leq 300$	$p_c \leq 1,6$ $t \leq 200$

The results of the material tests are to be proven by
BCS Material Certificates.

4.2 For pressure vessel class II parts subject to mandatory testing, proof of material quality may take the form of Manufacturer Inspection Certificates provided that the test result certified therein comply with the requirements for Chapter 2 - Material of **BCS**.

Manufacturer Inspection Certificates may also be recognized for series-manufactured class I vessel components made of unalloyed steels, e.g. hand - and manhole covers, and for forged flanges and branch pipes where the product of PB [N/mm²] · DN [mm] \leq 250 [N/mm] and the nominal diameter $DN \leq$ 250 mm. for service temperatures \leq 300°C.

4.3 For all parts which are not subject to testing of materials according to 4.1 and 4.2, alternative proof of the characteristics of the material is to be provided, e.g. by a Manufacturer Test Reports or by a works certificate (DIN-EN 10204-2.2) as to the properties of the materials used.

C. Manufacturing Principles

1. Manufacturing Processes Applied to Materials

Manufacturing processes must be compatible with the materials concerned. Materials whose grain structure has been adversely affected by hot or cold working are to undergo heat treatment in accordance with requirements for Chapter 2 - Material.

2. Welding

The execution of welding work, the approval of welding shops and the qualification testing of welders are to be in accordance with Chapter 3 - Welding Rules at Pressure Vessels and Machinery Components.

3. End Plates

3.1 The flanges of dished ends may not be unduly hindered in their movement by any kind of

Table 14.2 Approved materials

Material and product form		Grades of material in accordance with the Rules for Materials, Chapter 2			
		Pressure vessel class			
		I	II	III	
Rolled and forged steel	Steel plate, shapes and bars	Plates for boilers and pressure vessels to Section 3, (high temperature steels).			
		Low-temperature steels to Section 3, (steels tough at sub-zero temperature).			
		Austenitic stainless steels to Section 3, (stainless steels).			
		General structural steels to Section 3 ⁽¹⁾ .			
	Pipes	Specially killed steels to Section 3. (with testing of each rolled plate)	-	Shipbuilding steels to Section 3.	
			Seamless and welded ferritic steel pipes to Section 4.		
			Low-temperature steel pipes to Section 4, (pipes tough at sub-zero temperature) for design temperatures below -10°C		
	Forgings	Austenitic stainless steel pipes to Section 4.			
		Forgings for boilers, pressure vessels and pipelines to Section 5.			
		Low-temperature steel forgings to Section 5, for design temperatures below -10°C			
	Bolts and nuts	-	Forgings for general plant engineering to Section 5, (forging for machine construction)		
		Bolts for general plant engineering to recognized standards, e.g. DIN 267 or ISO 898			
		High-temperature steels for design temperatures > 300°C			
Castings	Cast steel	Low-temperature steels for design temperatures below -10°C			
		Steel casting for boilers, pressure vessels and pipelines to Section 6, E			
		High-temperature steel castings for design temperatures > 300°C			
		Low-temperature steel castings to Section 6, (steel castings tough at sub-zero temperature) for design temperatures below -10°C			
	Nodular cast iron	-			
		Steel castings for plant engineering to Section 6			
	Grey cast iron	Nodular cast iron to Section 7: Ferritic grades only Standard grades up to 300°C Special grades up to 350°C			
		At least grade GG 20 to Section 7, Not permitted for vessels in thermal oil systems.			
	Non-ferrous metals	Copper copper alloy pipes castings	not permitted		
		Aluminium alloy plates, pipes and castings	Copper alloys to Section 9, within the following limits: copper-nickel alloys up to 300°C high-temperature bronzes up to 260°C others up to 200°C		
			Aluminium alloys to Section 8 within the following limits: design temperature up to 200°C Only with the special agreement of BCS		
	(1) Instead of unalloyed structural steel also hull structural steel according to Chapter 2, Section 3.B may be applied				

Table 14.3 Requirements to pressure vessel classes

Requirements	PV Class I	PV Class II	PV Class III
Design/Drawing Approval	required	required	required, Exceptions see A.1
Welding Shop Approval, see BCS Rules Chapter 3 - Welding	required	required	-
Welding Procedure Test, see BCS Rules Chapter 3 - Welding	required	required	-
Testing of Materials/Test Certificates	BCS Material Certificates See 4.1	Manufacturer Inspection Certificates, See 4.2	Manufacturer Test Report, See 4.3
BCS approved material manufacturer	required	required	-
Constructional check, see F.1.1	required	required	required
Hydraulic pressure test, see F.1.1	required	required	required
Non destructive testing, BCS Rules for Welding Chapter 3 - Welding, Section 10	required	required	required
	For welding seams radiographic examination depends on weld factor v		

fixtures, e.g. fastening plates or stiffeners, etc. Supporting legs may only be attached to dished ends which have been adequately dimensioned for this purpose.

3.2 Where covers or ends are secured by hinged bolts, the latter are to be safeguarded against slipping off.

4. Branch Pipes

The wall thickness of branch pipes is to be so dimensioned as to enable additional external stresses to be safely absorbed. The wall thickness of welded-in branch pipes should be appropriate to the wall thickness of the part into which they are welded. The walls are to be effectively welded together.

Pipe connections in accordance with Section 16 are to be provided for the attachment of piping.

5. Tube Plates

Tube holes are to be carefully drilled and deburred. Bearing in mind the tube-expansion procedure and the combination of materials involved, the ligament width must be such as to ensure the proper execution of the expansion process and the sufficient anchorage of the tubes. The expanded length should not be less than 12 mm.

6. Compensation for Expansion

The design of vessels and equipment has to take account of possible thermal expansion, e.g. between the shell and bundle of heating tubes.

7. Corrosion Protection

The elements of pressure vessels, which come contact with sea water or other aggressive media, are to be manufactured from corrosion-resistant materials.

If other materials are used, their protection against corrosion is to be subject to special consideration by **BCS** in each case.

8. Cleaning and Inspection Openings

8.1 Vessels and equipment are to be provided with inspection and access openings which should be as large as possible and conveniently located. For the minimum dimensions of these, see Section 12, C.9.

In order to provide access with auxiliary or protective devices, a manhole diameter of at least 600 mm is generally required. The diameter may be reduced to 500 mm where the pipe socket height to be traversed does not exceed 250 mm.

Vessels over 2.0 meters in length are to have inspection openings at each end at least or must contain a manhole.

Vessels with an inside diameter of more than 800 mm must be equipped at least with one manhole.

8.2 Manhole openings are to be designed and arranged in such a way that the vessels are accessible without undue difficulty. The edges of inspection and access openings are to be stiffened where they could be deformed by tightening the cover-retaining bolts or crossbars.

Special inspection and access openings are not necessary where internal inspection can be carried out by removing or dismantling parts.

8.3 Inspection openings may be dispensed with where experience has proved the unlikelihood of corrosion or deposits, e.g. in steam jackets.

Where vessels and equipment contain dangerous substances (e.g. liquefied or toxic gases), the covers of inspection and access openings shall be secured not by crossbars but by bolted flanges.

9. Identification and Marking

Each pressure vessel is to be provided with a plate or permanent inscription indicating the manufacturer, the serial number, the year of manufacture, the capacity, the maximum allowable working pressure and in case of service temperatures of more than 50°C or less than -10°C the service temperature of the pressurized parts. On smaller items of equipment, an indication of the working pressures is sufficient.

D. Design Calculations

1. Principles

1.1 Wall thickness

1.1.1 The wall thickness obtained by calculation is the lowest permissible values under normal operating conditions. The standards and methods of strength calculation do not take into account the manufacture tolerances for thicknesses, which shall be added as special allowances to the design thickness values.

Additional stresses due to the external loads (axial forces, bending moments and torques) acting upon the element under calculation (in particular, loads due to its own mass, the mass of attached elements, etc.) shall be specially taken into account as required by **BCS**.

1.1.2 The dimensions of structural elements of pressure vessels, for which no strength calculation methods given in the present requirements, are to be determined on the basis of experimental data and proved theoretical calculations, and are subject to special consideration by **BCS** in each case.

1.1.3 The parts subject to pressure of pressure vessels and equipment are to be designed, as far as they are applicable, by applying the formulae for steam boilers (Section 12, D.) and otherwise in accordance with the general rules of engineering practice **(1)**. The calculation parameters according to 1.2 to 1.7 are to be used.

1.2 Design pressure p_c

1.2.1 The design pressure to be used for strength calculations of the pressure vessels shall generally be taken to be equal to the maximum allowable working pressure (gauge), PB.

In determining the maximum allowable working pressure, due attention is to be given to hydrostatic pressures if these cause the loads on the walls to be increased by 5% or more.

1.2.2 In the case of feedwater preheaters located on the delivery side of the boiler feed water pump, the maximum allowable working pressure PB is the maximum delivery pressure of the pump.

1.2.3 For external pressures, the calculation is to be based on a vacuum of 100 kPa or on the external pressure at which the vacuum safety valves are actuated. In the event of simultaneous positive pressure externally and vacuum internally, or vice versa, the calculation is to assume an external or, respectively, internal pressure increased by 0.1 MPa or 0.1 N/mm².

(1) *The TRB/AD Merkblätter (Regulations of the Working Party on Pressure Vessels) constitute, for example, such rules of engineering practice.*

1.2.4 In the case of cargo tanks for liquefied gases, the design pressure is to be determined in accordance with the requirements for Chapter 10 - Liquefied Gas Tankers. Vessels and equipment in refrigerating installations are governed by the requirements of Section 1, D.17.

1.3 Strength characteristics of materials and allowable (permissible) stress

The dimensions of components are governed by the allowable stress σ_{perm} [N/mm²]. With the exception of cargo containers and process pressure vessels according to Chapter 10 – Liquefied Gas Tankers, the smallest value determined from the following expressions is to be applied in this case:

1.3.1 When determining the allowable stresses in Carbon and alloy steels with the ratio of the upper yield stress R_{eH} to ultimate tensile strength R_m not exceeding 0.6, or proof stress $R_{p0.2,t}$ and the average stress to produce rupture in 100,000 hours $R_{m,100000,t}$ at design temperatures is to be adopted as design characteristics.

For steels having the ratio of the upper yield stress to tensile strength above 0.6, the tensile strength $R_{m,t}$ at design temperature shall be adopted additionally.

For steels, the service conditions of which are characterized by creep (at temperatures above 450°C), irrespective of the value of the ratio R_{eH}/R_m , the creep strength $R_{1\%,100000,t}$ at design temperature is to be added the above characteristics.

Minimum values of $R_{p0.2,t}$ and $R_{m,t}$ as stipulated by the steel specifications are to be adopted, while of $R_{m,t}$ and $R_{1\%,100000,t}$ average values are to be adopted.

1.3.2 For materials having no clearly defined yield stress point, the minimum tensile strength value $R_{m,t}$ at the design temperature is to be taken as the design characteristic.

1.3.3 For spheroidal or nodal graphite cast iron and ductile cast iron with ferritic-perlitic and perlitic structure and with elongation less than 5%, the minimum tensile strength value $R_{m,20}$ at 20°C is to be taken as the design strength characteristic.

For cast irons with ferritic structure and elongation more than 5%, the design strength characteristic is to be the lesser one of the minimum ultimate strength $R_{m,20}$ either the proof stress for the materials having a permanent elongation of 0.2%, $R_{p0.2}$:

1.3.4 When non-ferrous metals and their alloys are used, it is to be taken into account that the heating during working or welding tends to relieve them of the strengthening effects realized under cold conditions. Therefore, the strength characteristics to be used for strength calculations of components and assemblies manufactured from such materials are to be those applied to their heat-treated conditions.

1.3.5 The allowable (permissible) stress σ , used for determining the scantlings is to be adopted equal to the smallest of the following values.

$$\sigma_{perm} = \frac{R_{m,t}}{n_t}$$

$$\sigma_{perm} = \frac{R_{1\%,100000,t}}{n_{cr}}$$

$$\sigma_{perm} = \frac{R_{p0.2,t}}{n_y}$$

$$\sigma_{perm} = \frac{R_{m,100000,t}}{n_{av}}$$

Where;

n_t = Tensile strength safety factor

n_{cr} = Creep strength safety factor

n_y = Yield stress safety factor

n_{av} = Safety factor for the average stress to produce rupture in 100,000 hours

1.3.6 Safety factors

1.3.6.1 For items manufactured of steel forgings and rolled steel, which are under internal pressure, the safety factors are to be taken of at least:

$$n_y = n_{av} = 1.6$$

$$n_t = 2.7$$

$$n_{cr} = 1.0$$

For the pressure vessels under external pressure, the safety factors n_t , n_y and n_{av} are to be increased by 20%.

1.3.6.2 For components of pressure vessels of Class II and Class III, which are made of steels having the ratio $R_{eH}/R_m \leq 0.6$, the safety factors may be adopted as follows:

$$n_y = n_{av} = 1.5$$

$$n_t = 2.6$$

1.3.6.3 For components of pressure vessels which are made of cast steel and are under internal pressure in service, the safety factors shall be chosen of at least:

$$n_y = n_{av} = 2.2$$

$$n_t = 3.0$$

$$n_{cr} = 1.0$$

For the pressure vessels under external pressure in service, the safety factors n_t , n_y and n_{av} are to be increased by 20% (except for n_{cr} which shall remain to be equal to 1).

1.3.7 When determining scantlings for the items made of grey cast iron, spheroidal or nodular graphite cast iron and ductile cast iron with ferritic-perlitic and perlitic structure having elongation less than 5%, the tensile strength safety factor n_t is to be adopted equal to 4.8 after annealing and to 7.0 without annealing both for the case of internal and external pressure.

For the items made of cast iron with ferritic structure having elongation more than 5%, the tensile strength safety factor n_t is to be adopted equal to 4.0 for the case of internal pressure and 4.8 for the case of external pressure.

1.3.8 Rolled and forged steels

For design temperatures up to 350°C

$$\sigma_{perm} = \min \left\{ \frac{R_{m,20^0}}{2.7}, \frac{R_{eH,20^0}}{1.7}, \frac{R_{eH,t}}{1.6} \right\}$$

For design temperatures above 350°C

$$\sigma_{perm} = \frac{R_{m,100000,t}}{1.5}$$

$$\sigma_{perm} = \frac{R_{eH,t}}{1.6}$$

Where;

$R_{P 0.2}$ = Proof stress at 20°C, at which the permanent elongation is 0.2% [N/mm²],

$R_{m,20^0}$ = Guaranteed minimum tensile strength at room temperature (may be dispensed with in the case of recognized fine-grained steels with $R_{eH} \leq 360$ N/mm²), [N/mm²],

$R_{eH,20^0}$ = Guaranteed yield strength or minimum value of the 0.2% proof stress **(2)** at room temperature [N/mm²],

$R_{eH,t}$ = Guaranteed yield strength or minimum value of the 0.2% proof stress at design temperatures above 50°C [N/mm²],

$R_{m,100000,t}$ = Mean value of the 100,000 hours fatigue strength at design temperature, [N/mm²]

t = Design temperature [°C].

Cargo containers and process pressure vessels for liquefied gases are governed by the values specified in Chapter 10 – Liquefied Gas Tankers.

(2) 1% proof stress in case of austenitic steel.

1.3.9 Cast materials

- Cast steel:

$$\sigma_{\text{perm}} = \min \left\{ \frac{R_{m,20^\circ}}{3.2}, \frac{R_{eH,t}}{2.0}, \frac{R_{m,100000,t}}{2.0} \right\}$$

- Nodular cast iron:

$$\sigma_{\text{perm}} = \min \left\{ \frac{R_{m,20^\circ}}{4.8}, \frac{R_{eH,t}}{3.0} \right\}$$

- Grey cast iron:

$$\sigma_{\text{perm}} = \frac{R_{m,20^\circ}}{11}$$

1.3.10 Non-ferrous metals

- Copper and copper wrought alloys:

$$\sigma_{\text{perm}} = \frac{R_{m,t}}{4.0}$$

- Aluminium and aluminium wrought alloys:

$$\sigma_{\text{perm}} = \frac{R_{m,t}}{4.0}$$

With non-ferrous metals supplied in varying degrees of hardness it should be noted that heating, e.g. at soldering or welding, can cause a reduction in mechanical strength. In these cases, calculations are to be based on the mechanical strength in the soft-annealed condition.

1.4 Design temperature

1.4.1 The design temperature to be applied is generally the maximum temperature of the medium to be contained.

1.4.2 Where heating is done by firing, exhaust gas or electrical means, Section 12, Table 12.3 is to be applied as appropriate. Where electrical heating is used, Table 12.3 applies only to directly heated surfaces.

1.4.3 With service temperatures below 20°C, a design temperature of at least 20°C is to be used in calculations.

1.4.4 The walls are considered to be non-heated in the following cases:

- The walls are separated from the combustion space or uptake by fire-resistant insulation the distance between walls and an insulation 300 mm and over, or,
- The walls are protected with fire-resistant insulation not exposed to radiant heat.

1.4.5 The walls are considered to be protected from radiant heat effect in the following cases:

- The walls are protected with fire-resistant insulation, or
- The walls are protected by a closely spaced row of tubes (with a maximum clearance between the tubes in the row up to 3 mm), or
- The walls are protected by two staggered rows of tubes with a longitudinal pitch equal to a maximum of two outside tube diameters or by three or more staggered rows of tubes with a longitudinal pitch equal to a maximum of two and a half outside tube diameters.

1.4.6 The design wall temperature for heat exchangers and pressure vessels operating under coolant pressure is to be taken as equal to 20°C if occurrence of higher temperatures is not possible.

1.5 Weakening factor, ligament efficiency factor

Weakening factor is also called as the ligament efficiency factor. For the weakening factor, v for the calculation of walls or parts of walls, see Section 12, Table 12.4.

1.6 Design thickness allowances for corrosion and wear

1.6.1 In all cases where the design wall thickness allowance c is not expressly specified, it shall be taken as equal to at least 1 mm.

For steel wall over 30 mm in thickness, walls manufactured from corrosion-resistant or having protective coating non-ferrous or high alloy materials, design wall thickness allowance may be reduced to zero on agreement with **BCS**

1.6.2 For the pressure vessels which are inaccessible for internal inspection, or the walls of which are heavily affected by corrosion or wear, the allowance c may be increased if required by **BCS**.

1.7 Minimum wall thicknesses

1.7.1 The wall thickness of the shells and end plates should generally not be less than 3 mm.

1.7.2 Where the walls of vessels are made from pipes or corrosion-resistant materials or for vessels and equipment in Class III a minimum wall thickness of 2 mm. can be allowed, provided that the walls are not subjected to external forces.

1.8 Other methods applicable to dimensional design

Where walls, or parts of walls, cannot be calculated by applying the formulae given in Section 12 or in accordance with the general rules of engineering practice, other methods are to be used to demonstrate that the allowable stresses are not exceeded.

E. Equipment and Installation

1. Shut-off Devices

Shut-off devices must be fitted in pressure lines as close as possible to the pressure vessel. Where several pressure vessels are grouped together, it is not necessary that each vessel should be capable of being shut off individually and means need only be provided for shutting-off the group. In general, not more than three vessels should be grouped together. Starting air receivers and other pressure vessels which are opened in service must be capable of being shut-off individually. Devices incorporated in piping, (e.g. water and oil separators) do not require shut-off devices.

2. Pressure Gauges

2.1 Each pressure vessel which can be shut-off and every group of vessels with a shut-off device must be equipped with a pressure gauge, also capable of being shut-off. The measuring range and calibration must extend to the test pressure with a red mark to indicate the maximum allowable working pressure.

2.2 Equipment is only be fitted with pressure gauges when these are necessary for its operation.

3. Safety Equipment

3.1 Each pressure vessel which can be shut-off or every group of vessels with a shut-off device must be equipped with a spring-loaded safety valve which cannot be shut-off and which closes again reliably after blow-off.

Appliances for controlling pressure and temperature are no substitute for relief valves.

3.2 Safety valves must be designed and set in such a way that the maximum allowable working pressure cannot be exceeded by more than 10%. Means must be provided to prevent the unauthorized alteration of the safety valve setting. Valve cones must be capable of being lifted at all times.

3.3 Means of drainage which cannot be shut-off are to be provided at the lowest point on the discharge side of safety valves for gases, steam and vapours. Facilities must be provided for the safe disposal of hazardous gases, vapours or liquids discharging from safety valves. Media flowing out must be drained off safely, preferably via an open funnel.

3.4 Steam-filled spaces are to be fitted with a safety valve if the steam pressure inside them is liable to exceed the maximum allowable working pressure.

3.5 Heated spaces which can be shut-off on both the inlet and the outlet side are to be fitted with a safety valve which will prevent an inadmissible pressure increase should the contents of the space undergo dangerous thermal expansion or the heating elements fail.

Besides a temperature controller, electrically heated appliances are to be also equipped with a safety thermal limiter.

3.6 Pressure water tanks are to be fitted with a safety valve on the water side. A safety valve on the air side may be dispensed with, if the air pressure supplied to the tank cannot exceed its maximum allowable working pressure.

3.7 Calorifiers are to be fitted at the cold water inlet with a safety valve.

3.8 Rupture discs are permitted only with the consent of **BCS** in applications where their use is specially justified. They must be designed that the maximum allowable working pressure PB cannot be exceeded by more than 10%.

Rupture discs are to be provided with a guard to catch the fragments of the rupture element and shall be protected against the damages from outside. The fragments of the rupture element are not to be capable of reducing the necessary section of the discharge aperture.

3.9 Pressure relief devices can be dispensed with in the case of accumulators in pneumatic and hydraulic control and regulating systems provided that the pressure which can be supplied to these accumulators cannot exceed the maximum allowable working pressure and that the pressure-volume product is $PB [MPa] \cdot I [litres] \leq 20$.

3.10 Electrically heated equipment has to be equipped with a temperature limiter of special design besides of a temperature controller.

3.11 The equipment on pressure vessels has to be suitable for the use on ships. The limiters for pressure, temperature and flow are safety devices and shall meet the requirements of Regulations for the Performance of the Type Tests, Part 7 – Test Requirements for Mechanical Components and Equipment.

3.12 Oil-fired warm water generators are to be equipped with limiters for temperature and pressure above a specified threshold. Additionally a low water level limiter, a limiter for minimum pressure or a low flow limiter is to be provided. The actuation of the limiters shall shut-down and interlock the oil burner.

Warm water generators heated by exhaust gases are to be equipped with the corresponding alarms.

4. Liquid Level Indicators and Feed Equipment for Heated Pressure Vessels

4.1 Heated pressure vessels in which a fall of the liquid level can result in unacceptably high temperatures in the vessel walls must be fitted with a device for indicating the level of the liquid.

4.2 Pressure vessels with a fixed minimum liquid level are to be fitted with a feed equipment of adequate size.

4.3 Warm water generating plants are to be designed as closed systems with external pressure generation and membrane expansion vessel. Water shall be circulated by forced circulation.

5. Sight Glasses

Sight glasses in surfaces subject to pressure are allowed only if they are necessary for the operation of the plant and other means of observation cannot be provided. They are not to be larger than required value and are preferred to have a rounded shape. Sight glasses are to be protected against to the mechanical damages, e.g. by wire mesh. When any combustible or explosive or poisonous media is considered, the sight glasses are to be fitted with closable covers.

6. Draining and Venting

6.1 Pressure vessels and equipment are to be capable of being depressurized and completely emptied or drained. Particular attention is to be given to the adequate drainage facilities of compressed air vessels.

6.2 Suitable connections for the execution of hydraulic pressure tests and a vent at the uppermost point are to be provided.

7. Installation

7.1 When installing and fastening the pressure vessels onboard ship, the full care is to be taken to ensure that the loads due to the contents and structural weight of the pressure vessel and to the movements of ship. Structural vibrations shall not cause to rise any excessive increasing in stress throughout the surface and walls of pressure vessel. Where necessary, the walls near supports and brackets are to be fitted as much as possible with reinforcing plates.

7.2 Pressure vessels and equipment are to be installed in such a way as to provide for practicable all-round visual inspection and to facilitate the execution of periodic tests. Where necessary, ladders or steps are to be fitted inside vessels.

7.3 Wherever possible, horizontally fastened compressed air receivers are to be installed at an angle and parallel to the fore-and-aft line of the ship. The angle shall be at least 10° (with the valve head at the top). Where the pressure vessels are installed athwartships, the angle shall be greater.

7.4 Where necessary, compressed air receivers are to be marked on the outside that they can be installed onboard ship in the position necessary for complete venting and drainage.

F. Tests

1. Pressure Tests

1.1 After completion, pressure vessels and heat exchangers have to undergo constructional checks and a hydrostatic test. No permanent deformation of the walls may result from these tests.

All completed pressure vessels (after all required non-destructive examination and after postweld heat treatment) are to be subjected to a hydrostatic test at not less than 1.3 times the design pressure or the maximum allowable pressure (the pressure to be

stamped on the nameplate is to be used) in the presence of **BCS** Surveyor. The pressure gauge used in the test is to have a maximum scale of about twice the test pressure, but in no case is the maximum scale to be less than 1.3 times the test pressure. Following the hydrostatic test, the test pressure may be reduced to the design or the maximum allowable working pressure, and an inspection is to be made by **BCS** Surveyor of all joints and connections. During the hydrostatic pressure tests, the loads specified below may not be exceeded:

For materials with a definite yield point;

$$\leq \frac{R_{eH,20^{\circ}}}{1.1}$$

For materials without a definite yield point;

$$\leq \frac{R_{m,20^{\circ}}}{2.0}$$

1.2 The test pressure PP for pressure vessels and heat exchangers is generally 1.5 times of the maximum allowable working pressure PB, subject to a minimum of PB + 0.1 MPa respectively 1.5 times of the design pressure PR if this is higher than PB.

In the case of pressure vessels and equipment which are only subjected to pressure below atmospheric, the test pressure shall at least match the working pressure. Alternatively a pressure test can be carried out with 0.2 MPa or 0.2 N/mm² of pressure in excess of atmospheric pressure.

For the test pressures to be applied to steam condensers, see Section 3.

1.3 All pressure vessels and equipment located in the fuel oil pressure lines of boiler firing equipment are to be tested on the oil side at a test pressure of 1.5 times the maximum allowable working pressure PB, subject to a minimum of 0.5 MPa. On steam side, the test is to be performed as specified in 1.2.

1.4 Pressure vessels in water supply systems which correspond to Standard DIN 4810 are to be tested at pressures of 520 kPa, 780 kPa or 1.3 MPa as specified in the Standard.

1.5 Air coolers are to be tested on the water side at 1.5 times the maximum allowable working pressure PB, subject to a minimum of 0.4 MPa or 0.4 N/mm².

1.6 Pressure tests with media other than water may be agreed to in special cases.

1.7 Warm water generators are to be subjected to a test pressure in accordance with the Standard or Directive applied, but at least with 1.3 times the maximum allowable working pressure.

2. Tightness Tests

For pressure vessels and equipment containing dangerous substances (e.g. liquefied gases), **BCS** reserves the right to call for a special test of gas tightness.

3. Testing after Installation on Board

Following installation onboard ship, a check is carried out on the fittings of vessels and equipment and on the arrangement and setting of safety appliances, and operating tests are performed wherever necessary.

G. Gas Cylinders

1. General

The requirements given below cover the following conditions depending on the ratio of outer diameter to inner diameter of gas cylinder:

- At $D_o/D_i \leq 1.6$ for cylindrical walls;
- At $D_o/D_i \leq 1.7$ for tubes;
- At $D_o/D_i \leq 1.2$ for spherical walls;

Cylindrical walls with $D_o \leq 200$ mm are regarded as tubes.

1.1 For the purposes of these requirements, gas cylinders are bottles with a capacity of not more than 150 litres with an outside diameter of ≤ 420 mm and a

length of ≤ 2000 mm which are charged with gases in special filling stations and are thereafter brought onboard ship where the pressurized gases are used (see also Section 18).

1.2 These requirements are not valid for gas cylinders with

- A maximum allowable working pressure of maximum 0.05 N/mm², or
- A capacity ≤ 0.5 litres.

1.3 These requirements are only valid in a limited range for gas cylinders with

- A maximum allowable working pressure of maximum 20 N/mm² and
- A capacity > 0.5 litres and < 4 litres

For these gas cylinders, the drawing approval can be waived. The tests according to 5.2 – 5.5 and the marking according to 6, respectively a possible recognition according to 7 are to be performed.

2. Approval Procedure

2.1 Documentation

Drawings with definition of the planned form of stamp are to be submitted in triplicate.

2.2 Materials

2.2.1 Details of the raw materials to be used (range of chemical analysis, name of manufacturer, scope of necessary characteristics and form of proof) are to be submitted.

2.2.2 Details of the scheduled heat treatment are to be submitted.

2.2.3 Details of the designated material properties (yield point, tensile strength, impact strength, fracture strain) of the finished product are to be submitted.

3. Manufacture

3.1 Gas cylinders are to be manufactured by established methods using suitable materials and must be so designed that they are well able to withstand the expected loads.

The following variants are to be distinguished:

- Seamless gas cylinders made of steel,
- Welded gas cylinders made of steel.

All other variants are subject to special approval by **BCS**.

3.2 The manufacturing process for seamless gas cylinders is to be approved by **BCS**

3.3 Gas cylinders with the basic body made by welding are for the aforementioned requirements subject of this Section.

4. Design Calculation

4.1 Terms used

p_c = Design pressure (specified test pressure), [N/mm²]

s = Minimum wall thickness, [mm]

c = Corrosion allowance, [mm]

= 1 mm, if required,

D_a = Outside diameter of gas cylinder, [mm]

D_i = Inner diameter of gas cylinder, [mm]

R_{eH} = Guaranteed upper yield point, [N/mm²]

$R_{p0.2}$ = Guaranteed 0.2% proof stress, [N/mm²]

R_m = Guaranteed minimum tensile strength, [N/mm²]

R_e = Yield point needed as comparative value for the determination of R , [N/mm²]

either $R_e = R_{eH}$,

or $R_e = R_{p0.2}$,

R = In each case the smaller of the following two values, [N/mm²]

1) R_e

2) - 0.75 R_m for normalized or normalized and tempered cylinders

- 0.90 R_m for quenched and tempered cylinders

σ_{perm} [N/mm²] Allowable stress (= $\frac{3}{4} R$),

β = Design coefficient for dished ends, (see Section 12, Steam Boilers, D.4) [-],

v = Weaking factor, (see Section 12, Steam Boilers, D.2) [-],

4.2 Test pressure

The specified test pressure for CO₂ bottles with a filling factor of 0.66 kg/litres is 25 N/mm² (or 250 bars) gauge.

For other gases, the test pressure can be taken from the Technical Rules for Gases under Pressure (TRG) or may be agreed with **BCS**.

If not agreed otherwise the test pressure is to be at least 1.5 times of the maximum allowable working pressure, PB.

4.3 Cylindrical surfaces

Minimum wall thickness of cylindrical shaped pressure vessels shall not be less than the value from following formula. Plates are not to be less than 2.4 mm thick after forming and without allowance for corrosion.

$$s = c + \frac{D_a \cdot p_c}{2 \cdot \sigma_{perm} \cdot v + p_c}$$

4.4 Spherical ends

$$s = c + \frac{D_a \cdot p_c}{4 \cdot \sigma_{perm} \cdot v + p_c}$$

4.5 Ends dished to outside

$$s = c + \frac{D_a \cdot p_c \cdot \beta}{4 \cdot \sigma_{perm}}$$

4.6 Ends dished to inside

The conditions applicable to dished ends are shown in Figure 14.1.

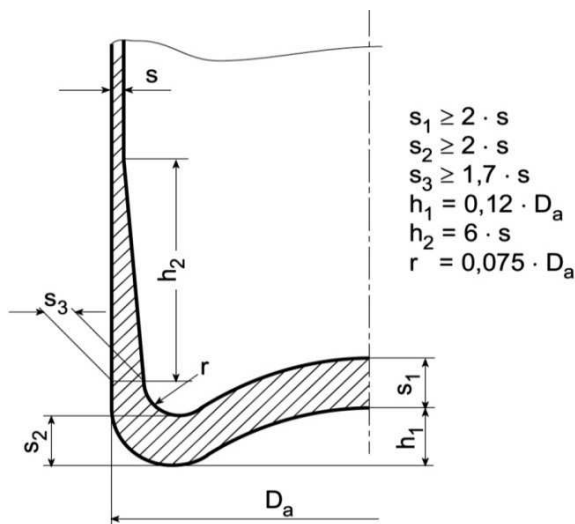


Figure 14.1 Ends dished to inside

4.7 Alternative calculation

Alternatively a calculation according to EN 1964-1 or ISO 9809-1 may be performed, provided that the results are at least equivalent.

5. Testing of Gas Cylinders

5.1 Approval procedure

BCS may approve according to the following procedures:

5.1.1 Single test in lots

After approval of the documentation by BCS, the required tests according to 5.3 to 5.5 are to be performed.

The facilitations according to 5.4.3 are not to be applied.

5.1.2 Type approval and single test in lots.

After approval of the documentation by BCS, the first production series serves to test the specimens according to 5.3 to 5.5. Afterwards for each production lot the required tests according to 5.3 to 5.5 are to be performed.

The facilitations according to 5.4.3 may apply.

5.1.3 Type approval and test arrangement

After approval of the documentation by BCS, the manufacturer may make special arrangements with BCS concerning the tests for approval.

5.2 Sampling

5.2.1 Normalized cylinders

Two sample cylinders from each 400 originating from each melt and each heat treatment are to be taken.

5.2.2 Quenched and tempered cylinders

Two sample cylinders from each 200 originating from each melt and each heat treatment are to be taken.

5.3 Testing on the first sample cylinder

5.3.1 One longitudinal tensile tests specimen, three transverse bending test specimens and a set of ISO V-type notched bar impact test specimens are to be taken from the sample cylinders according to 5.2.1 and 5.2.2. The notched bar impact test specimens are to be tested at -20°C. The average impact work shall be at least 35 Joule.

5.3.2 The cylindrical wall thickness of all sample cylinders is to be measured in transverse planes at three levels (neck, middle and base). The end plate is also to be sawn through and the thickness measured.

5.3.3 At the first sample cylinder examination of the inner surface of the neck and bottom portions to detect possible manufacturing defects.

5.4 Testing on the second sample cylinder

5.4.1 The second test bottle is to be subject to a bursting test according to 5.4.2.

5.4.2 Bursting test

5.4.2.1 Test bottles intended to be subjected to a bursting test must be clearly identified as to the lot from which they have been taken.

5.4.2.2 The required bursting pressure has to be at least 1.8 times the test pressure, PP (in formulae p_p).

5.4.2.3 The hydrostatic bursting test is to be carried out in two subsequent stages, by means of a testing device enabling the pressure to be continuously increased up to bursting of the cylinder and the pressure curve to be recorded as a function of time. The test must be carried out at room temperature.

5.4.2.4 During the first stage, the pressure has to increase continuously up to the value at which plastic deformation starts; the pressure increase must not exceed 0.5 N/mm² per second.

Once the point of plastic deformation has been reached (second stage), the pump capacity must not exceed double the capacity of the first stage; it has then to be kept constant until bursting of the cylinder.

5.4.2.5 The appearance of the fracture has to be evaluated. It shall not be brittle and no breaking pieces are to be detached.

5.4.3 In the case of lots of less than 400 pieces of normalized and/or 200 pieces of quenched and tempered cylinders, the bursting pressure is waived for every second lot.

5.5 Testing on all gas cylinders

5.5.1 For all gas cylinders submitted for testing a hydrostatic pressure test with a test pressure according to 4.2 is to be performed.

5.5.2 All gas cylinders submitted for testing are subjected to a final visual inspection. The gas cylinders have to meet the requirements defined in the documentation for approval.

As far as an inspection by **BCS** is to be provided, a check of the weight and volumetric capacity as well as of the stamped marking is to be performed for 10% of the gas cylinders by the **BCS** Surveyor.

5.5.3 The manufacturer shall establish the volumetric capacity and weight of each cylinder.

5.5.4 Cylinders which have been quenched and tempered are to be subjected by the manufacturer to 100% hardness testing. As far as not otherwise agreed, the hardness values evaluated for one test lot according to 5.2 shall not be differing by more than 55 HB.

5.6 Presence of the BCS Surveyor

As far as not agreed otherwise (see 5.1.3) the presence of the **BCS** Surveyor is required for the tests according to 5.3, 5.4.2, 5.5.1 and 5.5.2.

6. Marking and Identification

Each gas cylinders is to be marked with the following:

- Name or trade name of the manufacturer,
- Serial number,
- Type of gas,
- Design strength value [N/mm²],
- Capacity [litres],
- Test pressure [N/mm²],
- Empty weight [kg],
- Date of test,
- Test stamp.

7. Recognition of Equivalent Tests

Test verified by other bodies may be recognized provided that they are established as being equivalent of those prescribed above.

7.1 Recognition for single tests in lots

7.1.1 If the approval of the documents respectively the type approval of an institution recognized by **BCS** is submitted, already manufactured gas cylinders checked by single test in lots may be recognized by **BCS**.

7.1.2 Herewith the complete documentation

including manufacturing records is to be made available to **BCS** and has to be evaluated with positive result.

7.1.3 The gas cylinders are to be subjected to an external check and a survey for conformity with the documentation.

7.2 Recognition for tests with own responsibility

For gas cylinders which have been manufactured under the manufacturer's own responsibility on the basis of an approval by an institution outside **BCS**, an approval procedure according to 5.1.1 shall be performed.

SECTION 15**OIL BURNERS AND OIL FIRING EQUIPMENT**

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A. General**1. Scope**

1.1 The oil burners and oil firing equipment of main steam boilers and auxiliary steam boilers and thermal oil heaters, warm water and hot water generators as well as inert gas generators according to Section 12 E, in the following referred to as heat generators, are subject to the subsequent requirements.

1.2 Where steam is required for the main propelling engines, or where steam or thermal oil is required for auxiliary machinery for essential services, or for heating of heavy oil fuel and is generated by burning oil fuel under pressure, there are to be not less than two oil burning units. For auxiliary boilers, a single oil burning unit may be accepted, provided that alternative means, such as an exhaust gas boiler or composite boiler, are available for supply of essential services. Where the oil burning unit is not of the monobloc type (i.e. separate register and oil supply unit), each oil burning unit is to comprise a pressure pump, suction filter, discharge filter and, when required, a heater.

1.3 In installations consisting of two or more oil burning units, the number, arrangement and capacity of such units is to be capable of supplying sufficient fuel to allow the steam to be generated or thermal oil heated, as applicable to provide essential services with any one unit out of action.

1.4 For oil burners of other heating appliances which are not important for the operation of the machinery, but which are located in the engine room or in spaces containing equipment essential for the operation of the machinery, the subsequent requirements are to be applied analogously.

1.5 Where oil burners are to be used additionally for burning the waste oil and oil sludge, the necessary measures are to be agreed with **BCS** in each single case.

1.6 In addition, the following general requirements of this section are mandatory for all installations and appliances.

2. Additional Requirements

The following requirements are to be applied

analogously:

Section 12,	for steam boilers and hot water generators
Section 13,	for thermal oil systems
Section 14,	for pressure vessels and warm water generators
Section 16, A to D, G, M, Q, R for pumps, pipelines, valves and fittings	
Section 18	for fire protection and fire fighting equipment
Electrical Installations, Chapter 5	for electrical installations.
Automation, Chapter 4-1	for automated machinery systems (AUT).

3. Documents for approval

3.1 Design drawings, plans and particulars of oil burners installed on heat generators are to be submitted to **BCS** in triplicate for approval. The documents are required to contain the details of all the installation components:

- General drawings of the oil burner,
- Piping and equipment diagram of the burner including part list,
- Description of function,
- Electrical diagrams,
- List of equipment regarding electrical control and safety.
- Confirmation by the manufacturer that the oil burner and the oil firing equipment are suitable for the fuels intended to be used.

3.2 For oil burners, which comply with the requirements according to TS/EN 267 or to a recognized standard as equivalent by **BCS** and have been certified by a third party, the scope of the drawing approval is to be agreed with **BCS** in each individual case.

However, safety related components have to be suitable for shipboard installation

B. Oil Firing Equipment for Boilers and Thermal Oil Heaters

1. General

1.1 Boilers and thermal oil heaters, heat generators without constant and direct supervision are to be operated with automatic firing system.

1.2 Adequate purging by means of a fan has to be ensured prior to each ignition effected by the controls. In general, a purging period of at least 15 seconds may be regarded to be sufficient. Where the flue gas ducting is unfavourable, the purging time is to be extended accordingly.

1.3 Oil firing equipment with electrically operated components is also to be capable of being shut down by emergency switches located at the operating panel and from a position outside the space in which the equipment is installed. In analogous manner, means are to be provided for a remote shut down of steam-operated fuel oil service pumps.

1.4 Heat generators according to A.1.1 are to be provided for manual operation, enabling the safe operation of oil burners in case of electrical malfunction of the burner control box or the control equipment of the heat generator. Flame monitoring shall remain operative even in manual operating.

1.5 Manual operation demands constant and direct supervision of the system.

1.6 Safety devices may only be set out of function (e.g. bridged) by means of a key-operated switch. The operating of the key-operated switch is to be indicated.

1.7 It is recommended that the inlets of boiler fans be protected against penetration of moisture or solids.

1.8 Trays shall be provided in places where oil may leak.

1.9 Where boiler oil is heated, structural measures are to be taken to prevent the oil overheating in heaters in case steam-generating capacity of the boiler is reduced or burners are shut-off.

2. Adjustment of the Heat Generators and Burner Arrangement

2.1 The burner arrangements are to be such that a burner cannot be withdrawn unless the fuel oil supply to that burner is shut-off, and that the oil cannot be turned on unless the burner has been correctly coupled to the supply line.

2.2 Oil burners are to be designed, fitted and adjusted in such a manner as to prevent flames from causing damage to the boiler surfaces or tubes which border on the combustion space. Boiler parts which might otherwise suffer damage are to be protected by refractory lining.

The firing system shall be so arranged as to prevent flame from blowing back into the boiler or engine room and shall allow unburned fuel to be safely drained.

2.3 Observation openings are to be provided at suitable points on the heat generator or burner through which the ignition flame, the main flame and the lining can be observed.

2.4 Where burners are provided with steam purging and/or atomising connections, the arrangements are to be such that oil fuel cannot find its way into the steam system in the event of valve leakage.

2.5 Fuel leaking from potential leak points is to be safely collected in oil tight trays and drained away (see the requirements of Section 18).

3. Simultaneous Operation of Oil Firing Equipment and Internal Combustion Engines

The operation of oil firing equipment in spaces containing other items of plant with high air consumption, e.g. internal combustion engines or air compressors, is not to be impaired by variations in the air pressure.

4. Preheating of Fuel Oil

4.1 Fuel oil preheating equipment has to enable the heat generators to be started up with the facilities available on board.

4.2 Where only steam-operated preheaters are present, fuel which does not require preheating has to be available to start up the boilers.

4.3 Any controllable heat source may be used to preheat fuel oil. Preheating with open flame is, however, not permitted.

4.4 Fuel oil circulating lines are to be provided to enable the preheating of the fuel oil prior to the start-up of the heat generators.

When a change is made from heavy to light oil, the light oil may not be passed through the heater or be excessively heated (alarm system).

4.5 The preheating temperature is to be selected so as to avoid excessive foaming, the formation of vapour or gas and also the formation of deposits on the heating surface.

Where fuel oil is preheated in tanks at atmospheric pressure, the requirements in Section 16, V are to be complied with.

Provision is to be made, by suitable non-return arrangements, to prevent oil from spill systems being returned to the burners when the oil supply to these burners has been shut-off.

The design and construction of pressurized fuel oil heaters are subject to the requirements in Section 14.

4.6 Temperature or viscosity control shall be done automatically. For monitoring purposes, a thermometer or viscosimeter is to be fitted to the fuel oil pressure line in front of the burners.

4.7 Should the oil temperature or viscosity

deviate above or below the permitted limits, an alarm system must signal this fact to the heat generator operating platform.

5. Pumps, Pipelines, Valves and Fittings

5.1 For pumps, pipelines, valves and fittings see Section 16, G.9.

5.2 By means of a hand-operated, quick-closing device mounted at the fuel oil manifold it shall be possible to isolate the fuel supply to the burners from the pressurized fuel lines. Depending on design and method of operation, a quick-closing device may also be required directly in front of each burner.

6. Approved Fuels

See Section 1, D.16.

7. Safety Equipment

7.1 The correct sequence of safety functions when the burner is started up or shut down is to be ensured by means of a burner control box.

7.2 Two automatic quick-closing devices have to be provided at the fuel oil supply line to the burner.

For the fuel oil supply line to the ignition burner one automatic quick-closing device will be sufficient, if the fuel oil pump is switched off after ignition of the burner.

7.3 An automatic quick-closing master valve is to be fitted to the oil supply to each boiler manifold, suitably located so that the valve can be readily operated in an emergency, either directly or by means of remote control, having regard to the machinery arrangements and location of controls.

7.4 The automatic quick-closing devices shall not release the oil supply to the burners during start-up and have to interrupt the oil supply during operation (automatic restart possible) if one of the following faults occurs:

- Failure of the required pressure of the atomizing medium (steam and compressed-air atomizers);
- Failure of the oil pressure needed for atomization (pressure atomizers) **(1)**,
- Exceeding of the maximum allowable pressure in the return line (burners with returnline)
- Insufficient rotary speed of spinning cup or primary air pressure too low (rotary atomizers);
- Failure of combustion air supply **(1)**;
- Failure of control power supply;
- Failure of induced-draught fan or insufficient opening of exhaust gas register;
- Burner not in operating position.

7.5 The fuel oil supply has to be interrupted by closing the automatic quick-closing devices and interlocked by means of the burner control box if

- The flame does not develop within the safety period following start-up (see. 7.7);
- The flame is extinguished during operation and an attempt to restart the burner within the safety period is unsuccessful; or
- Limit switches are actuated.

7.6 The return line of burners with return lines have also to be provided with an automatic quick-closing device. The shutoff device in the return line may be

(1) *Where there is no oil or air supply monitoring device spring-loaded fast closing device in the pump, the above requirements are considered to have been met if there is a motor-fan-pump assembly in the case of a single shaft motor output or a fan-motor-oil pump assembly in the case of a double ended shaft motor output. In the latter case, there shall be a positive coupling between the motor and the fan.*

dispensed with if the return line is not under pressure and no oil is able to flow back when the burner is shut down.

7.7 Every burner is to be equipped with safety device for flame monitoring. This appliance has to comply with the following safety periods **(2)** on burner start-up or when the flame is extinguished in operation:

- On start-up 5 seconds
- In operation 1 second

Where this is justified, longer safety periods may be permitted for burners with an oil throughput of up to 30 kg/h. Measure are to be taken to ensure that the safety period for the main flame is not prolonged by the action of the igniters (e.g. ignition burners).

7.8 The suitability of safety and monitoring devices (e.g. burner control box, flame monitoring device, automatic quick-closing device and limiters) for marine use have to be type approved and suitable for shipboard installation. See the requirements in A.2.

7.9 The tripping of the safety and monitoring devices has to be indicated by visual and audible alarms at the control panel of the heat generator, engine control room and another appropriate site.

7.10 The electrical interlocking of the firing system following tripping by the safety and monitoring devices is only to be cancelled out at the firing system control panel.

7.11 A warning notice is to be fitted in a prominent position at local manual control station of each oil burners. The warning notice shall specify that burners operated with manual or local overrides in use are only to be ignited after sufficient purging of the furnace and of any additional precautions required when operating in this condition.

(2) *The safety period is the maximum permitted time during which fuel oil may be supplied to the combustion space in the absence of a flame.*

8. Design and Construction of Burners (3)

8.1 The type and design of the burner and its atomizing and air turbulence equipment shall ensure virtually complete combustion.

8.2 Oil burners are to be so designed and constructed that personnel cannot be endangered by moving parts. This applies particularly to blower intake openings. The latter are also to be protected to prevent the entry of drip water.

8.3 Burners, which can be retracted or pivoted out of position, are to be automatically interlocked that they cannot be operated, when they are retracted or pivoted. A catch is to be provided to hold the burner in the swung out position.

8.4 Steam atomizers have to be fitted with appliances to prevent fuel oil entering the steam system.

(3) *For the purpose of these Rules, the following definitions apply:*

"Fully automatic oil burners" are burners equipped with automatic igniters, automatic flame monitors and automatic controls so that the ignition, flame monitoring and burner start-up and shutdown are effected as a function of the controlled variable without the intervention of operating personnel.

"Semi-automatic oil burners" are burners equipped with automatic igniters, automatic flame monitors and automatic controls. Burner start-up is initiated manually. Shutdown may be initiated manually. Burner shutdown is not followed by automatic re-ignition.

"Manually operated oil burners" are burners where every ignition sequence is initiated and carried through by hand. The burner is automatically monitored and shut down by the flame monitor and by limiters where required by the safety system. Re-starting can only be carried out directly at the burner and by hand.

8.5 Where an installation comprises several burners supplied with combustion air by a common fan, each burner is to be fitted with a shutoff device (e.g. a flap). Means are to be provided for retaining the shutoff device in position and its position shall be indicated.

8.6 Every burner is to be equipped with an igniter. The ignition operation is to be initiated immediately after purging. In the case of low-capacity burners of monoblock type (permanently coupled oil pump and fan) ignition may begin with start-up of the burner unless the latter is located in the roof of the chamber.

8.7 Where burners are blown through following shutdown, provision must be made for the safe ignition of the residual oil ejected.

8.8 In systems where oil is fed to the burners by gravity, duplex filters are to be fitted in the supply pipeline to the burners and so arranged that one filter can be opened up when the other is in use.

8.9 A starting-up oil fuel unit, including an auxiliary heater and hand pump, or other suitable starting-up device, which does not require power from shore, is to be provided.

8.10 Equipment used, especially pumps and shut-off devices, shall be suitable for the particular application and the fuel oils in use.

9. Purging of Combustion Chamber and Flues, Exhaust Gas Ducting

9.1 The combustion chamber and flues are to be adequately purged with air prior to every burner start-up. A warning sign is to be mounted to this effect.

9.2 Arrangements are to be such that furnace prepurging is completed prior to any burner ignition sequence. The purge time is to be based on a minimum of 4 air changes of the combustion chamber, furnace and uptake spaces. The purge timing is to take account of the air flow rate and the sequence is not to commence until all air registers and dampers, as applicable, are fully open and the forced draft fans are operating.

9.3 A threefold renewal of the total air volume of the combustion chamber and the flue gas ducts up to the funnel inlet is considered sufficient. Normally purging shall be performed with the total flow of combustion air for at least 15 seconds. It shall, however, in any case be performed with at least 50% of the volume of combustion air needed for the maximum heating power of the firing system.

9.4 Bends and dead corners in the exhaust gas ducts are to be avoided.

Dampers in uptakes and funnels should be avoided. Any damper which may be fitted is to be so installed that no oil supply is possible when the cross-section of the purge line is reduced below a certain minimum value. The position of the damper has to be indicated at the boiler control platform.

9.5 Where dampers or similar devices are fitted in the air supply duct, care has to be taken to ensure that air for purging the combustion chamber is always available unless the oil supply is necessarily interrupted.

9.6 Where an induced-draught fan is fitted, an interlocking system shall prevent start-up of the firing equipment before the fan has started. A corresponding interlocking system is also to be provided for any flaps which may be fitted to the funnel opening.

10. Electrical Equipment

Electrical equipment and its degree of protection have to comply with the **BCS** requirements of Chapter 5, Electrical Installations.

High voltage igniters have to be sufficiently safe against unauthorized operation.

11. Testing

11.1 Test at the manufacturer's shop

For burners for heat generators the following examinations have to be performed at the manufacturer's shop and are to be proven by **BCS** Approval Certificate:

- Visual inspection and completeness check,
- Pressure test of the oil preheater, if available, and required by design
- Pressure test of the burner,
- Insulation resistance test,
- High voltage test,
- Functional test of the safety related equipment.

11.2 Tests on board

The installation on board is to be subjected to operational tests including, in particular, determination of the purging time required prior to burner start-up. Satisfactory combustion at all the load settings and the reliable operation of the safety equipment are to be checked.

11.2.1 After installation a pressure and tightness test of the fuel system including fittings has to be performed, see Section 16, B.4.

11.2.2 The system including the switchboard installed at the heat generator on board the vessel has to be function tested as follows, especially the required purging time has to be identified and manual operation has to be demonstrated.

- Completeness check for the required components of the equipment,
- Functional test of all safety relevant equipment,
- Functional test of the burner control box,
- Identification of maximum and minimum burner power,
- Identification of flame stability on start-up, at maximum and at minimum burner power under consideration of combustion chamber pressure. Unspecified pressure changes are not permitted.
- Proof regarding required purging of flues and safety times,

- Proof regarding combustion properties like CO₂ –, possibly O₂ –, CO – volumetric content and soot number at minimum, mean and maximum power, in case of statutory requirements.
- In case the oil burner is operated with different fuel oils, the proper change-over to another fuel oil quality and especially the safe operation of the flame monitoring, the quick closing devices and the preheater, if existing are to be checked.

The correct combustion at all settings as well as function of safety equipment has to be verified. An Approval Certificate of **BCS** regarding examination at the manufacturer's shop is to be presented to **BCS** during functional testing.

11.3 Burners according to A.1.2 do not require an examination at manufacturer's shop.

Those are to be functional tested, with special regard to the safety related equipment, on board the vessel in presence of the **BCS** Surveyor.

11.4 It is to be demonstrated to the **BCS** Surveyor's satisfaction during trials that burner shut-off times due to flame failure comply with the following requirements, and details of the procedures and means used to set this time interval are to be submitted for consideration:

- The time interval at burner start up between the burner oil fuel valve being opened and then closed in the event of flame failure is to be long enough to allow a stable flame to be established and detected under normal operational circumstances, but is to be set to minimise the quantity of oil fuel delivered to the furnace and the possibility of subsequent damage as a result of unintended ignition.
- The time interval between flame failure detection and closing of burner oil fuel valve is to be long enough to prevent shutdown due to incorrect detection of a flame failure under normal operational circumstances, but is to be set to minimise the quantity of unburned oil fuel delivered to the furnace and the possibility of subsequent damage as a result of unintended ignition.

11.5 After installation, the pressurized fuel oil system is to be subjected to a pressure and tightness test; see Section 16, B.4.

C. Oil Burners for Hot Water Heaters, Oil-Fired Heaters and Small Heating Appliances

1. Atomizer Burners

1.1 Fully and semi-automatic atomizer burners must meet the requirements of TS/EN 267 or must be recognized as equivalent. Adequate purging by means of a fan must be ensured prior to each ignition effected by the controls. In general, a purging period of at least 5 seconds may be deemed sufficient. Where the flue gas ducting is unfavourable, the purging time is to be extended accordingly.

1.2 Electrical equipment items and their type of enclosure must comply with the requirements of **BCS** - Electrical Installations . High -voltage igniters must be adequately protected against unauthorized interference.

1.3 Where dampers or similar devices are mounted in the air supply line, care must be taken to ensure that air is available in all circumstances for purging the combustion space.

1.4 Pivoted oil burners may be swivelled out only after the fuel oil has been cut off. The high-voltage ignition equipment must likewise be disconnected when this happens.

1.5 The plant must also be capable of being shut down by means of an emergency switch located outside the space in which the plant is installed.

2. Evaporation burners

2.1 The burner design (e.g. dish or pot-type burner) must ensure that the combustion of the fuel oil is as complete as possible at all load setting. At the maximum oil level and with all possible angles of inclination of the ship (see Section 1, C.1) no fuel oil may spill from the combustion vessel or its air holes. Parts of the equipment important for the operation, monitoring and cleaning of the plant must be readily accessible.

2.2 Burners must be fitted with regulators ensuring a virtually constant flow of fuel oil at the selected setting. A safety device is required to prevent the oil in the combustion vessel from rising above the maximum permitted level. The regulators must function reliably despite all the movements and inclinations of the ship at sea.

2.3 Burners are normally to be equipped with a blower to ensure a sufficient supply of combustion air. Should the blower fail, the oil supply must be cut off automatically. Heating equipment with burners not supplied by a blower may only be installed and operated in the spaces mentioned in A.1 provided a supply of air adequate to maintain trouble-free combustion is guaranteed.

3. Oil-Fired Heaters

3.1 Oil-fired heaters having an evaporation burner without blower may be installed in the spaces mentioned in A.1 only if their thermal capacity does not exceed 42,000 kJ per hours. They may only be operated, however, if items of equipment with high air consumption such as internal combustion engines or air compressors do not draw air from the same space.

Compliance is to be ensured by an appropriate directive in the operating instructions and by a warning sign fixed to such heaters. Attention is also to be drawn to the danger of blowbacks when the burner is reignited in the hot heater.

3.2 Oil-fired heaters must comply with the requirements of DIN EN 1 and be tested

and approved accordingly, or must be recognized as equivalent. Control and safety equipment must ensure the safe and reliable operation of the burner despite the movements and inclinations which occur when the ship is at sea.

3.3 Smoke tubes and uptakes must have a cross-section at least equal to that of the flue gas duct on the heater and must follow as direct a path as possible. Horizontal flue gas ducts are to be avoided.

Funnel (stack) outlets are to be fitted with safety appliances (e.g. Meidinger discs) to prevent downdraughts.

4. Small Oil-Fired Heaters for Heating Air

4.1 Depending on their mode of operation, the requirements set out in items C.1 to C.3 apply in analogous manner to these units.

Equipment which does not entirely meet the requirements of the standards mentioned can be allowed provided that its functional safety is assured by other means, e.g. by the explosion-proofing of the combustion chamber and flue gas ducts.

4.2 Heating ducts are to be competently installed in accordance with the manufacturer's installation and operating instructions, and reductions in cross-section, throttling points and sharp bends are to be avoided so as not to incur the danger of the equipment overheating. A thermostatic control must shut the appliance down in the event of overheating.

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A. General**1. Scope**

These requirements apply to the design, testing, and certification of pipe lines and pumping systems, whether they are pressurized or not, including pumps, pipes, tubes, hoses, valves, fittings such as elbows, flanges, glands, filters and collectors etc. which are necessary for the operation of the main propulsion plant together with its auxiliaries and equipment. The requirements in this section are to be applied the metallic or non-metallic pipe lines and pumping system.

The requirements also apply to piping systems used in the operation of the ship whose failure could directly or indirectly impair the safety of ship or cargo, and to piping systems which are dealt with the requirements in other Sections.

The cargo handling and transfer pumping systems and pipe lines in all tankers for the carriage of flammable, toxic, corrosive or otherwise hazardous liquids are additionally subject to the provisions of the relevant requirements in Section 20.

Chemical cargo and process piping are excluded from the scope of the present requirement.

Gas welding equipment is subject to the "Guidelines for the Design, Equipment and Testing of Gas Welding Equipment on Seagoing Ships".

2. Documents for Approval

2.1 The following drawings/ documents/ information for the plastic pipes, fittings and joints are to be submitted for approval in triplicate:

- Specifications for the plastic piping, including thermal and mechanical properties and chemical resistance, production details and confirmed international standards or relevant accepted standards by **BCS**,
- Certificates and reports for relevant test previously carried out, documentation verifying the certification of the

manufacturer's quality system and that the system addresses the testing requirements,

- The booklet of standard details, containing standard practices to be used in the construction of the vessel, typical details of such items as bulkhead, deck and shell penetrations, welding details, pipe joint details, etc.
- Machinery space arrangement, including location of fuel oil tanks,
- Intended services, installation locations, pipe and fitting dimensions, and spacing of pipe supports, all relevant design drawings, catalogues, data sheets, calculations and functional descriptions,
- Fully detailed sectional assembly drawings denoting pipes, joints and fittings.
- Piping systems relating to the operation of internal combustion engines,
- Piping systems relating to the operation of steam turbine and steam generating plants,
- Other piping systems, such as hydraulic piping system, pneumatic piping system, oxygen-acetylene piping system, etc.,
- Ballast system,
- Bilges and gravity drains piping systems, and piping systems serving tanks (other than cargo tanks);
- Boiler feed water and condensate systems,
- Compressed air system,
- Cooling water systems,
- Exhaust piping (for boilers, incinerators and engines),
- Transfer and processing system of fuel oil including storage tank arrangements, drip trays and drains,

- Transfer and processing system of lubricating oil including storage tank arrangements, drip trays and drains,
- Helicopter refueling system, fuel storage tank and its securing and bonding arrangements, see Section 18, O,
- Sanitary system,
- Sea water systems,
- Vent, overflow and sounding arrangements,
- Steam piping analyses (as applicable),
- Tank venting and overflow systems,
- All Class I and Class II piping systems not covered above,
- Fire extinguishing systems, which are provided in Section 18.

2.2 Cargo piping systems and other piping systems specific to specialized vessel types are to be specially considered by **BCS** for approval.

2.3 Diagrammatic plans of the piping system in 2.1 are to be included following information and details necessary for approval.

- Terms and definitions, used in this section,
- Types, sizes, nominal diameter, wall thickness, inner diameter, roughness or friction factor or pressure loss per unit length of the plastic pipe,
- Maximum internal and external working pressure, working temperature range,
- Material properties, resin type, catalyst and accelerator types and concentration employed in the case reinforced polyester resin pipes or hardeners where epoxide resins are employed, full information regarding the type of gel-coat or thermoplastic liner employed during construction, cur/post-cure conditions, cure and post cure temperatures and durations

employed for given resin/reinforcement ratio, winding angle, orientation, joint bonding procedures,

- Details of marking, legends for symbols used, manufacturer's directions, installation instructions, serviceable life,
- Properties of intended fluids, i.e., flashing point of flammable fluids, limits of flow rates, maximum pump pressures and/or relief valve settings,
- Electrical conductivity and earthing details,
- Level of fire encurance,
- Instrumentation and control,

2.4 Essential components of the piping system, their technical details and manufacturing standards are to be approved by **BCS** for certification requirements.

2.5 The booklet of standard details must contain standard practices to be used in the construction of the vessel, typical details of such items as bulkhead, deck and shell penetrations, welding details, pipe joint details, etc. This information may be included in the approved system plans in 2.1, if desired.

2.6 For remotely controlled valves, the following plans and documents shall be submitted for approval:

- Diagrammatic plans of the piping system,
- Arrangements of the control and command assemblies, actuator mechanism,
- Power supply system confirming the requirements in Chapter 5 - Electrical Installation.

2.7 For steam lines with working temperatures more than 400°C, the corresponding stress calculations together with isometric data are to be submitted.

3. Pipe Classes

Pipes are to be manufactured according to the International Standards approved by **BCS** and made of materials given in Figure 16.1.

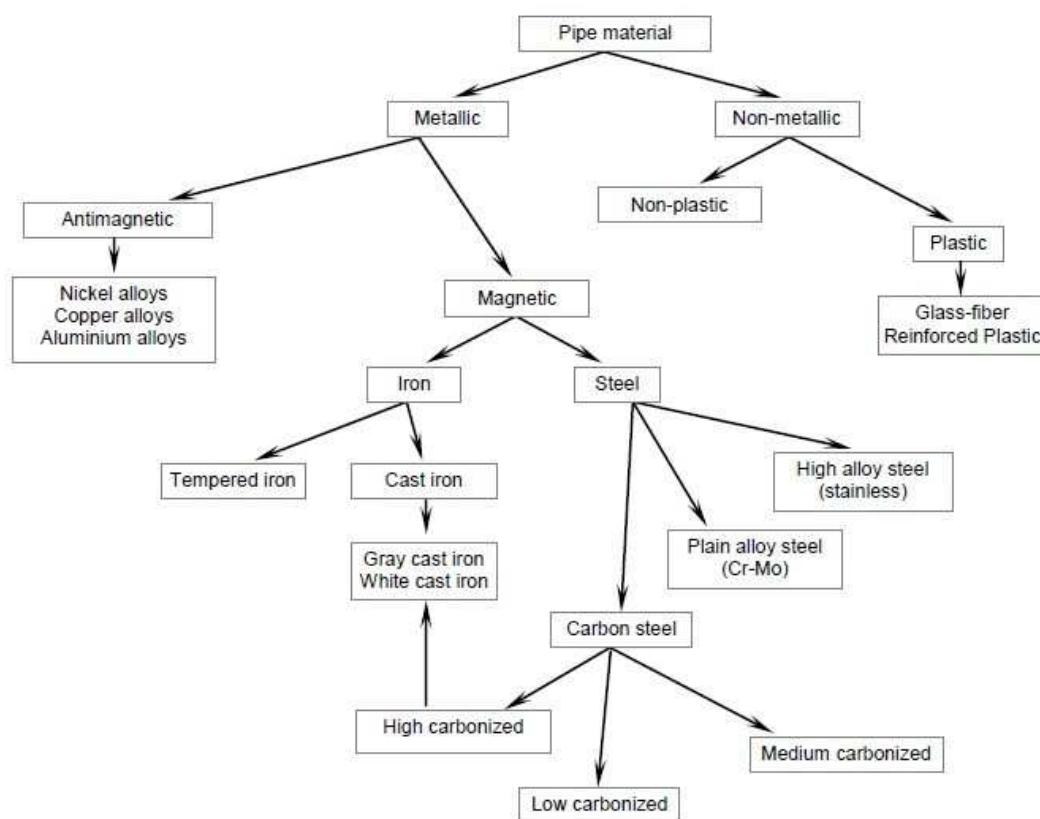


Figure 16.1 Material of pipes

Table 16.1 Classification of piping systems

Type of piping system	PR (Design pressure, bars), t (Design temperature, °C)		
	Pipe class - I	Pipe class - II	Pipe class - III
Toxic media	all	-	-
Corrosive media	all	(1)	-
Inflammable media with service temperature above the flash point	all	(1)	-
Inflammable media with a flash point below 60°C or less	all	(1)	-
Liquefied gases (LG)	all	(1)	-
Steam	PR > 16 or t > 300	7 < PR ≤ 16 170 < t ≤ 300	PR ≤ 7 and t ≤ 170
Thermal oil	PR > 16 or t > 300	7 < PR ≤ 16 150 < t ≤ 300	PR ≤ 7 and t ≤ 150
Liquid fuels, lubricating oil, inflammable hydraulic fluid	PR > 16 or t > 150	7 < PR ≤ 16 60 < t ≤ 150	PR ≤ 7 and t ≤ 60
Air, gas Non-flammable hydraulic fluid Boiler feedwater, condensate Seawater and fresh water for cooling Brine in refrigerating plant	PR > 40 or t > 300	16 < PR ≤ 40 200 < t ≤ 300	PR ≤ 16 and t ≤ 200
Cargo pipelines for oil tankers	-	-	all
Cargo and venting lines for gas and chemical tankers	all	-	-
Refrigerants	-	all	-
Open-ended pipelines (without shut-off), e.g. drains, venting pipes, overflow lines and boiler blowdown lines	-	-	all

(1) Classification in Pipe Class II is possible if special safety arrangements are available and structural safety precautions are arranged.

Piping systems are divided into three classes according to service, design pressure and temperatures as indicated in Table 16.1. Each class has specific requirements for joint design, fabrication and testing. The requirements in this regard are given in this section for all type of metallic piping except B.2.6. Specified requirements for plastic pipes are given in B.2.6.

B. Materials and Testing

1. General

Materials must be suitable for the proposed application and comply with the **BCS's** Rules for Materials. In case of especially corrosive media, **BCS** may impose special requirements on the materials used. For welds, see Rules for Welding of Pressure Vessels, Piping and Machinery Components (Section 14). For the materials used for pipes and valves for steam boilers and thermal oil system, see Section 12 and 13.

Materials with low heat resistance (melting point below 925 °C) are not acceptable for piping systems and components where fire may cause outflow of flammable liquids, flooding of any watertight compartment or destruction of watertight integrity. Deviations from this requirement will be considered on a case by case basis.

Materials other than steel may be assessed in relation to the risk of fire associated with the component and its installation (e.g. engine, turbine and gearbox installations). The use of materials other than steel is considered acceptable for the following applications:

1.1 Internal pipes which cannot cause any release of flammable fluid onto the machinery or into the machinery space in case of failure, or

1.2 Components that are only subject to liquid spray on the inside when the machinery is running, such as machinery covers, rocker box covers, camshaft end covers, inspection plates and sump tanks. It is a condition that the pressure inside these components and all the elements contained therein is less than 0,18 N/mm² and that wet sumps have a volume not exceeding 100 litres, or

1.3 Components attached to machinery which

satisfy fire test criteria according to Standard ISO 19921:2005/19922:2005 or other standards acceptable to the Administration, and which retain mechanical properties adequate for the intended installation.

2. Materials

2.1 Material manufacturers

Pipes, elbows, fittings, valve casings, flanges and semi-finished products intended to be used in pipe class I and II are to be manufactured by **BCS** approved manufacturers.

For the use in pipe class III piping systems an approval according to other recognized standards may be accepted.

2.2 Pipes, valves and fittings of steel

Pipes belonging to Classes I and II are to be either seamless drawn or fabricated by a welding procedure approved by **BCS**. In general, carbon and carbon - manganese steel pipes, valves and fittings are not to be used for temperatures above 400 °C. However, they may be used for higher temperatures provided that their metallurgical behavior and their strength property according to C.2.3 after 100,000 hours of operation are in accordance with national or international regulations or standards and if such values are guaranteed by the steel manufacturer.

Otherwise, special alloy steel pipes, valve and fittings should be employed according to **BCS's** Rules for Materials.

Consideration is to be given to the possibility of graphite formation in the following steels:

- Carbon steel above 425°C,
- Carbon-molybdenum steel above 470°C,
- Chrome-molybdenum steel (with chromium under 0.60%) above 525°C,
- Ferrous materials used in piping systems operating at lower than -18°C are to have adequate notch toughness properties.

Other alloy steels not mentioned here are to confirm the requirements in **BCS** Rules of Materials for approval.

2.3 Pipes, valves and fittings of copper and copper alloys

Pipes of copper and copper alloys are to be of seamless drawn material or fabricated by a method approved by **BCS**. Copper pipes for Classes I and II must be seamless.

Copper and copper alloys are not to be used for the fluids having a temperature greater than the following limits:

- Copper-nickel alloys 300°C,
- High temperature bronze 260°C,
- Copper and aluminium brass 200°C,

2.4 Pipes, valves and fittings of nodular cast iron

Pipes, valves and fittings of nodular ferritic cast iron according to the Rules for Materials may be accepted for bilge, ballast and cargo pipes within double bottom tanks and cargo tanks and for other purposes approved by **BCS**. In special cases (applications corresponding in principle to classes II and III) and subject to the **BCS**'s special approval, valves and fittings made of ferritic nodular cast iron may be accepted for temperatures up to 350 °C. Nodular ferritic cast iron for pipes, valves and fittings fitted on the ship's side must comply with the **BCS**'s Rules for Materials (see also Rule 22 of the 1966/1988 Load Line as amended).

2.5 Pipes, valves and fittings of lamellar-graphite cast iron (grey cast iron)

Pipes, valves and fittings of grey cast iron may be accepted by the **BCS** for Class III. Pipes of grey cast iron may be used for cargo pipe lines within cargo tanks of tankers.

Pipes, valves and fittings of grey cast iron may be used for cargo lines on the weather deck of oil tankers up to a working pressure of 16 bar.

Ductile materials are to be used for cargo hose connections and distributor headers. This applies also to the hose connections of fuel and lubricating oil filling lines.

The use of grey cast iron is not allowed:

- In cargo lines on chemical tankers (see Section 20),
- For valves fitted on the collision bulkhead,
- For sea valves and pipes fitted on the ship sides,
- For pipes, valves and fittings for media having temperatures above 220°C
- For pipelines subject to water hammer, severe stresses or vibrations,
- For valves fitted on the outside of fuel oil, lubricating oil, cargo oil and hydraulic oil tanks where subjected to a static head of oil,
- For relief valves.

The use of grey cast iron for other service will be subject to special consideration by **BCS**.

2.6 Production and application of plastic piping systems on ships

For terms and conditions, BCS-R P4 apply.

The requirements in this section deal with the plastic pipes apply to all piping and piping systems independent of service or location. However, the plastic pipes may be used after special approval by **BCS**.

For testing and applications 2010 FTP CODE requirements and IMO Resolution A.753(18), as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95), is to be fulfilled.

2.6.1 Material properties and manufacturing methods of plastic pipes are to be approved by **BCS** to be used for marine applications. Plastics pipes are produced of following material compositions, separately or combined:

- Elastomers (entirely elastic structured),

- Thermoplastics (solid under ambient atmospheric conditions, but can be re-shaped by heat treatment),
- Thermosets (permanently solid, cannot be melted or re-shaped after cured due to the resin based additives),

Thermoset plastics are applicable for coating, moulding or glass-fiber reinforced.

Glassfiber Reinforced Plastic (GRP) pipes approved the requirements in this section are accepted by **BCS** to be used in marine applications.

2.6.2 Plastic piping systems including valves, fittings, connecting pieces etc. are to be designed and manufactured according to the recognized standards and be subjected by the manufacturer to a continuous **BCS** approved quality control.

Piping systems and pipe lines made of plastic material including pipes, valves, fittings, connecting pieces, whether reinforced or not, must have **BCS** type approval certificate to be used in marine applications.

The following documents apply to type approval certificate by **BCS**:

- Durability and tightness test results against to the design pressure and design temperature, and performance characteristics and response for surrounding and/or contained chemical medium previously carried out by the manufacturer,
- National and international standards and codes about plastic pipes applied to the design and manufacturing stages,
- Plans, drawings, documents including design calculations and functional descriptions,
- Documentation verifying manufacturer's quality management system,

- Detailed sectional assembly drawings of piping components.

2.6.3 Approved plastic piping system shall also meet the following additional performance guidelines of **BCS**:

2.6.3.1 The piping should have sufficient strength to take account of the most severe coincident conditions of pressure, temperature, the weight of the piping itself and any static and dynamic loads imposed by the design or environment.

2.6.3.2 For the purpose of assuring adequate robustness for all piping including open ended piping (e.g. overflows, vents and open-ended drains), all pipes should have a minimum wall thickness to ensure adequate strength for use on board ships, also to withstand loads due to transportation, handling, personnel traffic, etc. This may require the pipe to have additional thickness than otherwise required by service considerations

2.6.3.3 The performance requirements for any component of a piping system such as fittings, joints, and method of joining are the same as those requirements for the piping system they are installed in.

2.6.4 Pipe penetrations through watertight bulkheads and decks as well as through fire divisions are to be approved by **BCS**. Plastic pipes are only approved to be used for piping system.

Dependent on the application and installation location specific means respectively additional flame tests may be required.

2.6.5 Design pressures for plastic pipes

2.6.5.1 Internal pressure

The hydrostatic test results guiding time-to-failure analysis of both thermoplastic and reinforced thermosetting/resin pipe under constant internal pressure are to be submitted to **BCS** for approval.

The hydrostatic tests confirming the ASTM D1598 standard are to be carried out under the following conditions:

- Atmospheric pressure of 0.1 MPa,
- Relative humidity of 30%
- Fluid temperature of 25 °C

Plastic piping systems shall be designed for an internal pressure not less than the maximum working pressure to be expected under operating conditions or the highest set pressure of any safety valve or pressure relief device on the system, if fitted.

Hoop stress in the pipe specimens is calculated using equations (approximation) for the hoop stress, as follows:

$$\sigma_{\text{hoop}} = \frac{p_{\text{int}} (d_a - s)}{2 \cdot s}$$

Where:

σ_{hoop} = Hoop stress [N/mm²]

p_{int} = Internal pressure, [MPa],

d_a = Measured average outside diameter, [mm].
For reinforced thermosetting pipe, outside diameter shall not include nonreinforced covers,

s = Measured minimum wall thickness, [mm].
For reinforced thermosetting pipe use minimum reinforced wall thickness.

Maximum allowable hydrostatic pressure, P_{int} , for plastic pipes is not to be greater than

$$P_{\text{int}} = \frac{2 \cdot s \cdot \sigma_{\text{hoop}}}{d_a - s}$$

The nominal internal pressure, P_{int} , for a plastic pipe is to be the lesser of the followings:

$$P_{\text{int}} \leq \frac{P_{\text{sth}}}{4} \quad \text{or} \quad P_{\text{int}} \leq \frac{P_{\text{lt}}}{2.5}$$

Where:

P_{sth} = Short-term hydrostatic test failure pressure,

P_{lt} = Long-term hydrostatic test failure pressure (> 100,000 hours).

These long and short term hydrostatic failure pressures can be found by a combination of prototype testing and calculation. Due to the length of time stipulated for the long term test it is expected that testing will be carried out to a suitable standard, such as ASTM D2837 and ASTM D1598. These standards allow tests to be carried out over a shorter period of time and the results extrapolated. It should be remembered that the nominal internal pressure may need to be adjusted to take account of results obtained from ageing tests, and a further allowance will also have to be made where a high maximum service temperature is envisaged.

2.6.5.2 External pressure

(for any installation which may be subject to vacuum conditions inside the pipe or a head of liquid acting on the outside of the pipe; and for any pipe installation required to remain operational in case of flooding damage, as per Regulation II-1/8-1 of SOLAS 1974 Convention, as amended, or for any pipes that would allow progressive flooding to other compartments through damaged piping or through open ended pipes in the compartments).

Piping should be designed for an external pressure not less than the absolute pressure acting on the outside of pipe, i.e., the sum of the maximum potential head of liquid outside the pipe, plus full vacuum pressure of 0.1 MPa.

The nominal external pressure for a pipe should be determined by dividing the collapse test pressure by a safety factor of 3. The collapse test pressure should be verified experimentally or by a combination of testing and calculation methods which are to be submitted to **BCS** for approval.

$$P_{\text{ext}} \leq \frac{P_{\text{coll}}}{3}$$

In no case is the collapse external pressure to be less than 0.3 MPa.

The maximum working external pressure is a sum of the vacuum inside the pipe and a head of liquid acting on the outside of the pipe.

Notwithstanding the requirements of 2.6.5.1 or 2.6.5.2 above as applicable, the pipe or pipe layer minimum wall thickness is to follow recognized standards. In the absence of standards for pipes not subject to external pressure, the requirements of 2.6.5.2 above are to be met.

The maximum permissible working pressure is to be specified with due regard for maximum possible working temperatures in accordance with Manufacturer's recommendations.

In systems pumping fresh water and sea water, pressure and temperature limits shall not exceed 1 MPa and 60°C.

Depending upon the intended application, **BCS** reserves the right to require the hydrostatic pressure testing of each pipe and/or fitting.

2.6.6 Axial strength

The sum of the longitudinal stresses due to pressure, weight and other dynamic and sustained loads should not exceed the allowable stress in the longitudinal direction. Forces due to thermal expansion, contraction and external loads, where applicable, are to be considered when determining longitudinal stresses in the system.

In the case of fibre reinforced plastic pipes, the sum of the longitudinal stresses shall not exceed one-half of the nominal circumferential stress derived from the maximum internal pressure determined according to paragraph 2.6.5. The permissible longitudinal stress is to be verified experimentally or by a combination of testing and calculation methods.

2.6.7 Temperature

Plastic piping system shall meet the design requirements of these guidelines over the range of service temperatures it will experience.

The minimum heat distortion/deflection temperature should not be less than 80°C. This minimum heat distortion temperature requirement is not applicable to pipes and pipe components made of thermoplastic materials, such as polyethylene (PE), polypropylene (PP), polybutylene (PB) and intended for nonessential services.

The maximum working temperature should be at least 20°C lower than the minimum heat distortion/deflection temperature (determined according to ISO 75 method A, or equivalent, e.g. ASTM D648) of the resin or plastic material.

Where low temperature services are considered, special attention is to be given with respect to material properties.

2.6.8 Fire endurance

2.6.8.1 Pipes and their associated fittings whose integrity is essential to the safety of ships, including plastic piping required by SOLAS II-2, Reg. 21.4 to remain operational after a fire casualty, are required to meet the minimum fire endurance requirements of Appendix 1 or 2, as applicable, of IMO Res. A.753(18), as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95).

2.6.8.2 Depending on the capability of a piping system to maintain its strength and integrity, there exist three different levels of fire endurance for piping systems.

2.6.8.2.1 Level 1. Piping having passed the fire endurance test specified in Appendix 1 of IMO Res. A.753(18), as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95) for a duration of a minimum of

one hour without loss of integrity in the dry condition is considered to meet level 1 fire endurance standard (L1). Level 1W – Piping systems similar to Level 1 systems except these systems do not carry flammable fluid or any gas and a maximum 5% flow loss in the system after exposure is acceptable (L1W).

2.6.8.2.2 Level 2. Piping having passed the fire endurance test specified in Appendix 1 of IMO Res. A.753(18), as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95) for a duration of a minimum of 30 minutes in the dry condition is considered to meet level 2 fire endurance standard (L2).

Level 2W – Piping systems similar to Level 2 systems except a maximum 5% flow loss in the system after exposure is acceptable (L2W).

2.6.8.2.3 Level 3. Piping having passed the fire endurance test specified in Appendix 2 of IMO Res. A.753 (18) for a duration of a minimum of 30 minutes in the wet condition is considered to meet level 3 fire endurance standard (L3).

2.6.8.3 Permitted use of piping depending on fire endurance, location and piping system is given in Table 16.2 “Fire Endurance Requirement Matrix”.

2.6.8.4 For Safe Return to Port purposes (SOLAS II-2, Reg.21.4), plastic piping can be considered to remain operational after a fire casualty if the plastic pipes and fittings have been tested to L1 standard.

2.6.9 Test method for fire endurance testing of plastic piping

Plastic pipes are tested according to IMO Resolution A.753(18) Guidelines for the application of plastic pipes on ships appendix 1, appendix 2, appendix 3 as amended by MSC.313(88) and MSC.399(95).

See BCS- R P 4.7 for the Type Approval of plastic pipes.

2.6.10 Ageing

Before selection of a piping material, the manufacturer should confirm that the environmental effects including but not limited to ultraviolet rays, saltwater exposure, oil and grease exposure, temperature, and humidity, will not degrade the mechanical and physical properties of the piping material below the values necessary to meet these guidelines. The manufacturer should establish material ageing characteristics by subjecting samples of piping to an ageing test acceptable to **BCS** and then

confirming its physical and mechanical properties by the performance criteria in these guidelines. For the acceptance and validity of the determination of the age of pipe by pipe manufacturer, the experimental method applied for this purpose should be approved by **BCS**.

The criteria of the acceptable ageing performance for the plastic pipes is that there is a linear relationship between the magnitude of the chemical or optical drawbacks the pipe material will be exposed to and the decrease of the mechanical and physical properties of the pipe.

In every situation, age of the plastic pipe shall not be less than 25 years.

2.6.11 Fatigue

In cases where design loadings incorporate a significant cyclic or fluctuating component, fatigue should be considered in the material selection process and be taken into account in the installation design and be approved by **BCS**.

In addressing material fatigue, the designer may rely on experience with similar materials in similar service or on laboratory evaluation of mechanical test specimens. However, the designer is cautioned that small changes in the material composition may significantly affect fatigue behaviour.

Table 16.2 Fire endurance requirement matrix for different piping systems

Piping Systems		Location (13)										
		A	B	C	D	E	F	G	H	I	J	K
Cargo (Flammable cargoes f.p. < 60°C)												
1	Cargo lines	NA	NA	L1	NA	NA	0	NA	0(10)	0	NA	L1(2)
2	Crude oil washing lines	NA	NA	L1	NA	NA	0	NA	0(10)	0	NA	L1(2)
3	Vent lines	NA	NA	NA	NA	NA	0	NA	0(10)	0	NA	X
Inert Gas												
4	Water seal effluent line	NA	NA	0(1)	NA	NA	0(1)	0(1)	0(1)	0(1)	NA	0
5	Scrubber effluent line	0(1)	0(1)	NA	NA	NA	NA	NA	0(1)	0(1)	NA	0
6	Main line	0	0	L1	NA	NA	NA	NA	NA	0	NA	L1(6)
7	Distribution lines	NA	NA	L1	NA	NA	0	NA	NA	0	NA	L1(2)
Flammable Liquids (f.p. > 60°C)												
8	Cargo lines	X	X	L1	X	X	NA(3)	0	0(10)	0	NA	L1
9	Fuel oil	X	X	L1	X	X	NA(3)	0	0	0	L1	L1
10	Lubricating	X	X	L1	X	X	NA	NA	NA	0	L1	L1
11	Hydraulic oil	X	X	L1	X	X	0	0	0	0	L1	L1
Seawater (1)												
12	Bilge main and branches	L1(7)	L1(7)	L1	X	X	NA	0	0	0	NA	L1
13	Fire main and water spray	L1	L1	L1	X	NA	NA	NA	0	0	X	L1
14	Foam system	L1 W	L1 W	L1 W	NA	NA	NA	NA	NA	0	L1 W	L1 W
15	Sprinkler system	L1 W	L1 W	L3	X	NA	NA	NA	0	0	L3	L3
16	Ballast	L3	L3	L3	L3	X	0(10)	0	0	0	L2 W	L2 W
17	Cooling water, essential services	L3	L3	NA	NA	NA	NA	NA	0	0	NA	L2 W
18	Tank cleaning services fixed machines	NA	NA	L3	NA	NA	0	NA	0	0	NA	L3(2)
19	Non essential systems	0	0	0	0	0	NA	0	0	0	0	0
Fresh Water												
20	Cooling water, essential services	L3	L3	NA	NA	NA	NA	0	0	0	L3	L3
21	Condensate return	L3	L3	L3	0	0	NA	NA	NA	0	0	0
22	Non essential systems	0	0	0	0	0	NA	0	0	0	0	0
Sanitary/Drains/Scuppers												
23	Deck drains (internal)	L1W(4)	L1W(4)	NA	L1W(4)	0	NA	0	0	0	0	0
24	Sanitary drains (internal)	0	0	NA	0	0	NA	0	0	0	0	0
25	Scuppers and dischargers (overboard)	0(1,8)	0(1,8)	0(1,8)	0(1,8)	0(1,8)	0	0	0	0	0(1,8)	0
Sounding/Air												
26	Water tanks/ dry spaces	0	0	0	0	0	0(10)	0	0	0	0	0
27	Oil tanks (f.p.> 60°C)	X	X	X	X	X	X(3)	0	0(10)	0	X	X

Piping Systems		Location (13)										
		A	B	C	D	E	F	G	H	I	J	K
Miscellaneous												
28	Control air	L1(5)	L1(5)	L1(5)	L1(5)	L1(5)	NA	0	0	0	L1(5)	L1(5)
29	Service air (non essential)	0	0	0	0	0	NA	0	0	0	0	0
30	Brine	0	0	NA	0	0	NA	NA	NA	0	0	0
31	Auxiliary low pressure steam < 7 bar)	L2W	L2W	0(9)	0(9)	0(9)	0	0	0	0	0(9)	0(9)
32	Central vacuum cleaners	NA	NA	NA	0	NA	NA	NA	NA	0	0	0
33	Exhaust gas cleaning system effluent line	L3(1)	L3(1)	NA	NA	NA	NA	NA	NA	NA	L3 (1,11) NA	NA
34	Urea transfer/supply system (SCR installations)	L1(12)	L1(12)	NA	NA	NA	NA	NA	NA	0	L3 (11) NA	0

Table 16.2 Fire endurance requirement matrix for different piping systems (continued)

Abbreviation

L1 Fire endurance test (appendix 1) of IMO Resolution A.753(18), as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95)) in dry conditions, 60 min.

L1W Fire endurance test

L2 Fire endurance test (appendix 1) of IMO Resolution A.753(18), as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95)) in dry conditions, 30 min.

L2W Fire endurance test

L3 Fire endurance test (appendix 2) of IMO Resolution A.753(18), as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95)) in wet conditions, 30 min.

0 No fire endurance test required.

NA Not applicable

X Metallic materials having a melting point greater than 925 °C.

Location

A Machinery spaces of Category A

B Other machinery spaces and pump rooms

C Cargo pump rooms

D Ro-ro cargo holds

E Other dry cargo holds

F Cargo tanks

G Fuel oil tanks

H Ballast water tanks

I Cofferdams void spaces pipe tunnel and ducts

J Accommodation service and control spaces

K Open decks

Footnotes:

- (1) *Where non-metallic piping is used, remotely controlled valves to be provided at ship's side. These valves are to be controlled from outside the space.*
- (2) *Remote closing valves to be provided at the cargo tanks.*
- (3) *When cargo tanks contain flammable liquids with a flash point >60°C. "O" may replace "NA" or "X".*
- (4) *For drains serving only the space concerned, "O" may replace "LIW".*
- (5) *When controlling functions are not required by statutory requirements or guidelines, "O" may replace "LI".*
- (6) *For pipe between machinery space and deck water seal, "O" may replace "LI".*
- (7) *For passenger vessels, "X" is to replace "LI".*
- (8) *Scuppers serving open decks in positions 1 and 2, as defined in regulation 13 of the International Convention on Load Lines, 1966, should be "X" throughout unless fitted at the upper end with the means of closing capable of being operated from a position above the freeboard deck in order to prevent downflooding.*
- (9) *For essential services, such as fuel oil tank heating and ship's whistle, "X" is to replace "O".*
- (10) *For tankers where compliance with paragraph 3.6 of regulation 19 of Annex I of MARPOL 73/78 as amended, is required, "NA" is to replace "O".*
- (11) *L3 in service spaces, NA in accommodation and control spaces.*
- (12) *Type Approved plastic piping without fire endurance test (0) is acceptable downstream of the tank valve, provided this valve is metal seated and arranged as fail-to-closed or with quick closing from a safe position outside the space in the event of fire.*
- (13) *For Passenger Ships subject to SOLAS II-2, Reg.21.4 (Safe return to Port), plastic pipes for services required to remain operative in the part of the ship not affected by the casualty thresholds, such as systems intended to support safe areas, are to be considered essential services. In accordance with MSC Circular MSC.1/Circ.1369, interpretation 12, for Safe Return to Port purposes, plastic piping can be considered to remain operational after a fire casualty if the plastic pipes and fittings have been tested to LI standard.*

2.6.12 Erosion resistance

In the cases where fluid in the system has high flow velocities, abrasive characteristics or where there are flow path discontinuities producing excessive turbulence the possible effect of erosion should be considered. If erosion cannot be avoided then adequate measures should be taken such as increased wall thickness, special liners, change of materials, etc.

2.6.13 Impact Resistance

Plastic pipes and joints are to have a minimum resistance to impact not less than specified at National and International Standards recognized by **BCS**.

After the impact resistance test the specimen is to be subjected to hydraulic test with pressure equal to 2.5 times the design pressure for at least 1 hour. If a leakage is determined, then it is concluded that there is no impact resistance.

2.6.14 Electrical conductivity

2.6.14.1 Electrostatic charges can be generated on the inside and outside of plastic pipes. The plastic piping systems carrying fluids capable of generating electrostatic charges (static accumulators) inside the pipe. The plastic pipes passing throughout hazardous areas (i.e. areas that could, either in normal or fault conditions, contain an explosive atmosphere), are to be connected with each other through internal gas outside the pipe. The resulting sparks can create punctures through pipe walls leading to leakage of pipe contents, or can ignite surrounding explosive atmospheres.

2.6.14.2 In practice, fluids with conductivity less than 1,000 pico Siemens per metre (pS/m) are considered to be non-conductive and therefore capable of generating electrostatic charges. Refined products and distillates fall into this category and piping used to convey these liquids should therefore

be electrically conductive. Fluid with conductivity greater than 1,000 pS/m are considered to be static non-accumulators and can therefore be conveyed through pipes not having special conductive properties when located in non hazardous areas.

2.6.14.3 Regardless of the fluid being conveyed, plastic piping should be electrically conductive if the piping passes through a hazardous area.

2.6.14.4 Where conductive piping is required, the resistance per unit length of the pipe, bends, elbows, fabricated branch pieces, etc., should not exceed $1 \times 10^5 \text{ Ohm/m}$.

It is preferred that pipes and fittings be homogeneously conductive. Pipes and fittings having conductive layers may be accepted subject to the arrangements for minimizing the possibility of spark damage to the pipe wall being satisfactory. Satisfactory earthing should be provided.

The resistance to earth from any point in the piping system should not exceed $1 \times 10^6 \text{ Ohm}$.

Fluids with conductivity greater than 1,000 pS/m are considered to be static non-accumulators and can therefore be conveyed through pipes not having special conductive properties when located in non hazardous areas.

After completion of the installation, the resistance to earth should be verified. Earthing wires should be accessible for inspection.

2.6.15 Fluid absorption

Absorption of fluid by the piping material should not cause a reduction of mechanical and physical properties of the material below that required by these guidelines.

The fluid being carried or in which the pipe is immersed should not permeate through the wall of the pipe. Testing for fluid absorption characteristics of the pipe material should be to a recognized standard by **BCS**.

2.6.16 Material compatibility

The piping material should be compatible with the fluid being carried or in which it is immersed such that its design

strength does not degenerate below that recognized by these guidelines. Where the reaction between the pipe material and the fluid is unknown, the compatibility should be demonstrated to **BCS** for approval.

2.6.17 Flame spread

2.6.17.1 All pipes, except those fitted on open decks and within tanks, cofferdams, void spaces, pipe tunnels and ducts if separated from accommodation, permanent manned areas and escape ways by means of an A class bulkhead are to have low flame spread characteristics not exceeding average values listed in Appendix 3 of IMO Resolution.753(18), as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95).

2.6.17.2 Surface flame spread characteristics are to be determined using the procedure given in the 2010 FTP Code, Annex 1, Part 5 with regard to the modifications due to the curvilinear pipe surfaces as also listed in Appendix 3 of IMO Resolution A.753(18), as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95).

2.6.17.3 Surface flame spread characteristics may also be determined using the test procedures given in ASTM D635, or in other national equivalent standards. Under the procedure of ASTM D635 a maximum burning rate of 60 mm/min applies. In case of adoption of other national equivalent standards, the relevant acceptance criteria are to be defined.

2.6.18 Smoke generation

2010 FTP CODE annex 1, part 2 requirements with the modifications listed in Appendix 3 of IMO Resolution A.753(18), as amended by as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95), is to be fulfilled.

Criteria for smoke production need only be applied to pipes within the accommodation, service, and control spaces.

A fire test procedure is being developed and when finalized and appropriate smoke obscuration criteria have been recommended, this test will be incorporated into these guidelines. In the meantime, an absence of

this test, the usage of plastics needs the special approval by **BCS**.

2.6.19 Toxicity

2010 FTP CODE annex 1, part 2 requirements with the modifications listed in Appendix 3 of IMO Resolution A.753(18), as amended by as amended by IMO Res. MSC. 313(88) and IMO Res. MSC. 399(95), is to be fulfilled.

Toxicity testing is still being investigated and criteria developed. Before meaningful conclusions can be made, further experimentation and testing is needed. In the absence of a toxicity test, the usage of plastics needs the special approval by **BCS**.

2.6.20 Fire protection coatings

2.6.20.1 Where a fire protective coating of pipes and fittings is necessary for achieving the fire endurance standards required, the following requirements apply:

- Pipes should be delivered from the manufacturer with the protective coating on in which case on-site application of protection would be limited to what is necessary for installation purposes (e.g. joints). Alternatively pipes may be coated on site in accordance with the approved procedure for each combination, using the approved materials of both pipes and insulations.
- The liquid absorption properties of the coating and piping should be considered. The fire protection properties of the coating should not be diminished when exposed to saltwater, oil or bilge slops. **BCS** should be satisfied that the coating is resistant to products likely to come in contact with the piping.
- Fire protection coatings should not degrade due to environmental effects over time, such as ultraviolet rays, saltwater exposure, temperature and humidity. Other areas to consider are thermal expansion, resistance against vibrations, and elasticity. Ageing of

the fire protection coatings should be demonstrated to the satisfaction of **BCS** in a manner consistent with the ageing test specified above.

- The adhesion qualities of the coating should be such that the coating does not flake, chip, or powder, when subjected to an adhesion test approved by **BCS**.
- The fire protection coating should have a minimum resistance to impact to the satisfaction of **BCS**.

Pipes should be an appropriate distance from hot surfaces in order to be adequately insulated.

2.6.20.2 Special testing may be required as part of the approval procedure.

2.6.21 Installation

2.6.21.1 Supports

Selection and spacing of pipe supports in shipboard systems are to be determined as a function of allowable stresses and maximum deflection criteria. Support spacing is not to be greater than the pipe Manufacturer's recommended spacing. The selection and spacing of pipe supports are to take into account pipe dimensions, length of piping, mechanical and physical properties of the pipe material, mass of pipe and contained fluid, external pressure, operating temperature, thermal expansion effects, loads due to external forces, thrust forces, water hammer, vibrations, maximum accelerations to which the system may be subjected, and the type of support. The support spans are also to be checked for combination of loads.

Each support is to evenly distribute the load of the pipe and its contents over the full width of the support and be designed to minimize wear and abrasion.

Heavy components in the piping system such as valves and expansion joints are to be independently supported.

2.6.21.2 Expansion

Suitable provision is to be made in each pipeline to allow for relative movement between pipes made of plastics and the steel structure, having due regard to:

- The difference in the coefficients of thermal expansion;
- Deformations of the ship's hull and its structure.

When calculating the thermal expansions, account is to be taken of the system working temperature and the temperature at which assembling is performed.

2.6.21.3 External loads

Where applicable, allowance is to be made for temporary point loads. Such allowances are to include at least the force exerted by a load (person) of 100 kg at midspan on any pipe of more than 100 mm nominal outside diameter.

Pipes are to be protected from mechanical damages where necessary.

2.6.21.4 Strength of connections

The requirements for connections are the same as those requirements for the piping system in which they are installed. Pipes may be assembled using adhesive-bonded, flanged or mechanically coupled joints.

To qualify joint bonding procedures, the tests and examinations specified herein should be successfully completed.

The procedure for making bonds should include: all materials and supplies, tools and fixtures, environmental requirements, joint preparation, dimensional requirements and tolerances, cure time, cure temperature, protection of work, tests and examinations and acceptance criteria for the completed test assembly.

Adhesives, when used for joint assembly, are to be suitable for providing a permanent seal between the pipes and fittings throughout the temperature and pressure range of the intended application.

Tightening of flanged or mechanically coupled joints is to be performed in accordance with the manufacturer's instructions.

2.6.22 Penetrations of fire divisions

Where "A" or "B" class divisions are penetrated for the passage of plastic pipes, arrangements are to be made to ensure that the fire resistance is not impaired. These arrangements are to be tested in accordance with Recommendations for fire test procedures for "A" "B" and "F" bulkheads 2010 FTP Code, annex 1, part 3.

2.6.23 Penetrations of watertight bulkheads and decks

Where plastic pipes pass through watertight bulkheads or decks, the watertight integrity and strength integrity of the bulkhead or deck is to be maintained. For pipes not able to satisfy the requirements in 2.6.5.2, a metallic shut-off valve operable from above the freeboard deck should be fitted at the bulkhead or deck.

If the bulkhead or deck is also a fire division and destruction by fire of the plastic pipes may cause the inflow of liquids from tanks, a metallic shut-off valve operable from above the freeboard deck should be fitted at the bulkhead or deck.

2.6.24 Methods of repair

At sea, the pipe material should be capable of temporary repair by the crew, and the necessary materials and tools kept on board.

Permanent repairs to the piping material should be capable of exhibiting the same mechanical and physical properties as the original base material. Repairs carried out and tested under supervision of **BCS** Surveyor.

2.6.25 Installation of conductive pipes

2.6.25.1 In piping systems for fluids with conductivity less than 1000 pico siemens per metre (pS/m) such as refined products and distillates use is to be made of conductive pipes.

2.6.25.2 Regardless of the fluid being conveyed, plastic piping is to be electrically conductive if the piping passes through a hazardous area. The resistance to earth from any point in the piping system is not to exceed 1×10^6 Ohm. It is preferred that pipes and fittings be homogeneously conductive. Pipes and fittings having conductive layers are to be protected against a possibility of spark damage to the pipe wall. Satisfactory earthing is to be provided.

2.6.25.3 After completion of the installation, the resistance to earth is to be verified. Earthing wires are to be accessible for inspection.

2.6.26 Application of fire protection coatings

2.6.26.1 Fire protection coatings are to be applied on the joints, where necessary for meeting the required fire endurance as for 2.6.20, after performing hydrostatic pressure tests of the piping system.

2.6.26.2 The fire protection coatings are to be applied in accordance with Manufacturer's recommendations, using a procedure approved in each particular case.

2.6.27 Control during installation

2.6.27.1 Installation is to be in accordance with the Manufacturer's guidelines.

2.6.27.2 Prior to commencing the work, joining techniques are to be approved by BCS.

2.6.27.3 The tests and explanations specified in this subitem are to be completed before shipboard piping installation commences.

2.6.27.4 The personnel performing this work are to be properly qualified and certified to the satisfaction of BCS

2.6.27.5 The procedure of making bonds is to include:

- materials used,
- tools and fixtures
- joint preparation requirements,
- cure temperature,
- dimensional requirements and tolerances, and
- tests acceptance criteria upon completion of the assembly

2.6.27.6 Any change in the bonding procedure which will affect the physical and mechanical properties of the joint is to require the procedure to be requalified.

2.6.28 Bonding procedure quality testing

2.6.28.1 A test assembly is to be fabricated in accordance with the procedure to be qualified and it is to consist of at least one pipe-to-pipe joint and one pipe-to-fitting joint.

2.6.28.2 When the test assembly has been cured, it is to be subjected to a hydrostatic test pressure at a safety factor 2,5 times the design pressure of the test assembly, for not less than one hour. No leakage or separation of joints is allowed. The test is to be conducted so that the joint is loaded in both longitudinal and circumferential directions.

2.6.28.3 Selection of the pipes used for test assembly, is to be in accordance with the following:

- When the largest size to be joined is 200 mm nominal outside diameter, or smaller, the test assembly is to be the largest piping size to be joined.
- When the largest size to be joined is greater than 200 mm nominal outside diameter, the size of the test assembly is to be either 200 mm or 25% of the largest piping size to be joined, whichever is greater.

2.6.28.4 When conducting performance qualifications, each bonder and each bonding operator are to make up

test assemblies, the size and number of which are to be as required above.

2.6.29 Testing after installation on board

Plastic piping systems for essential services are to be subjected to a test pressure not less than 1.5 times the design pressure of the system. The test pressure shall not be less than 4 bar.

Piping systems for non-essential services are to be checked for leakage under operational conditions.

For piping required to be electrically conductive, the resistance to earth is to be checked. Earthing wires should be accessible for inspection.

2.6.30 Test specification for plastic pipes

2.6.30.1 Scope

This item contains requirements for the Type Approval of plastic pipes. It is applicable to rigid pipes, piping systems, including pipe joints and fittings, made predominately of other material than metal.

2.6.30.2 Documentation

The following information for the plastic pipes, fittings and joints is to be submitted for consideration and approval:

2.6.30.2.1 General information

- Pipe and fitting dimensions
- Maximum internal and external working pressure
- Working temperature range
- Intended services and installation locations
- The level of fire endurance
- Electrically conductive
- Intended fluids
- Limits on flow rates
- Serviceable life
- Installation instructions
- Details of marking

2.6.30.2.2 Drawings and supporting documentation

- Certificates and reports for relevant tests previously carried out.
- Details of relevant standards
- All relevant design drawings, catalogues, data sheets, calculations and functional descriptions.
- Fully detailed sectional assembly drawings showing pipe, fittings and pipe connections.

2.6.30.2.3 Materials (as applicable)

- The resin type
- Catalyst and accelerator types, and concentration employed in the case of reinforced polyester resin pipes or hardeners where epoxide resins are employed
- A statement of all reinforcements employed where the reference number does not identify the mass per unit area or the tex number of a roving used in a filament winding process, these are to be detailed.
- Full information regarding the type of gel-coat or thermoplastic liner employed during construction, as appropriate
- Cure/post-cure conditions. The cure and post cure temperatures and times employ resin/reinforcement ratio
- Winding angle and orientation
- Joint bonding procedures and qualification tests results, see 2.6.27.5.

2.6.30.3 Testing

Testing is to demonstrate compliance of the pipes, fittings and joints for which Type Approval is sought with item 2.6.

Pipes, joints and fittings are to be tested for compliance with the requirements of standards acceptable to **BCS**.

2.7 Aluminium and aluminium alloys

Aluminium and aluminium alloys must comply with the **BCS** 's Rules Chapter 2 - Material and may in individual cases, with the agreement of **BCS**, be used for

temperatures up to 200°C. They are not acceptable for use in fire extinguishing lines.

2.8 Application of materials

For the pipe classes mentioned in A.3 materials must be applied according to Table 16.3.

3. Material Tests

3.1 For piping systems belonging to class I and II, tests in accordance with the rules Chapter 2 - Material and under the **BCS**'s supervision are to be carried out in accordance with Table 16.5 for:

- Pipes, bends and fittings;
- Valve bodies and flanges,
- Valve bodies and flanges >DN 100 in cargo and process pipe lines gas tankers with design temperature <-55°C.

3.2 Welded joint in pipe lines of classes I and II are to be tested in accordance with the rules Chapter 3 - Welding.

Table 16.3 Approved materials

Material or application		Pipe classes		
		I	II	III
Steels	Pipes	Steel pipes above 300°C high-temperature below -10°C pipes made of steels with high/low temperature toughness, stainless steel pipes for chemicals	Pipes for general applications	Steel not subject to any special quality specification, weldability in accordance with Rules for Welding
	Forgings, plates, flanges, steel sections and bars	Steels suitable for the corresponding service and processing conditions, for temperatures > 300°C, high-temperature steels, for temperatures below -10°C, steels with high/low-temperature toughness		
	Bolts, nuts	Bolts for general machine construction, temperatures >300°C high temperature steels, below -10°C steels with high/low-temperature toughness	Bolts for general machine construction	
Castings (valves, fittings, pipes)	Cast steel	Cast steel above 300°C high temperature below -10°C cast steel with high/low-temperature toughness, for aggressive media stainless castings	Cast steel for general applications	
	Nodular cast iron	Only ferritic grades, elongation A ₅ at least 15%		
	Cast iron with lamellar graphite	-	-	Up to 220°C, gray cast iron is not permitted in valves and fittings on ship's side, on the collision bulkhead and on fuel and oil tanks and for relief valves.
Non-ferrous metals (valves, fittings, pipes)	Copper, copper alloys	In cargo lines on tank ships carrying chemicals only with special approval low-temperature copper nickel alloys by special agreement	For seawater and alkaline water only corrosion resistant copper and copper alloys	
	Aluminium, aluminium alloy	In cargo and processing lines on gas tankers	Only with the agreement of BCS up to 200°C, not permitted in fire extinguishing systems	
Non-metallic materials	Plastics	-	-	On special approval (see 2.6)

4. Hydraulic Tests for Pipes

4.1 Definitions

4.1.1 Maximum allowable working pressure, PB [bar], Formula symbol: $p_{e,perm}$

This is the maximum allowable internal or external working pressure for a component or piping system with regard to the materials used, piping design requirements, the working temperature and undisturbed operation.

4.1.2 Nominal pressure, PN [bar]

This is the term applied to a selected pressure temperature relation used for the standardization of structural components. In general, the numerical value of the nominal pressure for a standardized component made of the material specified in the standard will correspond to the maximum allowable working pressure PB at 20°C.

4.1.3 Test pressure, PP [bar], Formula symbol: p_p

This is the pressure to which components or piping systems are subjected for testing purposes.

4.1.4 Design pressure, PR [bar], Formula symbol: p_c

This is the maximum allowable working pressure PB for which a component or piping system is designed with regard to its mechanical characteristics. In general, the design pressure is the maximum allowable working pressure at which the safety equipment will interfere (e.g. activation of safety valves, opening of return lines of pumps, operating of overpressure safety arrangements, opening of relief valves) or at which the pumps will operate against closed valves. The design pressure for fuel pipes shall be chosen according to Table 16.4. Valves and fittings in piping systems are also to be compatible with the pipes to which they are attached in respect of their strength and are to be suitable for effective operation at the maximum working pressure they will experience in service.

Table 16.4 Design pressure for fuel pipes

Max. working temperature Max. working pressure	T ≤ 60°C	T > 60°C
PB ≤ 7 bar	3 bar or maximum working pressure, whichever is greater	3 bar or maximum working pressure whichever is greater
PB > 7 bar	Maximum working pressure	14 bar or maximum working pressure whichever is greater

4.2 Pressure test prior to installation on board

4.2.1 All Class I and II pipes as well as steam lines, feedwater pressure pipes, compressed air and fuel lines having a design pressure PR greater than 3,5 bar together with their integral fittings, connecting pieces, branches and bends, after completion of manufacture but before insulation and coating, is this is provided, shall be subjected to a hydraulic pressure test in the presence of the Surveyor at the following value of pressure:

$$p_p \leq 1.5 \cdot p_c \quad [\text{bar}]$$

where p_c is the design pressure.

Class III steam, boiler feed, compressed air and fuel oil pipes and their integral fittings, where the design pressure is greater than 3.5 bar, are to be hydrostatically tested to the test pressure p_c , as defined above.

For steel pipes and integral fittings where the design temperature is above 300°C, the test pressure p_p is to be determined by the following formula.

$$p_p = 1.5 \cdot \frac{\sigma_{perm}(100^\circ \text{C})}{\sigma_{perm}(t)} p_c \quad [\text{bar}]$$

Where;

$\sigma_{perm}(100^\circ)$ = Permissible stress at 100°C,

$\sigma_{perm}(t)$ = Permissible stress at design temperature.

The test pressure is to be determined by formula above, but need not exceed $2p_c$.

$$p_p \leq 2 \cdot p_c [\text{bar}]$$

With the approval of **BCS**, this test pressure may be reduced to $1.5p_c$, where it is necessary to avoid excessive stress in way of bends, T-pieces and other shaped components.

In no case is the membrane stress to exceed 90% of the yield stress or 0.2% of maximum elongation.

4.2.2 All valves intended for installation on the side shell at or below the deepest load waterline, including those at the sea chests, are to be hydrostatically tested in the presence of the **BCS** Surveyor, before installation, to a pressure of at least 5 bar.

4.2.3 Where for technical reasons it is not possible to carry out complete hydraulic pressure tests on all sections of piping before assembly on board, proposals are to be submitted to **BCS** for approval for testing pipe connections carried out on board, particularly in respect of welding seams.

4.2.4 Where the hydraulic pressure test of piping is carried out on board, these tests may be conducted in conjunction with the tests required in 4.3.

4.2.5 Pressure testing of pipes with less than DN15 may be omitted at **BCS**'s discretion depending on the application.

4.3 Test after installation on board

4.3.1 After assembly on board, all pipelines

covered by these requirements are to be subjected to a tightness test in the presence of a **BCS** Surveyor.

All piping systems are to be tested for leakage under working conditions after installation in the presence of the **BCS** Surveyor. Where necessary, other techniques of tightness test in lieu of a working pressure test may be considered.

Gas and liquid fuel systems and heating coils in tanks are to be hydrostatically tested in the presence of the Surveyor after installation to $1.5p_c$, but not less than 4 bars.

4.4 Pressure testing of valves

The following valves are to be subjected in the manufacturer's works to a hydraulic pressure test in the presence of a **BCS** Surveyor:

- Valves of pipe Classes I and II to $1.5 PR$,
- All valves intended for installation on the side shell at or below the deepest load waterline, including those at the sea chests, are to be hydrostatically tested in the presence of the Surveyor, before installation, to a pressure of at least 5 bar.

Shut-off devices are to be additionally tested for tightness with the nominal pressure. Shut-off devices for boilers, see Section 12, E.10.

5. Manufacturer's Tests, Heat Treatments and Non-Destructive Tests

Attention should be given to the workmanship in construction and installation of the piping systems according to the approved data in order to obtain the maximum efficiency in service. For details concerning structural tests and tests following heat treatments, see Chapter 2 - Material.

Table 16.5 Approved materials and types of certificates

Type of component	Approved materials	Design temperature	Pipe class	Nominal diameter DN	Type of material certificate according to EN 10204		
					3.2 (BCS)	3.1	2.2
Pipes (1), Pipe elbows, Fittings	Steel Copper, Copper alloys Aluminium Aluminium alloys Plastics	-	I	> 50 ≤ 50	x -	- x	- -
			II	> 50 ≤ 50	- -	x -	- x
			III	All	-	-	x
Valves (1), Flanges	Steel Cast steel, Nodular cast iron	> 300°C	I, II	DN > 100 DN ≤ 100	x -	- x	- -
	Copper Copper alloys	> 225°C					
	Steel Cast steel, Nodular cast iron	≤ 300°C	I, II	PBxDN > 2500 or DN > 250	x	-	-
				PBxDN ≤ 2500 or DN ≤ 250	-	x	-
	Steel Cast steel, Nodular cast iron Grey cast iron	-	III	All	-	-	x
	Copper Copper alloys	≤ 225°C	I, II	PBxDN > 1500	x	-	-
	Aluminium Aluminium alloys	≤ 200°C		PBxDN ≤ 1500	-	x	-
	Plastics	Acc. to Type Approval Certificate	III	All	-	-	x
Semi-finished products, Screws and other components	According to Table 16.3	-	I, II	-	-	x	-
			III	-	-	-	x
(1) Casing of valves and pipes fitted on the ship's side and bottom and bodies of valves fitted on collision bulkhead are to be included in pipe Class II.							

Table 16.6 Minimum wall thickness groups N, M and D of steel pipes and approved locations

Piping system	Location																
	Machinery spaces	Cofferdams/void spaces	Cargo holds	Ballast water tanks	Fuel and changeover tanks	Fresh cooling water tanks	Lubricating oil tanks	Hydraulic oil tanks	Drinking water tanks	Thermal oil tanks	Condensate & feedwater tanks	Accommodation	Cargo tanks, tank ships	Cofferdams, tank ships	Cargo pump rooms	Weather deck	
Bilge lines	M	M	M	D								M	X	M		-	
Ballast lines					D							X	(1)		M		
Seawater lines			D	M		X	X	X		X	X	M (2)			M		
Fuel lines	N			D	N								X				
Lubricating lines			-	X	X		N		X			X		-	-		
Thermal oil lines										N							
Steam lines				M	M	M	M	-				N	M		N	N	
Condensate lines											N						
Feedwater lines			M		X	X	X		X	X		X		X	X		
Drinking water lines				X				X	N			N					
Fresh cooling water lines					D	N	D					X	X	-	-		
Compressed air lines				M	M	M	M	N	X	N	X	N		N	N		
Hydraulic lines						X	X			X		X	N				
<p>(1) See Section 20.B.4.3</p> <p>(2) Seawater discharge lines, see T-Sewage System</p> <p>X Pipelines are not to be installed.</p> <p>(-) Pipelines may be installed after special agreement with BCS.</p>																	

C. Calculation of Wall Thickness and Elasticity

1. Minimum Wall Thickness

1.1 The pipe thickness stated in Tables 16.6÷16.9 is the assigned minimum thicknesses, unless due to stress analysis, see 2, greater thicknesses are necessary.

Provided that the pipes are effectively protected against corrosion, the wall thicknesses of group M and D stated in Table 16.7 may with the BCS's agreement be reduced by up to 1 mm, the amount of the reduction is to be in relation to the wall thickness.

The minimum thicknesses listed in Table 16.7 are the nominal wall thickness. No allowance needs to be made for negative tolerance or for reduction in thickness due to bending.

For threaded pipes, where approved, the thickness is to be measured to the bottom of the thread.

Protective coatings, e.g. hot-dip galvanizing, can be recognized as an effective corrosion protection provided that the preservation of the protective coating during installation is guaranteed.

For steel pipes the wall thickness group corresponding to the laying position is to be as stated in Table 16.6.

1.2 The minimum wall thicknesses for austenitic stainless steel pipes are given in Table 16.8.

1.3 For the minimum wall thickness of air, sounding and overflow pipes through weather decks, see R, Table 16.23.

For CO₂ fire extinguishing pipelines, see Section 18, Table 18.6.

1.4 Where the application of mechanical joints results in reduction in pipe wall thickness (bite type rings or other structural elements) this is to be taken into account in determining the minimum wall thickness.

2. Design Calculations

The following requirements apply for pipes where the ratio outside-diameter to inside-diameter does not exceed the value 1.7.

2.1 The following formula is to be used for calculating the wall thicknesses of cylindrical pipes and bends subject to internal pressure:

$$s = s_o + c + b \quad [\text{mm}] \quad (1a)$$

$$s_o = \frac{d_a \cdot p_c}{20 \cdot \sigma_{perm} \cdot v + p_c} \quad [\text{mm}] \quad (1a1)$$

s = Minimum thickness (See 2.7) [mm],

s_o = Calculated thickness [mm],

d_a = Outer diameter of pipe [mm],

p_c = Design pressure (see B.4.1.4), **(1)** [bar]

σ_{perm} = Maximum permissible design stress (see 2.3) [N/mm²],

b = Allowance for bends (see 2.2) [mm],

v = Weld efficiency factor (see 2.5) [-],

c = Corrosion allowance (see 2.6). [mm],

2.2 For straight cylindrical pipes which are to be bent, an allowance (b) shall be applied for the bending of the pipes. The value of (b) shall be such that the stress due to the bending of the pipes does not exceed the maximum permissible design stress (σ_{perm}). The allowance (b) can be determined as follows:

$$b = 0.4 \frac{d_a}{R} s_o \quad (1a2)$$

R = Bending radius [mm].

2.3 Permissible stress: σ_{perm}

2.3.1 Steel pipes

The permissible stress σ_{perm} to be considered in formula (1a1) is to be chosen as the lowest of the following values:

2.3.1.1 Design temperature $\leq 350^\circ\text{C}$

$\frac{R_{m,20^\circ}}{A}$ $R_{m,20^\circ}$ = Specified minimum tensile strength at room temperature.

$\frac{R_{eH,t}}{B}$ $R_{eH,t}$ = Specified minimum yield stress at design temperature,

or

$\frac{R_{p,0.2,t}}{B}$ $R_{p,0.2,t}$ = Minimum value of the 0.2 % proof stress at design temperature.

2.3.1.2 Design temperature $> 350^\circ\text{C}$, whereby it is to be checked whether the calculated values according to 2.3.1.1 give the decisive smaller value.

$\frac{R_{m,100000,t}}{B}$ $R_{m,100000,t}$ = Minimum stress to produce rupture in 100,000 hours at the design temperature t ,

$R_{p,1\%,100000,t}$ = Mean value of the stress to produce 1% creep in 100,000 hours at the design temperature t ,

(1) For pipes containing fuel heated above 60°C the design pressure is to be taken not less than 14 bar.

$R_{m,100000,(t+15)}$ = Average stress to produce rupture in 100,000 hours at the design temperature t plus 15°C (see 2.4)

In the case of pipes which:

- Are covered by a detailed stress analysis acceptable to **BCS**, and
- Are made of material tested by **BCS**, **BCS** may, on special application, agree to a safety factor B of 1.6 (for A and B see Table 16.11).

2.3.2 Pipes made of metallic materials without a definite yield point

Materials without a definite yield point are covered by Table 16.10. For other materials, the maximum allowable stress is to be stated with **BCS** agreement, but must be at least

$$\sigma_{perm} \leq \frac{R_{m,t}}{5}$$

where $R_{m,t}$ is the minimum tensile strength at the design temperature.

2.3.3 The mechanical characteristics of materials which are not included in Chapter 2 - Material are to be agreed with **BCS** with reference to Table 16.11.

Steel pipes without guaranteed properties may be used only up to a working temperature of 120°C where the maximum allowable stress $\sigma_{perm} \leq 80 \text{ N/mm}^2$ will be approved.

2.4 Design temperature

2.4.1 The design temperature is the maximum temperature of the medium inside the pipe. In case of steam pipes, filling pipes from air compressors and starting air lines to internal combustion engines, the design temperature is to be at least 200°C.

Table 16.7 Minimum wall thickness for steel pipes

Group N				Group M		Group D	
d_a [mm]	s [mm]	d_a [mm]	s [mm]	d_a [mm]	s [mm]	d_a [mm]	s [mm]
10.2	1.6	From 406.4	6.3	From 21.3	3.2	From 38.0	6.3
From 13.5	1.8	From 457.2	6.3	From 38.0	3.6	From 82.5	6.3
From 20.0	2.0	From 660.4	7.1	From 51.0	4.0	From 88.9	7.1
From 48.3	2.3	From 762.0	8.0	From 76.1	4.5	From 114.3	8.0
From 70.0	2.6	From 863.6	8.8	From 177.8	5.0	From 152.4	8.8
From 88.9	2.9	From 914.4	10.0	From 193.7	5.4	From 457.2	8.8
From 114.3	3.2			From 219.1	5.9		
From 133.0	3.6			From 244.5	6.3		
From 152.4	4.0			From 660.4	7.1		
From 177.8	4.5			From 762.0	8.0		
From 244.5	5.0			From 863.6	8.8		
From 298.5	5.6			From 914.4	10.0		

Table 16.8 Minimum wall thickness for austenitic stainless steel pipes

External Diameter d_a [mm]	Minimum Wall Thickness s [mm]
10.2 – 17.2	1.0
21.3 – 48.3	1.6
60.3 – 88.9	2.0
114.3 – 168.3	2.3
219.1	2.6
273.0	2.9
323.9 – 406.4	3.6
Over 406.4	4.0

Table 16.9 Minimum wall thickness for copper and copper alloy pipes

Outside Diameter d_a [mm]	Minimum Wall Thickness s [mm]	
	Copper	Copper Alloy
8 – 10	1.0	0.8
12 – 20	1.2	1.0
25 – 44.5	1.5	1.2
50 – 76.1	2.0	1.5
88.9 – 108	2.5	2.0
133 – 159	3.0	2.5
193.7 – 267	3.5	3.0
273 – 457.2	4.0	3.5
470	4.0	3.5
508	4.5	4.0

2.4.2 Design temperatures for superheated steam lines are as follows:

2.4.2.1 Pipes behind de-superheaters

- With automatic temperature control:
the working temperature **(2)** (design temperature)
- With manual control:
the working temperature +15°C **(2)**

2.4.2.2 Pipes before de-superheaters: the working temperature +15°C **(2)**

(2) Transient excesses in the working temperature need not be taken into account when determining the design temperature.

Table 16.10 Allowable stress, σ_{perm} for copper and copper alloy pipes (annealed)

Pipe material		Minimum tensile strength [N/mm²]	Allowable stress σ_{perm} [N/mm²]										
			50°C	75°C	100°C	125°C	150°C	175°C	200°C	225°C	250°C	275°C	300°C
Copper		215	41	41	40	40	34	27.5	18.5	-	-	-	-
Aluminium brass Cu Zn 20 Al		325	78	78	78	78	78	51	24.5	-	-	-	-
Copper nickel alloys	Cu Ni 5 Fe	275	68	68	67	65.5	64	62	59	56	52	48	44
	Cu Ni 10 Fe												
	Cu Ni 30 Fe	365	81	79	77	75	73	71	69	67	65.5	64	62

2.5 Weld efficiency factor, “v”

- For seamless pipes, $v = 1.0$

In the case of welded pipes, the value of v is to be equal to that assigned at the **BCS** acceptance test.

- For boiler pipes, $v = 0.6$

The value of weld efficiency factor v in pipes must be equal to **BCS**'s approval test value.

Table 16.11 Coefficients A, B for determining the allowable stress σ_{perm} .

Pipe Class Material	I		II, III	
	A	B	A	B
Unalloyed and alloyed carbon steel	2.7	1.6	2.7	1.8
Rolled and forged stainless steel	2.4	1.6	2.4	1.8
Steel with, $\sigma_{s,20^\circ} > 400$ N/mm ² (1)	3.0	1.7	3.0	1.8
Grey cast iron	-	-	11.0	-
Nodular cast iron	-	-	5.0	3.0
Cast steel	3.2	-	4.0	-
(1) Minimum yield strength or minimum 0.2 % proof stress at 20 °C.				

Table 16.12 Corrosion allowance “c” for carbon steel pipes

Type of piping system	Corrosion allowance c [mm]
Superheated steam lines	0.3
Saturated steam lines	0.8
Steam heating coils inside cargo tanks	2.0
Feedwater lines:	
- in closed circuit systems	0.5
- in open circuit systems	1.5
Boiler blow down lines	1.5
Compressed air lines	1.0
Hydraulic oil lines, lubricating oil lines	0.3
Fuel lines	1.0
Cargo oil lines	2.0
Refrigerant lines for Group 1 (1) refrigerants	0.3
Refrigerant lines for Group 2 (1) refrigerants	0.5
Seawater lines	3.0
Fresh water lines	0.8
(1) The refrigerants are classified by their explosion limit at atmosphere pressure and surrounding temperature to the groups 1, 2 and 3.	
Group 1: Refrigerants, which are not burning at any concentration when they are present in the air. Halogenated hydrocarbons are relatively non-flammable, non-toxic and non-explosive	
Group 2: Refrigerants, which mixture with air has a lower explosion limit of 3.5 % V/V as minimum. These refrigerants are either toxic or flammable. For example metil chloride and sulphur dioxide	
Group 3: Refrigerant, which mixture with air has a lower explosion limit of less than 3.5 % V/V. The lower explosion limit is calculated after certain standards, e. g. ANSI/ASTM E 681. These refrigerants are highly flammable and explosive ones like propane, propylene, ethane, ethylene, methane etc.	

2.6 Corrosion allowance, “c”

The corrosion allowance, *c*, depends on the application of the pipe, in accordance with Tables 16.12 and 16.13. With the agreement of **BCS**, the corrosion allowance of steel pipes effectively protected against corrosion may be reduced by not more than 50 %. With agreement of **BCS**, no corrosion allowance need be applied to pipes made of corrosion -resistant materials (e.g. austenitic steels and copper alloys) (see Tables 16.8 and 16.9). For pipes passing through tanks an additional corrosion allowance is to be considered according to the Table 16 .12 and depending on the external medium , in order to account for the external corrosion.

2.7 Tolerance allowance, “t”

The negative manufacturing tolerances on the thickness according to the standards of the technical terms of delivery are to be added to the minimum thickness *s* and specified as the tolerance allowance *t*. The value of *t* may be calculated as follows:

$$t = \frac{a}{100 - a} \cdot s_0 \quad [\text{mm}] \quad (1a3)$$

where;

a = Negative tolerance on the thickness (It can be taken % 12.5 for the calculations if there isn't a measured value) [%],

*s*₀ = Minimum thickness according to 2.1 [mm].

Table 16.13 Corrosion allowance, “c” for non-ferrous metals

Pipe material	Corrosion allowance <i>c</i> [mm]
Copper, brass and similar alloys	0.8
Copper-tin alloys except those containing lead	
Copper nickel alloys (with Ni ≥ 10 %)	0.5

3. Elasticity Analysis

3.1 The forces, moments and stresses caused by impeded thermal expansion and contraction are to be calculated for the following piping systems and the calculations submitted to **BCS** for approval:

- Steam pipes with working temperatures above 400°C;
-
- Pipes with working temperatures below - 110°C.

3.2 Only approved methods of calculation may be applied. The change in elasticity of bends and fittings due to deformation is to be taken into consideration. Procedure and principles of methods as well as the technical data are to be submitted for approval . **BCS** reserves the right to perform confirmatory calculations.

For determining the stresses, the hypothesis of the maximum shear stress is to be considered. The resulting comparison of stress of primary loads due to internal pressure and the dead weight of the piping system itself (gravitational forces) shall not exceed the maximum allowable stress according to 2.3. Equivalent stresses obtained by adding together the above-mentioned primary forces and the secondary forces due to impeded expansion or contraction shall not exceed the mean low cycle fatigue value or mean time yield limit in 100,000 hours whereby for fittings such as bends, T-connections, headers etc. approved stress increase factors are to be considered.

4. Fittings

Pipe branches may be dimensioned according to the equivalent surface areas method where an appropriate reduction of the maximum allowable stress as specified in 2.3 is to be proposed. Generally, the maximum allowable stress is equal to 70 % of the value according to 2.3 for pipes with diameters over than 300 mm. Below this figure, a reduction to 80 % is sufficient.

Where detailed stress measuring, calculations or type approvals are available, higher stresses can be permitted.

5. Flanges

Flange calculations by a recognized method and using the permitted stress specified in 2.3 are to be submitted if flanges do not correspond to a recognized standard, if the standards do not provide for conversion to working conditions or where there is a deviation from the standards.

Flanges in accordance with standards in which the value of the relevant stresses or the material are

specified may be used at higher temperatures up to the following pressure:

$$P_{\text{perm}} = \frac{\sigma_{\text{perm, standard}}}{\sigma_{\text{perm}}(t, \text{material})} \cdot P_{\text{standard}}$$

Where;

$\sigma_{\text{perm}}(t, \text{material})$ = Allowable stress according to 2.3
for proposed material at design
temperature t ,

$\sigma_{\text{perm standard}}$ = Allowable stress according to 2.3
for the material at the
temperature corresponding to
the strength data specified in the
standard.

P_{standard} = Nominal pressure PN specified
in the standard.

D. Principles for the Construction of Pipe Lines, Valves, Fittings and Pumps

1. General

1.1 Pipe lines are to be constructed and manufactured on the basis of standards generally used in shipbuilding and recognized by **BCS**.

1.1.1 Pipe marker labels shall contain text to identify pipe contents and use arrows to indicate flow direction.

1.1.2 Pipe marker labels shall either use different colored backgrounds or bands of colour on a solid neutral colored background to represent various pipe contents via a colour-coding scheme. Text labels shall be in all capital letters. Text labels shall appear in the centre of the pipe marker label or immediately adjacent to the colour band that identifies pipe contents

1.1.3 Arrows indicating flow direction on the pipe marker labels can be ordered with suitable colours representing the fluids according to ISO 14726.

1.1.4 The required dimensions of the pipe label format are given in Table 16.15.

1.1.5 Marker labels used for pipes up to 200 mm nominal size should be covered with black-colored wrap bands around.

1.1.6 Pipe marker labels should be placed at or near the inlet or outlet connection to equipment (for example, pumps, pressure vessels, filters), at the termination of a pipe run (for example, loading station, hose reels, at bulkhead penetration), and approximately every 5 meters on straight runs of pipe.

If the piping system is an open system, then pipe marker labels are placed on the inlet and outlet edges.

Table 16.14 Example colour coding scheme for vessel/structure piping

Main Colours	Medium
Black	Waste media (for example, wastewater, black water, gray water waste oil, exhaust gas)
Blue	Fresh water
Brown	Fuel
Green	Sea water
Gray	Non-flammable gases
Maroon	Masses/bulk materials (dry and wet)
Orange	Oils other than fuels
Silver	Steam
Red	Fire fighting and fire protection
Violet	Acids, alkalis
White	Air in ventilation system
Yellow-ochre	Flammable gases

Table 16.15 Pipe label format

Pipe nominal size (mm)	Length along pipe (mm)	Width around pipe (mm)	Character height (mm)
10 – 15	125	N/A	N/A
20 – 65	205	N/A	20
50 – 200	305	N/A	30
> 200	610	100	90

Pipe marker labels should be placed on both sides of a bulkhead, deck or deckhead penetration, unless the label is visible from both sides of the penetration.

On vertical pipes, pipe marker labels should be placed approximately 1800 mm. above the standing surface.

1.1.7 Where pipe marker labels are used on two or more pipes in a group of pipes located side by side, such as in a pipe rack, all of the pipe marker labels shall be installed side by side so they can be scanned at one time.

1.1.8 Pipe marker labels may be self-adhesive or the label can be painted directly on the pipe according to Table 16.15 Pipe Label Format.

Self-adhesive pipe marker labels shall be made from an abrasion – and chemical – resistant vinyl or polyester-type material.

Where the pipe marker label may be exposed to sunlight, the material shall be resistant to ultra-violet (UV) damage. The material shall be durable enough to resist fading, chipping, or cracking. Self adhesive labels shall adhere to themselves when wrapped around a pipe rather than adhere to the piping.

For fibreglass, copper-nickel materials, or other pipes for which self-adhesive pipe marker labels are not satisfactory, the text labels and flow arrows may be painted directly onto the pipe without the use of a colour band. For copper-nickel pipe material, the colour yellow or white is preferred for the text labels and flow arrows. For black, green, or red unpainted fibreglass pipe material, the colour white is preferred.

1.2 Welded connections rather than detachable couplings should be used for pipe lines carrying toxic media and inflammable liquefied gases as well as for superheated steam pipes with temperatures exceeding 400°C.

1.3 Expansion in piping systems due to heating and shifting of their suspensions caused by deformation of the ship are to be compensated by bends,

compensators and flexible pipe connections. The arrangement of suitable fixed points is to be taken into consideration.

1.4 Where pipes are protected against corrosion by special protective coatings, e.g. hot-dip galvanising, rubber lining etc., it is to be ensured that the protective coating will not be damaged during installation.

1.5 Protection against corrosion and erosion

1.5.1 Pipes are to be efficiently protected against corrosion, particularly in their most exposed parts, either by selection of their constituent materials, or by an appropriate coating or treatment.

1.5.2 The layout and arrangement of sea water pipes are to be such as to prevent sharp bends and abrupt changes in section as well as zones where water may stagnate. The inner surface of pipes is to be as smooth as possible, especially in way of joints. Where pipes are protected against corrosion by means of galvanising or other inner coating, arrangements are to be made so that this coating is continuous, as far as possible, in particular in way of joints.

1.5.3 If galvanised steel pipes are used for sea water systems, the water velocity is not to exceed 3 m/s.

1.5.4 If copper pipes are used for sea water systems, the water velocity is not to exceed 2 m/s.

1.5.5 Arrangements are to be made to avoid galvanic corrosion.

1.5.6 If aluminium brass pipes are used for sea water systems, the water velocity is not to exceed 3 m/s.

1.5.7 If 90/10 copper-nickel-iron pipes are used for sea water systems, the water velocity is not to exceed 3,5 m/s.

1.5.8 If 70/30 copper-nickel pipes are used for sea water systems, the water velocity is not to exceed 5 m/s.

1.5.9 If GRP pipes are used for sea water systems, the water velocity is not to exceed 5 m/s.

1.6 Protection from mechanical damage

Seawater pipes located in cargo holds and in other spaces where pipes may be subject to impacts (e.g. fish holds, chain lockers) are to be protected from mechanical damage.

2. Pipe Connections

The following pipe connections may be used:

- Fully penetrating butt welds with/without provision to improve the quality of the root,
- Socket and slip-on sleeve welds with suitable fillet weld thickness and where appropriate in accordance with recognized standards,
- Steel flanges may be used in accordance with the permitted pressures and temperatures specified in the relevant standards,
- Mechanical joints (e.g. pipe unions, pipe couplings, press fittings) of approved type.

2.1 Welded Connections

For welded pipe connections Table 16.16 contains summarized guidelines.

Table 16.16 Pipe connections

Types of connections	Pipe class	Outside diameter
Welded butt-joints with special provisions for root side	I, II, III	All
Welded butt-joints without special provisions for root side	II, III	
Socket and slip-on sleeve welded	III	
	I, II (1)	≤ 88.9
(1) Except piping systems conveying toxic media or services where fatigue, severe erosion or crevice corrosion is expected to occur.		

2.1.1 Butt welded joints, where complete penetration at the root is achieved, may be used for all classes of piping.

2.1.2 Welded butt-joints without special provisions for root side can only be used for pipe class II and III.

2.1.3 Socket welded joints using standard fittings may be used for Classes I and II piping up to and including 88.9 mm. outside diameter, except in toxic and corrosive fluid services or services where fatigue, severe erosion or crevice corrosion is expected to occur.

Socket welded joints using standard fittings may be used for Class III piping without limitation.

The fillet weld leg size is to be at least 1.1 times the nominal thickness of the pipe. See Figure 16.2.

The thicknesses of the sockets are to be in accordance with C.1.1, yet at least equal to the thicknesses of the pipes.

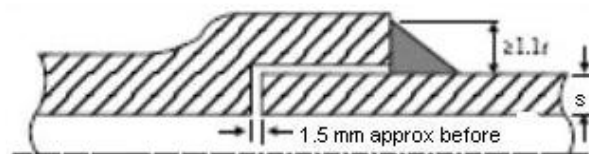


Figure 16.2 Typical Socket Weld Joint

2.1.4 Slip-on sleeve welded joints using standard fittings may be used for Classes I and II piping up to and including 88.9 mm. outside diameter, except in toxic and corrosive fluid services or services where fatigue, severe erosion or crevice corrosion is expected to occur.

Slip-on welded sleeve joints may be used for Class III piping without size limitation and approval of **BCS**

The requested dimensions for slip-on welded sleeve joints are shown in Figure 16.3.

The requirements for slip-on welded sleeve joints are:

- The inside diameter of the sleeve is not to exceed the outside diameter of the pipe by more than 2 mm.
- The depth of insertion of the pipe into the sleeve is to be at least 9.5 mm.

- The gap between the two pipes is to be at least 2 mm.

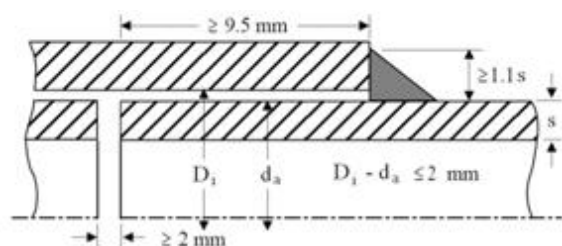


Figure 16.3 Typical Slip-on Welded Sleeve Joint

- The fillet weld leg size is to be at least 1.1 times the nominal thickness of the pipe.
- The thicknesses of the sleeves are to be in accordance with C.1.1, yet at least equal to the thicknesses of the pipes.

2.2 Flange connections

2.2.1 Dimensions of flanges and bolting shall comply with recognized standards and with Table 16.17.

Every type and dimension of flange and flange joints on Table 16.18 can be used in ships.

2.2.2 Gaskets are to be suitable for the intended media under design pressure and temperature conditions and their dimensions and construction shall be in accordance with recognized standards.

2.2.3 Steel flanges may be used as shown in Tables 16.17 and 16.18 in accordance with the permitted pressures and temperatures specified in the relevant standards.

2.2.4 Flanges made of non-ferrous metals may be used in accordance with the relevant standards and within the limits laid down in the approvals. Flanges and brazed or welded collars of copper and copper alloys are subject to the following requirements:

2.2.4.1 Welding neck flanges according to standard up to 200°C or 300°C according to the maximum temperatures indicated in Table 16.10; applicable to all classes of pipe,

2.2.4.2 Loose flanges with welding collar; as for 2.2.4.1,

2.2.4.3 Plain brazed flanges; only for pipe class III up to a nominal pressure of 16 bar and a temperature of 120°C.

2.2.5 Flange connections for pipe classes I and II with temperatures over 300 °C are to be provided with necked-down bolts.

2.3 Screwed socket connections

2.3.1 Screwed socket connections with parallel and tapered threads shall comply with requirements of recognized national or international standards.

Screwed socket connections are not permitted for piping systems conveying toxic or flammable media or services where fatigue, severe erosion or crevice corrosion is expected to occur

2.3.2 Screwed socket connections with parallel threads are permitted for pipes in class III with an outside diameter ≤ 60.3 mm. as well as for subordinate systems (e.g. sanitary and hot water heating systems).

2.3.3 Screwed socket connections with tapered threads are permitted for the following:

- Class I, outside diameter ≤ 33.7 mm.
 - Class II and III, outside diameter ≤ 60.3 mm.
- Screwed connections having tapered pipe threads complying with a recognized standard are not to be used for toxic and corrosive fluid services and for all services of temperatures exceeding 495°C.

2.4 Mechanical joints

2.4.1 Type approved mechanical joints may be used as shown in Tables 16.19, 16.20 and 16.21.

The number of mechanical joints in flammable fluid systems is to be kept to a minimum. In general, flanged joints conforming to recognised standards are to be used.

Piping in which a mechanical joint is fitted is to be adequately adjusted, aligned and supported. Supports or hangers are not to be used to force alignment of piping at the point of connection.

2.4.2 Where appropriate, mechanical joints are to be of fire resistant type as required by Table 16.20.

2.4.3 Mechanical joints, which in the event of damage could cause fire or flooding, are not to be used

in piping sections directly connected to the ship's side below the bulkhead deck of passenger ships and freeboard deck of cargo ships or tanks containing flammable liquids.

Table 16.17 Use of flange types

Pipe class	Toxic, corrosive and combustible media, liquefied gases (LG)		Steam, thermal oils		Lubricating oil, fuel oil	Other media	
	PR [bar]	Flange Type	Temperature [°C]	Flange type	Flange type	Temperature [°C]	Flange type
I	> 10 ≤ 10	A A, B (1)	> 400 ≤ 400	A A, B (1)	A, B	> 400 ≤ 400	A A, B
II	-	A, B, C	> 250 ≤ 250	A, B, C A, B, C, D, E	A, B, C, E (2)	> 250 ≤ 250	A, B, C A, B, C, D, E
III	-	-	-	A, B, C, D, E	A, B, C, E	-	A, B, C, D, E, F (3)
<p>(1) Type B only for $D_a < 150 \text{ mm}$</p> <p>(2) Type E only for $t < 150^\circ\text{C}$ and $PR < 16 \text{ bar}$</p> <p>(3) Type F only for water pipes and open-ended lines</p>							

2.4.4 The use of slip-on joints is not permitted in:

- Bilge lines inside ballast and fuel tanks,
- Seawater and ballast lines including air and overflow pipe inside cargo holds and fuel tanks,
- Piping system including sounding, vent and overflow pipes conveying flammable liquids as well as inert gas lines arranged inside machinery spaces of category A or accommodation spaces.
- Slip-on joints may be accepted in other machinery spaces provided that they are
- located in easily visible and accessible positions.
- Fuel and oil lines including air and overflow pipes inside machinery spaces, cargo holds and ballast tanks,
- Fire extinguishing systems which are not permanently water filled.

Slip-on joints inside tanks may be permitted only if the pipes and tanks contain a same medium. Usage of slip type slip-on joints as the main means of pipe connection is not permitted except for cases where compensation of axial pipe deformation is necessary.

2.4.5 Mechanical joints are to be tested to a burst pressure of 4 times the design pressure. For design pressures above 200 bar, the required burst pressure will be specially considered by **BCS**.

2.4.6 Requested convenient test by **BCS** for the mechanical joints are:

- Tightness test,
- Vibration (fatigue) test (where necessary),
- Pressure pulsation test (where necessary),
- Burst pressure test,
- Pull out test (where necessary),
- Fire endurance test (where necessary),

- Vacuum test (where necessary),
- Repeated assembly test (where necessary),
- See BCS- R P 2.11 for details of tests.

The installation of mechanical joints is to be in accordance with the manufacturer's assembly instructions. Where special tools and gauges are required for installation of the joints, these are to be supplied by the manufacturer.

3. Layout, Marking and Installation

3.1 Piping systems must be adequately identified according to their purpose. Valves are to be permanently and clearly marked.

3.2 Pipe penetrations leading through bulkheads, decks and tank walls must be water and oil tight. Bolts through bulkheads are not permitted. Holes for fastening screws are not to be drilled in the tank walls.

3.3 Sealing systems for pipe penetrations through watertight bulkheads and decks as well as through fire divisions which are not welded into the bulkhead or deck are to be approved by **BCS** (see Chapter 1 - Hull, Section 11). **(3)**

3.4 Piping systems close to electrical switchboards are to be so installed or protected that possible leakage cannot damage the electrical installation.

3.5 Piping systems are to be so arranged that they can be completely emptied, drained and vented. Piping systems in which the accumulation of liquids during operation could cause damage must be equipped with special drain arrangements.

3.6 Pipes lines laid through ballast tanks, which are coated in accordance with Chapter 1 - Hull, Section 22 are to be either effectively protected against corrosion or they are to be of low susceptibility to corrosion.

The protection method against corrosion of the tanks as well as that of the pipes must be compatible to each other.

3.7 The wall thickness of pipes between ship's

side and first shut-off device is to be in accordance with Table 16.23 column B. Pipes are to be connected by welding or by flanges.

4. Shut-off Devices

4.1 Shut-off devices must comply with a recognized standard. Valves with screwed-on covers are to be secured to prevent unintentional loosening of the cover.

4.2 Hand-operated shut-off devices are to be closed by turning in the clockwise direction.

4.3 Valves must be clearly marked to show whether they are in the open or closed position.

4.4 Change-over devices in piping systems in which a possible intermediate position of the device could be dangerous in service must not be used.

4.5 Valves are to be permanently marked. The marking must comprise at least the following details:

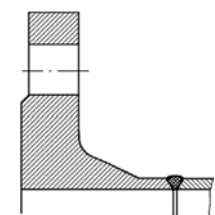
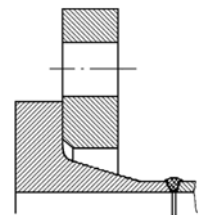


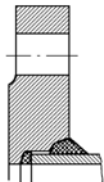
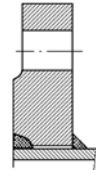
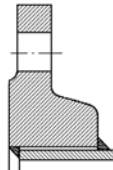
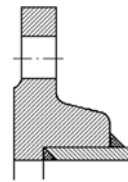
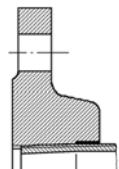
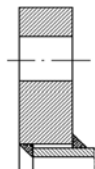
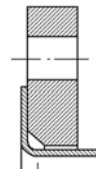
- Material of valve body,
- Nominal diameter,
- Nominal pressure.

4.6 The design pressure of valves intended for use onboard a vessel is to be at least the maximum pressure to which they will be subjected but at least 350 kPa.

Valves used in open-ended systems, except those attached to side shell, may be designed for pressure below 350 kPa. Such valves may include those in vent and drain lines, and those mounted on atmospheric tanks which are not part of the pump suction or discharge piping (e.g., level gauges, drain cocks, and valves in inert gas and vapour emission control system).

(3) *Regulations for the Performance of Type Tests, Part 3 – Test Requirements for Sealing Systems of Bulkhead and Deck Penetrations.*

Table 16.18 Types of flange connections

<p style="text-align: center;">Type A</p> <div style="display: flex; justify-content: space-around; align-items: center;">   </div> <div style="display: flex; justify-content: space-around; align-items: center;"> <p>Welding neck flange</p> <p>Loose flange with welding neck</p> </div>		
<p style="text-align: center;">Type B</p> <div style="display: flex; justify-content: space-around; align-items: center;">    </div> <p style="text-align: center;">Slip-on welding flange-fully welded</p>		
<p style="text-align: center;">Type C</p> <div style="display: flex; justify-content: space-around; align-items: center;">    </div> <p style="text-align: center;">Slip-on welding flange</p>		
<p style="text-align: center;">Type D</p>  <p style="text-align: center;">Socket screwed flange - conical threads -</p>	<p style="text-align: center;">Type E</p>  <p style="text-align: center;">Plain flange - welded on both sides -</p>	<p style="text-align: center;">Type F</p>  <p style="text-align: center;">Lap joint flange - on flanged pipe -</p>
<p><i>Note: For type D, the pipe and flange are to be screwed with a tapered thread and the diameter of the screw portion of the pipe over the thread is not to be appreciably less than the outside diameter of the unthreaded pipe. For certain types of thread, after the flange has been screwed hard home, the pipe is to be expanded into the flange.</i></p>		

4.7 All valves of Classes I and II piping systems having nominal diameters exceeding 50 mm are to have bolted, pressure seal or breech lock bonnets. All valves for Classes I and II piping systems and valves intended for use in steam or oil services are to be constructed so that the stem is positively restrained from being screwed out of the body.

All cast iron valves are to have bolted bonnets or are to be of the union bonnet type. For cast iron valves of the union bonnet type, the bonnet ring is to be of steel, bronze or malleable iron.

4.8 Stems, discs or disc faces, seats and other wearing parts of valves are to be of corrosion resistant materials suitable for intended service. Resilient materials, where used, are subject to service limitations as specified by the manufacturers. Use of resilient materials in valves intended for fire mains is to be specifically approved based on submittal of certified fire endurance tests conforming to a recognized standard.

Table 16.19 Examples of mechanical joints

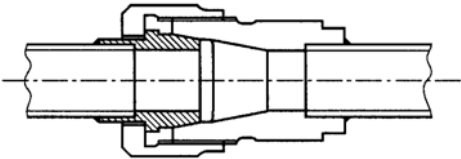
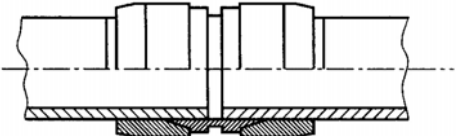
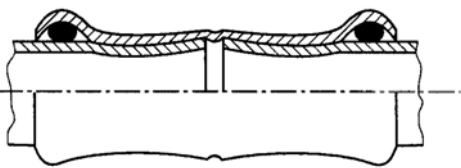
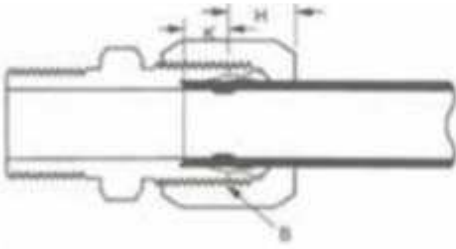
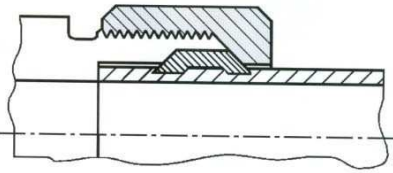
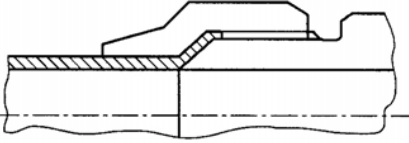
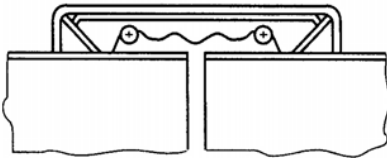
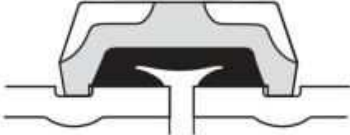
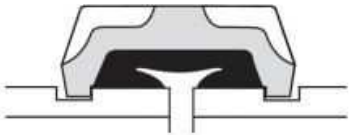
Pipe Unions	
Welded and Brazed Types	
Compression Couplings	
Swage Type	
Press Type	
Typical Compression Type	
Bite Type	
Flared Type	
Slip-on Joints	
Grip Type	
Machine Grooved Type	  <div style="display: flex; justify-content: space-around; margin-top: 5px;"> Roll Groove Cut Groove </div>

Table 16.19 Examples of mechanical joints (continued)

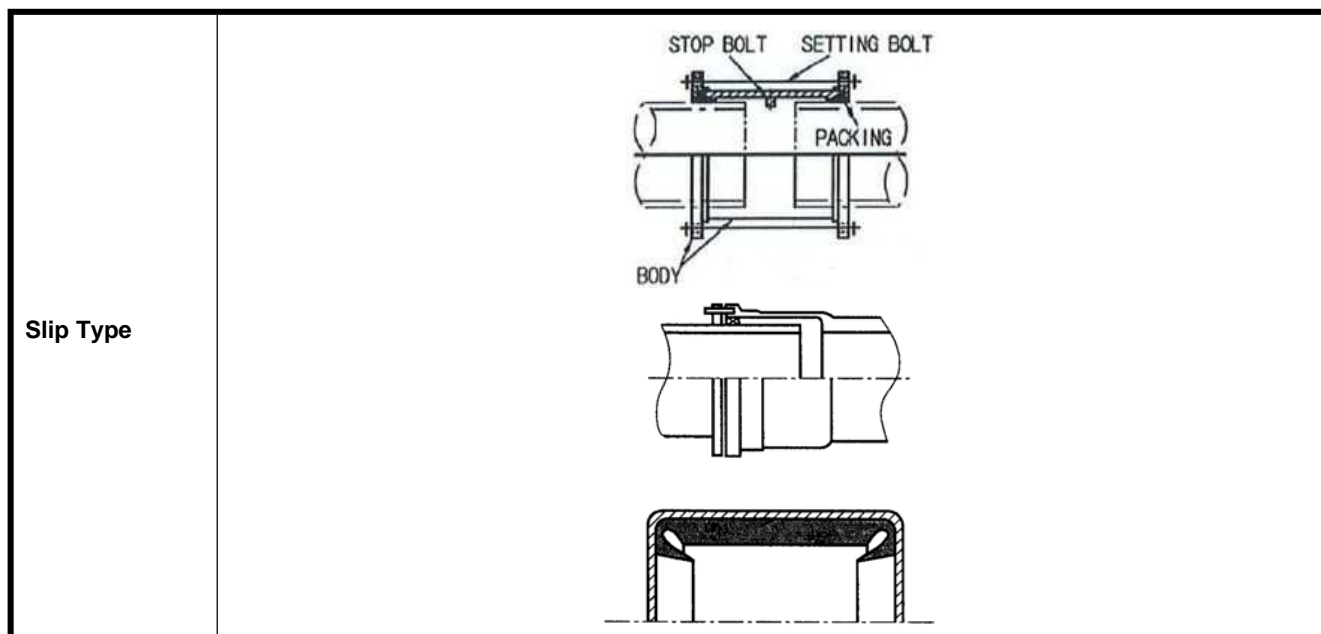


Table 16.20 Application of mechanical joints

Systems	Kind of connections		
	Pipe Unions	Compression couplings (6)	Slip-on joints
Flammable fluids (flash points <60°C)			
Cargo oil lines ⁴	+	+	+
Crude oil washing lines ⁴	+	+	+
Vent lines ³	+	+	+
Inert Gas			
Water seal effluent lines	+	+	+
Scrubber effluent lines	+	+	+
Main lines ^{2&4}	+	+	+
Distributions lines ⁴	+	+	+
Flammable fluids (Flash point > 60°C)			
Cargo oil lines ⁴	+	+	+
Fuel oil lines ^{3,2}	+	+	+
Lubricating oil lines ^{2,3}	+	+	+
Hydraulic oil ^{2,3}	+	+	+
Thermal oil ^{2,3}	+	+	+
Sea Water			
Bilge lines ¹	+	+	+
Water filled fire extinguishing systems, e.g. sprinkler systems ³	+	+	+
Non water filled fire extinguishing systems, e.g. foam, drencher systems ³	+	+	+
Fire main (not permanently filled) ³	+	+	+
Ballast system ¹	+	+	+
Cooling water system ¹	+	+	+
Tank cleaning services	+	+	+
Non-essential systems	+	+	+

Table 16.20 Application of mechanical joints (continued)

Systems	Pipe Unions	Compression couplings (6)	Slip-on joints
Fresh water			
Cooling water system ¹	+	+	+
Condensate return ¹	+	+	+
Non-essential system	+	+	+
Sanitary/Drains/Scuppers			
Deck drains (internal) ⁶	+	+	+ ⁴
Sanitary drains	+	+	+
Scuppers and discharge (overboard)	+	+	-
Sounding / Vent			
Water tanks/ Dry spaces	+	+	+
Oil tanks (F.p. > 60°C) ^{2,3}	+	+	+
Miscellaneous			
Starting /Control air ¹	+	+	-
Service air (non-essential)	+	+	+
Brine	+	+	+
CO ₂ system ¹	+	+	-
Steam	+	+	+ ⁵
Footnotes Table 16.20 – Fire resistance capability If mechanical joints include any components which readily deteriorate in case of fire, the following footnotes are to be observed: 1. Inside machinery spaces of category A-approved of flame resistant types. 2. Slip on joints are not accepted inside machinery spaces of category A or accommodation spaces. May be accepted in other machinery spaces provided the joint are located in easily visible and accessible positions. 3. Approved fire resistant types except in cases where such mechanical joints are installed on open decks, as defined in SOLAS II-2/Reg. 9.2.3.3.2.2(10) and not used for fuel oil lines 4. In pump rooms and open decks- approved fire resistant types. Footnotes Table 16.20 – General 5. Slip type slip-on joints as shown in Table 16.19. May be used for pipes on deck with a design pressure of 10 bar or less. 6. Only above bulkhead deck of passenger ships and freeboard deck of cargo ships. + Application is allowed - Application is not allowed			

Table 16.21 Application of mechanical joints depending upon the class of piping

Types of joints	Class I	Class II	Class III
Pipe Unions			
Welded and brazed type	+ (1)	+ (1)	+
Compression Couplings			
Swage-type	+	+	+
Press type	-	-	+
Typical compression type	+ (1)	+ (1)	+
Bite type	+ (1)	+ (1)	+
Flared type	+ (1)	+ (1)	+
Slip-on Joints			
Machine grooved type	+	+	+
Grip type	-	+	+
Slip type	-	+	+
(1) Outer pipe diameter should be less than 60.3 mm. + Application is allowed - Application is not allowed			

4.9 All valves of Classes I and II piping systems having nominal diameters exceeding 50 mm are to have flanged or welded ends. Welded ends are to be butt welding type, except that socket welding ends may be used for valves having nominal diameters of 80 mm or less with the approval of **BCS**.

5. Ship's Side (Shell Plating) Valves

5.1 For the mounting of valves on the ship's side, see Chapter 1 - Hull, Section 7, C.10.

5.2 Ship's side valves on the shell plating shall be easily accessible. Seawater inlet and outlet valves are to be capable of being operated from above the floor plates. The hand wheel of main cooling water inlet valves is not to be less than 460 mm above the bottom platform.

Cocks on the ship's side must be so arranged that the handle can only be removed when the cock is closed.

5.3 Valves with only one flange may be used on the ship's side (shell plating) and on the sea chests only after special approval.

Wafer type valves are not to be used for any connections to the vessel's shell unless specially approved. Lug type butterfly valves used as shell valves are to have a separate set of bolts on each end of the valve so that the inboard end may be disconnected with the valve closed to maintain its watertight integrity.

5.4 On ships with > 500 GT, in periodically unattended machinery spaces, for the controls of sea inlet and discharge valves see Chapter 4-1 - Automation, Section 6. I.

6. Remote Controlled Valves

6.1 Scope

These requirements apply to hydraulically, pneumatically or electrically operated valves in piping systems and sanitary discharge pipes.

6.2 Construction

6.2.1 Remote controlled bilge valves and essential

valves for the safety of the ship are to be equipped with an emergency operating arrangement.

6.2.2 For the emergency operation of remote controlled valves in cargo piping systems, see Section 20, B.2.3.3.

6.3 Arrangement of valves

The accessibility of the valves for maintenance and repairing is to be taken into consideration.

Valves in bilge lines and sanitary pipes must always be accessible.

6.3.1 Relief valve discharges and pressure vessels associated with piping system

A pressure vessel, which can be isolated from piping system relief valves, is to have another relief valve fitted either directly on the pressure vessel or between the pressure vessel and the isolation valve.

Each piping system or part of a system which may be exposed to a pressure greater than that for which it is designed is to be protected from over-pressurization by a relief valve. Other protective devices, such as bursting discs, may be considered for some systems.

For systems conveying flammable liquids or gases, relief valves are to be arranged to discharge back to the suction side of the pump or to a tank. The relief valve of a CO₂ system is to discharge outside of the CO₂ container storage compartment.

In all cases, when discharging directly to the atmosphere, the discharge is not to impinge on other piping or equipment and is to be directed away from areas used by personnel.

6.3.2 Bilge lines

Valves and control lines are to be located as far as possible from the bottom and sides of the ship.

6.3.3 Ballast Pipes

The requirements stated in 6.3.2 also apply here to the location of valves and control lines.

Where remote controlled valves are arranged inside the ballast tanks, the valves should always be located in the tank adjoining that to which they relate.

6.3.4 Fuel pipes

Remote controlled valves mounted on fuel tanks located above the double bottom must be capable of being closed from outside the compartment in which they are installed (See also G.2.1 and H.2.2).

If remote controlled valves are installed inside fuel or oil tanks, 6.3.3 has to be applied accordingly.

6.3.5 Bunker lines

Remote controlled shut-off devices mounted on fuel tanks shall not be automatically closed in case the power supply fails, unless suitable arrangements are provided, which prevent excessive pressure raise in the bunker line during bunkering.

6.3.6 Cargo pipes

For remote controlled valves inside cargo tanks, see Section 20, B.2.3.3.

6.4 Control stands

6.4.1 The control devices of remote controlled valves are to be arranged together in one control stand.

6.4.2 The control devices are to be clearly and permanently identified and marked.

6.4.3 The status (open or close) of each remote controlled valve is to be indicated by **BCS** approved position indicators.

6.4.4 The status of bilge valves “open” / “close” is

to be indicated by **BCS** approved position indicators.

In case of position indicators directly mounted on the valve a drawing approval by **BCS** is to be carried out.

Position indicators based on indirect measuring principles, i.e. volumetric position indicators, need to be type approved.

6.4.5 In case of volumetric position indicators the system pressure of the control line is to be monitored by a **BCS** type approved pressure switch (series connection of pressure switch and flow switch).

6.4.6 The control devices of valves for changeable tanks are to be interlocked to ensure that only the valve relating to the tank concerned can be operated. The same also applies to the valves of cargo holds and tanks in which dry cargo and ballast water are carried alternately.

6.4.7 On passenger ships, the control stand for remote controlled bilge valves is to be located outside the machinery spaces and above the bulkhead deck.

6.5 Power units

6.5.1 Power units are to be equipped with at least two independent sets for supplying power for remote controlled valves.

6.5.2 The energy required for the closing of valves which are not closed by spring power is to be supplied by a pressure accumulator.

6.5.3 Pneumatically operated valves can be supplied with air from the general compressed air system.

Where the quick-closing valves of fuel tanks are closed pneumatically, a separate pressure accumulator is to be provided. This is to be of adequate capacity and is to be located outside the engine room. Filling of this accumulator by a direct connection to the general compressed air system is allowed. A non-return valve is to be arranged in the filling connection of the pressure accumulator.

The accumulator is to be provided either with a pressure control device with a visual and acoustic alarm or with a hand-compressor as a second filling appliance.

The hand-compressor is to be located outside the engine room.

6.6 After installation on board, the entire system is to be subjected to an operational test.

7. Pumps

7.1 For materials and construction requirements the “Regulations for the Design, Construction and Testing of Pumps” of **BCS** are to be applied.

7.2 For the pumps listed below, a performance test is to be carried out in the manufacturer's works under the **BCS** supervision:

- Bilge pumps/bilge ejectors,
- Ballast pumps,
- Cooling sea water pumps,
- Cooling fresh water pumps,
- Fire pumps,
- Emergency fire pumps including drive units,
- Condensate pumps
- Boiler feedwater pumps,
- Boiler water circulating pumps,
- Lubricating oil pumps,
- Fuel oil booster and transfer pumps,
- Circulating pumps for thermal oil installations,
- Brine pumps,
- Refrigerant circulating pumps,
- Cargo pumps,

Cooling pumps for fuel injection valves,

- Hydraulic pumps for controllable pitch propellers.

Other hydraulic pumps/motors, see Section 10.A.

8. Protection of Piping Systems Against Overpressure

The following piping systems are to be fitted with safety valves to avoid unallowable overpressures:

- Piping systems and valves in which liquids can be enclosed and heated;
- Piping systems which may be exposed in service to pressures in excess of the design pressure.

Safety valves must be capable of discharging the medium at a maximum pressure increase of 10 % of the allowable working pressure. Safety valves are to be fitted on the low pressure side of reducing valves.

9. Piping on Ships with Added Classification Mark FS

9.1 The following requirements apply additionally to ships for which proof of buoyancy in the damaged condition is provided;

9.1.1 Passenger ships according to Chapter 1 - Hull, Section 30, K. as well as N.5 of this section.

9.1.2 Liquefied gas tankers according to Chapter 10 - Liquefied Gas Tankers, Section 2.

9.1.3 Chemical tankers according to Chapter 8 - Chemical Tankers, Section 2.

9.1.4 Other cargo ships according to Chapter 1 - Hull, Section 26.

9.2 Chapter 1 - Hull, Section 16, B is to be additionally applied for scuppers and discharge lines, Chapter 1 - Hull, Section 16, D is to be additionally applied for vent, overflow and sounding pipes.

For closed cargo holds on passenger ships, see N.4.4.

9.3 Pipe penetrations through watertight bulkheads are subject to the requirements of Chapter 1 - Hull, Section 11.

9.4 Pipes with open ends in compartments or tanks are to be so arranged that in any damaged condition to be considered no additional compartments or tanks could be flooded.

9.5 Where shut-off devices are arranged in cross flooding lines of ballast tanks, the position of the valves is to be indicated on the bridge.

9.6 For sewage discharge pipes, see T.2.

9.7 Where it is impossible to lay pipes outside the damaged zone, the tightness of the bulkheads is to be ensured by applying the provisions in 9.7.1 to 9.7.4.

9.7.1 In bilge pipelines, a non-return valve is to be fitted either on the watertight bulkhead through which the pipe passes to the bilge suction or at the bilge suction itself.

9.7.2 In ballast water and fuel pipelines for the filling and emptying of tanks, a shut-off valve is to be fitted either at the watertight bulkhead through which the pipe leads to the open end in the tank or directly at the tank.

9.7.3 The shut-off valves required in 9.7.2 must be capable of being operated from a control panel located on the navigation bridge, where it must be indicated when the valves are in the "closed" position. This requirement does not apply to valves which are opened at sea only shortly for supervised operations.

9.7.4 Overflow pipes of tanks in different watertight compartments which are connected to one common overflow system are either

- To be led, prior to being connected to the system, within the relevant compartment, on passenger ships high enough above the bulkhead deck and on other ships above the unsuitable damage water line, or

- A shut-off valve is to be fitted to each overflow pipe. This shut-off valve is to be located at the watertight bulkhead of the relevant compartment and is to be secured in open position to prevent unintended operation. The shut-off valves must be capable of being operated from a control panel located on the navigation bridge, where it must be indicated when the valve is in the "closed" position.

9.7.5 If on ships other than passenger ships, the bulkhead penetrations for these pipes are arranged high enough and so near to midship that in no damage condition, including at temporary maximum heeling of the ship, will be below the waterline, then the shut-off valves may be dispensed with.

10. Hoses (see also Section 16, U)

10.1 A flexible hose assembly is a short length of metallic or non-metallic hose normally with prefabricated end fittings ready for installation.

Flexible hoses of metallic or non-metallic material is used for a permanent connection between a fixed piping system and items of machinery. Temporary connections of flexible hoses or hoses of portable equipment are to be approved by **BCS**.

Flexible hose assemblies are to confirm **BCS** requirements in this section for being used in fuel oil, lubricating, hydraulic and thermal oil systems, fresh water and sea water cooling systems, compressed air systems, bilge and ballast systems, and Class III steam systems.

Flexible hoses are not acceptable in high pressure fuel oil injection systems.

These requirements for flexible hose assemblies are not applicable to hoses intended to be used in fixed fire extinguishing systems.

10.2 Design and Construction

Flexible hoses are to be designed and constructed in accordance with recognized National or International standards recognized to the **BCS**.

Flexible hoses constructed of rubber or plastics materials and intended for use in bilge, ballast, compressed air, oil fuel, lubricating, hydraulic and thermal oil systems are to incorporate a single or double closely woven integral wire braid or other suitable material reinforcement.

Flexible hoses of plastics materials for the same purposes, such as Teflon or Nylon, which are unable to be reinforced by incorporating closely woven integral wire braid are to have suitable material reinforcement as far as practicable.

Where rubber or plastics materials hoses are to be used in oil supply lines to burners, the hoses are to have external wire braid protection in addition to the integral reinforcement.

Flexible hoses for use in steam systems are to be of metallic construction.

Flexible hoses are to be permanently marked by the manufacturer with the following details:

- Hose manufacturer's name or trademark,
- Data of manufacture (month/year),
-
- Designation type of reference,
-
- Nominal diameter,
-
- Maximum permissible working pressure,
-
- Working temperature.

Where a flexible hose assembly is made up of items from different manufacturers, the components are to be clearly identified and traceable to evidence of prototype testing.

Flexible hoses are to be complete with approved end fittings in accordance with manufacturer's specification. The end connections that do not have a flange are to comply with D.2.4 as applicable and each type of hose/fitting combination is to be subject to prototype testing to the same standard as that required by the hose with particular reference to pressure and impulse tests.

The use of hose clamps and similar types of end attachments is not acceptable for flexible hoses in

piping systems for steam, flammable media, starting air or for sea water where failure may result in flooding. In other piping systems, the usage of hose clamps may be accepted where the working pressure is less than 5 bar and provided there are at least two stainless steel hose clamps at each end connection. The hose clamps are to be at least 12 mm wide and are not to be dependent upon spring tension to remain fastened.

Flexible hose assemblies constructed of non-metallic materials intended for installation in piping systems for flammable media and sea water systems where failure may result in flooding are to be of a fire-resistant type except in cases where such hoses are installed on open decks, as defined in SOLAS II-2/Reg. 9.2.3.3.2.2(10) and not used for fuel oil lines. The installation of a shut-off valve immediately upstream of a sea water hose does not satisfy the requirements for fire-resistant type hose. Fire resistance is to be demonstrated by testing to ISO 15540 and ISO 15541.

Flexible hose assemblies intended for installation in piping systems where pressure pulses and/or high levels of vibration are expected to occur in service, are to be designed for the maximum expected impulse peak pressure and forces due to vibration. The tests required by 10.5 shall take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.

10.3 Installation

In general, flexible hoses are to be limited to a length necessary to provide for relative movement between fixed and flexibly mounted items of machinery, equipment or systems.

Flexible hose assemblies are not to be installed where they may be subjected to torsion deformation (twisting) under normal operating conditions.

The number of flexible hoses, in piping systems is to be kept to minimum and is to be limited for the purpose stated in 10.1.

Where flexible hoses are intended to be used in piping systems conveying flammable fluids that are in close proximity of heated surfaces the risk of ignition due to failure of the hose assembly and subsequent release of fluids is to be mitigated as far as practicable by the use of screens or other similar protection.

Flexible hoses are to be installed in clearly visible and readily accessible locations.

The installation of flexible hose assemblies is to be in accordance with the manufacturer's instructions and use limitations with particular attention to the following:

- Orientation,
- End connection support (where necessary),
- Avoidance of hose contact that could cause rubbing and abrasion,
- Minimum bend radii.

10.4 Tests

Type test programs for flexible hose assemblies are to be submitted by the manufacturer to **BCS** for approval and type test results are to be sufficiently detailed to demonstrate performance in accordance with the specified standards.

10.4.1 A pressure test should be performed on a type expansion joint complete with all the accessories such as flanges, stays and articulations, at twice the design pressure at the extreme displacement conditions recommended by the manufacturer without permanent deformation. Depending on the materials used, **BCS** may require the test to be at the minimum design temperature.

10.4.2 All flexible hose assemblies are to be satisfactorily type burst tested to an international standard to demonstrate they are able to withstand a pressure not less than 4 times its design pressure without indication of failure or leakage.

10.4.3 A cyclic test (thermal movements) should be performed on a complete expansion joint, which is to successfully withstand at least as many cycles, under the conditions of pressure, temperature, axial movement, rotational movement and transverse movement, as it will encounter in actual service. Testing at ambient temperature is permitted, when this testing is at least as severe as testing at the

service temperature.

10.4.4 A cyclic fatigue test (ship deformation) should be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length, for at least 2,000,000 cycles at a frequency not higher than 5 cycles per second. This test is only required when, due to the piping arrangement, ship deformation loads are actually experienced.

10.4.5 The following standards are accepted by **BCS** to be applied for type tests of the expansion joints:

- ISO 6802 (Rubber and plastics hoses and hose assemblies with wire reinforcement – Hydraulic impulse test with flexing)
- ISO 6803 (Rubber or plastics hoses and hose assemblies – Hydraulic-pressure impulse test without flexing)
- ISO 15540 (Ships and marine technology – Fire resistance of hose assemblies – Test methods)
- ISO 15541 (Ships and marine technology – Fire resistance of hose assemblies – Requirements for test bench)
- ISO 10380 (Pipe work – Corrugated metal hoses and hose assemblies.)

Other standards may be accepted where agreed.

11. Expansion Joints (see also Section 16, U)

11.1 Moulded Expansion Joints

Where moulded expansion joints made of reinforced rubber or other suitable non-metallic materials are proposed for use in Class III circulating water systems in machinery spaces, the following requirements are applied:

- The expansion joint is to be oil resistant; its physical life shall not be shortened due to chemical effects.

- The maximum allowable working pressure is not to be greater than 25% of the hydrostatic bursting pressure determined by a burst test of a prototype expansion joint stated in D.10.4. Results of the burst test are to be submitted to **BCS**.
- Plans of moulded or built-up expansion joints over 150 mm, including internal reinforcement arrangements, are to be submitted **BCS** for approval.

11.2 The arrangement of expansion joints supports and collars is to be such that pipes and flanges are not subjected to abnormal bending stresses, taking into account their own mass, the metal they are made of, and the nature and characteristics of the fluid they convey, as well as the contractions and expansions to which they are subjected

11.3 Any misalignments between the pipe and moulded expansion joint shall be prevented. Moulded expansion joints are not permitted by **BCS** to be used in order to conceal /waylay any wicked but obligatory design approaches

Expansion joints can be movable axially. Expansion joints for the misalignment pipe connections might cause some unexpected strains and less life of running

11.4 The use of flexible hoses and expansion joints is to be limited as far as practicable.

11.5 The position of flexible hoses and expansion joints is to be clearly shown on the piping drawings submitted to **BCS**.

11.6 The use of non-metallic expansion joints on pipes connected to sea inlets and overboard discharges will be given special consideration by **BCS**. As a rule, the fitting of such joints between the ship sides is not permitted. Furthermore, unless the remote controlled valves are fitted with their controls operable from places

located above the freeboard deck, efficient means are to be provided, wherever necessary, to limit the flooding of the ship in the event of rupture of the expansion joints.

Expansion joints may be fitted in sea water lines provided they are arranged with guards which effectively enclose, but do not interfere with, the action of the expansion joints and reduce to the minimum practicable any flow of water into the machinery spaces in the event of failure of the flexible elements.

Use of expansion joints in water lines for other services, including ballast lines in machinery spaces, in duct keels and inside double bottom water ballast tanks, and bilge lines inside double bottom tanks and deep tanks, will be given special consideration by **BCS**.

Where expansion joints are subjected to a combination of longitudinal and transverse movements, both movements shall be considered in the design and application since the total life of expansion joint is shortened. All these arguments are to be submitted to **BCS** for approval before mounting their places.

Where moulded expansion joints of composite construction utilizing metallic material, such as steel or stainless steel or equivalent material, with rubberized coatings inside and/or outside or similar arrangements are proposed for use in oil piping systems (fuel, lubricating or hydraulic oil), the following requirements apply:

- Expansion joint ratings for temperature, pressure, movements and selection of materials are to be suitable for the intended service.
- The expansion joints are to pass the fire resistant test specified in ISO 15540 ve ISO 15541.

- The maximum allowable working pressure of the system is not to be greater than 25% of the hydrostatic bursting pressure determined by a burst test of a prototype expansion joints.
- The expansion joints are to be permanently marked with the manufacturer's name and the month and year of manufacture.

12. Piping Penetration Through Bulkheads, Decks and Tank Tops

12.1 Watertight integrity

Where it is necessary for pipes to penetrate watertight bulkheads, decks or tank tops, the penetrations are to be made by methods which will maintain the watertight integrity.

For this purpose, bolted connections are to have bolts threaded into the plating from one side; through bolts are not to be used.

Welded connections are either to be welded on both sides or to have full penetration welds from one side.

In general, the pipe is to be as short as possible. The pipe is to extend through the shell plating and is to be welded on both sides or with full strength welds from one side. Consideration is to be given to supporting the pipe to the surrounding structure

12.2 Fire Tight Integrity

Where pipes penetrate bulkheads, decks or tank-tops which are required to be fire tight or smoke tight, the penetrations are to be made by approved methods which will maintain the same degree of fire tight or smoke tight integrity.

13. Sea Chests

Sea chests are to comply with the following requirements:

- Located in positions where the possibility of blanking off the suction is minimized;

- Fitted with strainer plates through which the clear area is to be at least 2 times the area of the inlet valves;
- Means are provided for clearing the strainer plates, such as by using compressed air or low pressure steam.
- Additional requirements for sea chests on ice strengthened vessels in BCS Rules , Chapter 04 – Machinery Installation , Section 19 , Item E.2 and Chapter 33 – Polar Class Ships, Section 3, Item I.2 are to be complied with, where applicable.

E. Steam Lines

1. Operation

1.1 Steam lines are to be so laid out and arranged that important consumers can be supplied with steam from every main boiler as well as from a stand-by boiler or boiler for emergency operation

1.2 Important consumers are:

- All consuming units important for the propulsion, manoeuvrability and safe operation of the ship as well as the essential auxiliary machinery according to Section 1, H.
- All consuming units necessary to the safety of the ship.

1.3 Every steam consuming unit must be capable of being shut-off from the system.

2. Calculation of Pipelines

2.1 Steam lines are to be constructed for the design pressure (PR) according to B.4.1.4.

2.2 Calculations of pipe thickness and elasticity analysis in accordance with C are to be carried out. Sufficient compensation for thermal expansion is to be proven.

3. Laying Out of Steam Lines

3.1 Steam lines are to be so installed and supported that expected stresses due to thermal expansion, external loads and shifting of the supporting structure under both normal and interrupted service conditions will be safely compensated.

3.2 Steam lines are to be so installed that water pockets will be avoided.

3.3 Means are to be provided for the reliable drainage of the piping system.

3.4 Steam lines are to be effectively insulated to prevent heat losses.

3.4.1 At points there is a possibility of contact, the surface temperature of the insulated steam lines may not exceed 80°C.

3.4.2 Wherever necessary, additional protection arrangements against unintended contact are to be provided.

3.4.3 The surface temperature of steam lines in the pump rooms of tankers may nowhere exceed 220°C (see also Section 20).

3.5 Steam heating lines, except for heating purposes, are not to be led through accommodation.

3.6 Sufficiently rigid positions are to be arranged as fixed points for the steam piping systems.

3.7 It is to be ensured that the steam lines are fitted with sufficient expansion arrangements.

3.8 Where a system can be entered from a system with higher pressure, the former is to be provided with reducing valves and relief valves on the low pressure side.

3.9 Welded connections in steam lines are subject to the requirements specified in Chapter 3 - Welding.

4. Steam Strainers

Wherever necessary, machines and apparatus in steam systems are to be protected against foreign matter by steam strainers.

5. Penetration and Security

Steam connections to equipment and pipes carrying oil, e.g. steam atomizers or steam out arrangements, are to be so secured that fuel and oil cannot penetrate into the steam lines.

6. Inspection of Steam Lines for Expanding

Steam lines for superheated steam at above 500°C are to be provided with means of inspecting the pipe expanding. This can be in the form of measuring sections on straight lengths of pipe at the superheater outlet if it is possible. The length of these measuring sections is to be at least 2 d_a.

F. Boiler Feedwater and Circulating Arrangement, Condensate Recirculation**1. Feedwater Pumps**

1.1 At least two feedwater pumps are to be provided for each boiler installation.

1.2 Feedwater pumps are to be so arranged or equipped that no backflow of water can occur when the pumps are at a standstill.

1.3 Feedwater pumps are to be used only for feeding boilers.

2. Capacity of Feedwater Pumps

2.1 Where two feedwater pumps are provided, the capacity of each is to be equivalent to at least 1.25 times the maximum permitted output of all the connected steam generators.

2.2 Where more than two feedwater pumps are

installed, the capacity of all other feedwater pumps in the event of the failure of the pump with the largest capacity is to comply with the requirements of 2.1.

2.3 For continuous flow boilers the capacity of the feedwater pumps is to be at least 1.0 times the maximum steam output.

2.4 Special requirements may be approved for the capacity of the feedwater pumps for plants incorporating a combination of oil fired and exhaust gas boilers.

3. Delivery Pressure of Feedwater Pumps

Feedwater pumps are to be so laid out that the delivery pressure can satisfy the following requirements:

- The required capacity according to 2 is to be achieved against the maximum allowable working pressure of the steam producer;
- In case the safety valve is blowing off the delivery capacity is to be equal 1.0 times the approved steam output at 1.1 times the allowable working pressure.

The flow resistance in the piping between the feedwater pump and the boiler are to be taken into consideration. In the case of continuous flow boilers the total resistance of the boiler must be taken into account.

4. Power Supply to Feedwater Pumps for Main Boilers

4.1 For steam-driven feedwater pumps, the supply of all the pumps from only one steam system is allowed provided that all the steam producers are connected to this steam system. Where feedwater pumps are driven solely by steam, a suitable filling and starting up pump which is to be independent of steam is to be provided.

4.2 For electric drives, a separate lead from the common bus-bar to each pump motor is sufficient.

5. Feedwater Lines

Feedwater lines may not pass through tanks which do not contain feedwater.

5.1 Feedwater lines for main boilers

5.1.1 Each main boiler is to be provided with a main and an auxiliary feedwater line.

Where a steam generation system consists of two or more adequately sized boilers, and the feed water for each of these boilers is supplied by a single feed water pipe, the level of redundancy for the piping of the feedwater system is considered to comply with SOLAS II- 1/32.4.

5.1.2 Each feedwater line is to be fitted with a shut-off valve and a check valve at the boiler inlet. Where the shut-off valve and the check valve are not directly connected in series, the intermediate pipe is to be fitted with a drain.

5.1.3 Each feedwater pump is to be fitted with a shut-off valve on the suction side and a screw-down non-return valve on the delivery side. The pipes are to be so arranged that each pump can supply each feedwater line.

5.2 Feedwater lines for auxiliary steam generators (auxiliary and exhaust gas boilers)

5.2.1 The provision of only one feedwater line for auxiliary and exhaust gas boilers is sufficient if the preheaters and automatic regulating devices are fitted with by-pass lines.

5.2.2 The requirements in 5.1.2 are to apply as appropriate to the valves required to be fitted to the boiler inlet.

5.2.3 Continuous flow boilers need not be fitted with the valves required according to 5.1.2 provided that the heating of the boiler is automatically switched off should the feedwater supply fail and that the feedwater pump supplies only one boiler.

6. Boiler Water Circulating Systems

6.1 Each forced-circulation boiler is to be equipped with two circulating pumps powered independently of each other. Failure of the circulating pump in operation is to be signalled by an alarm. The alarm may only be switched off if a circulating pump is started or when the boiler firing is shut down.

6.2 The provision of only one circulating pump for each boiler is sufficient if:

- The boilers are heated only by gases whose temperature does not exceed 400°C; or
- A common stand-by circulating pump is provided which can be connected to any boiler; or
- The burners of oil or gas fired auxiliary boilers are so arranged that they are automatically shut-off should the circulating pump fail and the heat stored in the boiler does not cause any unacceptable evaporation of the available water in the boiler.

7. Feedwater Supply, Evaporators

7.1 The feedwater supply is to be stored in several tanks.

7.2 One storage tank may be considered sufficient for auxiliary boiler units.

7.3 Two evaporators are to be provided for main steam generator units.

8. Condensate Recirculation

8.1 The main condenser is to be equipped with two condensate pumps, each of which is to be able to transfer the maximum volume of condensate produced.

8.2 The condensate of all heating systems used to heat oil (fuel, lubricating, cargo oil etc.) is to be led to condensate observation tanks. These tanks are to be fitted with air vents.

8.3 Heating coils of tanks containing fuel or oil residues e.g. sludge tanks, leak oil tanks, bilge water tanks etc. are to be provided at the tank outlet with shut-off devices and devices for testing the condensate for the presence of oil (see V).

G. Fuel Oil Systems**1. Bunker Lines**

The bunkering of oil fuels is to be effected by means of permanently installed lines either from the open deck or from bunkering stations located below deck which are to be isolated from other spaces.

Bunker stations are to be so arranged that the bunkering can be performed from both sides of the ship without danger.

This requirement is considered to be fulfilled where the bunkering line is extended to both sides of the ship. The bunkering lines are to be fitted with blind flanges on deck.

2. Tank Filling and Suction Lines

2.1 Filling and suction lines from storage, settling and daily service tanks situated above the double bottom and from which in case of their damage fuel oil may leak, are to be fitted directly on the tanks with shut-off devices capable of being closed from a safe position outside the space concerned.

In the case of deep tanks situated in shaft or pipe tunnel or similar spaces, shut-off devices are to be fitted on the tanks. The control in the event of fire may be affected by means of an additional shut-off device in the pipe outside the tunnel or similar space. If such additional shut-off device is fitted in the machinery space it shall be operated from a position outside this space.

2.2 Shut-off devices on fuel oil tanks having a capacity of less than 500 t need not be provided with remote control.

2.3 Filling lines are to extend to the bottom of the tank. Alternatively, short filling lines directed to the side of the tank may be admissible.

Storage tank suction lines may also be used as filling lines.

2.4 For valves at the fuel tanks see V.2.2.2.7.5.

2.5 Where filling lines are led through the tank top and end below the maximum oil level in the tank, a non-return valve at the tank top is to be arranged.

2.6 The inlet connections of suction lines are to be so arranged far enough from the drains in the tank that the water and impurities which have settled out will not enter the suctions

2.7 For the release of remotely operated shut-off devices, see Section 18, B.10.

3. Pipe Layout

3.1 Fuel lines may not pass through tanks containing feedwater, drinking water, lubricating oil or thermal oil.

3.2 Fuel lines which pass through ballast tanks are to have an increased wall thickness according to Table 16.6.

3.3 Fuel lines are not to be laid directly above or in the vicinity of boilers, turbines or equipment with high surface temperatures (over 220 °C) or in way of other sources of ignition.

3.4 Flanged and screwed socket connections in fuel oil lines are to be screened or otherwise suitably protected to avoid, as far as practicable, oil spray or oil leakages onto hot surfaces, into machinery air intakes, or other sources of ignition. The number of detachable pipe connections is to be limited. In general, flanged connections according to recognized standards are to be used.

3.4.1 Flanged and screwed socket connections in fuel oil lines which lay directly above hot surfaces or

other sources of ignition are to be screened and provided with drainage arrangements.

3.4.2 Flanged and screwed socket connections in fuel oil lines with a maximum allowable working pressure of more than 0.18 N/mm² and within about 3 meters from hot surfaces or other sources of ignition and direct sight of line are to be screened. Drainage arrangements need not to be provided.

3.4.3 Flanged and screwed socket connections in fuel oil lines with a maximum allowable working pressure of less than 0.18 N/mm² and within about 3 meters from hot surfaces or other sources of ignition are to be assessed individually taking into account working pressure, type of coupling and possibility of failure.

3.4.4 Flanged and screwed socket connections in fuel oil lines with a maximum allowable working pressure of more than 1.6 N/mm² need normally to be screened.

3.4.5 Pipes running below engine room floor need normally not to be screened.

3.5 Shut-off valves in fuel lines in the machinery spaces are to be operable from above the floor plates.

3.6 Glass and plastic components are not permitted in fuel systems. Sight glasses made of glass located in vertical overflow pipes may be permitted.

3.7 Fuel pumps are to be capable of being isolated from the piping system by shut-off valves.

3.8 For fuel flow-meters a by-pass with shut-off valve shall be provided.

4. Fuel Transfer, Feed and Booster Pumps

4.1 Fuel transfer, feed and booster pumps shall be designed for the proposed operating temperature.

4.2 At least two means of transfer are to be provided. One of these means is to be a power pump. The other may consist of:

- A standby pump, or, alternatively,

- An emergency connection to another suitable power pump.

Note:

Where provided, purifiers may be accepted as means of transfer.

4.3 At least two means of oil fuel transfer are to be provided for filling the daily (service) tanks. Provisions are to be made to allow the transfer of fuel oil from any storage, settling or service tank to another tank.

4.4 Where a feed or booster pump is required to supply fuel to main or auxiliary engines, standby pumps shall be provided.

Where, the pumps are attached to the engines, standby pumps may be dispensed with for auxiliary engines.

Fuel supply units of auxiliary diesel engine are to be designed such that the auxiliary engines start without aid from the emergency generator within 30 sec after black-out.

Note:

To fulfil the above requirements for example the following measures could be a possibility:

- *Air driven MDO service pump*
- *MDO gravity tank*
- *Buffer tank before each auxiliary diesel engine*

4.5 For ships intending to use Heavy Fuel Oil (HFO) or Marine Diesel Oil (MDO) in non-restricted areas and marine fuels with a sulphur content not exceeding 0,1 % m/m and minimum viscosity of 2 cSt in emission control areas, the following arrangements are considered to be in compliance with SOLAS II-1/26.3.4.

4.5.1 In non-restricted areas, ships provided with two (2) fuel oil pumps that can each supply the fuel primarily used by the ship (i.e. HFO or MDO) in the required capacity for normal operation of the propulsion machinery.

4.5.2 In emission control areas one of the following configurations:

- Fuel oil pumps as in 4.5.1, provided these are each suitable for marine fuels with a sulphur content not exceeding 0,1 % m/m and minimum viscosity of 2 cSt operation at the required capacity for normal operation of propulsion machinery,
- When the fuel oil pumps in 4.5.1 are suitable to operate on marine fuels with a sulphur content not exceeding 0,1 % m/m and minimum viscosity of 2 cSt but one pump alone is not capable of delivering marine fuels with a sulphur content not exceeding 0,1 % m/m and minimum viscosity of 2 cSt at the required capacity, then both pumps may operate in parallel to achieve the required capacity for normal operation of propulsion machinery. In this case, one additional fuel oil pump shall be provided. The additional pump shall, when operating in parallel with one of the pumps in 4.5.1, be suitable for and capable of delivering marine fuels with a sulphur content not exceeding 0,1 % m/m and minimum viscosity of 2 cSt at the required capacity for normal operation of the propulsion machinery.
- In addition to 4.5.1, two separate fuel oil pumps shall be provided, each capable of and suitable for supplying marine fuels with a sulphur content not exceeding 0,1 % m/m and minimum viscosity of 2 cSt at the required capacity for normal operation of propulsion machinery.

Note:

If a marine distillate grade fuel with a different maximum sulphur content is specified by regulation for the area of operation of the ship (e.g., ECA, specific ports or local areas, etc.) then that maximum is to be applied.

Where electrical power is required for the operation of propulsion machinery, the requirements are also applicable for machinery for power generation when such machinery is supplied by common fuel supply pumps.

4.6 For emergency shut-down devices, see Section 18, B.9.

5. Plants with More Than One Main Engine

For plants with more than one engine, complete spare feed or booster pumps stored on board may be accepted instead of stand-by pumps provided that the feed or booster pumps are so arranged that they can be replaced with the means available on board.

For plants with more than one main engine, see also Section 2, G.

6. Shut-off Devices

6.1 On cargo ships 500 gross tonnage or above and on all passenger ships for plants with more than one engine, shut-off devices for isolating the fuel supply and overproduction/recirculation lines to any engine from a common supply system shall be provided. These valves are to be operable from a position not rendered inaccessible by a fire on any of the engines.

6.2 Instead of shut-off devices in the overproduction/recirculation lines check valves may be fitted. Where shut-off devices are fitted, they are to be locked in the operating position.

7. Filters

7.1 Fuel oil filters are to be fitted in the delivery line of the fuel pumps.

7.2 For ships with class notation AUT, the filter equipment shall confirm **BCS** Rules of Automation, Section of Monitoring Equipment and Control Ranges.

7.3 Mesh size and filter capacity are to be in accordance with the requirements of the manufacturer of the engine.

7.4 Uninterrupted supply of filtered fuel has to be ensured under cleaning and maintenance conditions of filtering equipment. In case of automatic back-flushing filters, it is to be ensured that a failure of the automatic back-flushing will not lead to a total loss of filtration.

7.5 Back-flushing intervals of automatic back-flushing filters provided for intermittent back-flushing are to be additionally monitored.

7.6 Fuel oil filters are to be fitted with differential pressure control. On engines provided for operation with gas oil only, differential pressure monitoring may be dispensed with.

7.7 Engines for the exclusive operation of emergency generators and emergency fire pumps may be fitted with simplex filters

7.8 Fuel transfer units are to be fitted with a simplex filter on the suction side.

7.9 Filter arrangement, see Section 2, G.3.5.

8. Purifiers

8.1 Manufacturers of purifiers for cleaning fuel and lubricating oil must be approved by **BCS**.

8.2 Where fuel oil needs to be purified, at least two purifiers are to be installed on board, each capable of efficiently purifying the amount of fuel oil necessary for the normal operation of the engines.

Note:

On ships with a restricted navigation notation where fuel oil needs to be purified, one purifier only may be accepted.

8.3 Where a fuel purifier may exceptionally be used to purify lubricating oil the purifier supply and discharge lines are to be fitted with a change-over arrangement which prevents the possibility of fuel and lubricating oils being mixed.

Suitable equipment is also to be provided to prevent such mixing occurring over control and compression lines.

8.4 The sludge tanks of purifiers are to be fitted with a level alarm which ensures that the level in the sludge tank cannot interfere with the operation of the purifier.

9. Oil Firing Equipment

Oil firing equipment shall be installed in accordance with Section 15. Pumps, pipelines and fittings are subject to the following requirements:

9.1 Oil fired main boilers shall be equipped with at least 2 service pumps and 2 preheaters. For filters see 7. Pumps and heaters are to be rated and arranged that

the oil firing equipment remains operational even if one unit should fail.

This also applies to oil fired auxiliary boilers and thermal oil heaters unless other means are provided for maintaining continuous operation at sea even if a single unit fails.

9.2 Hose assemblies for the connection of the burner may be used. Hose assemblies shall not be longer than required for retracting of the burners for the purpose of routine maintenance. Only approved hose assemblies may be used.

10. Service Tanks

10.1 On cargo ships of 500 gross tons or above and all passenger ships 2 fuel oil service tanks for each type of fuel used on board necessary for propulsion and essential systems are to be provided. This requirement need not to be applied non-propelled ships.

10.2 Each service tank shall have a capacity of at least 8 hours at maximum continuous rating of the propulsion plant and normal operation load of the generator plant.

A service tank is a fuel oil tank which contains only fuel of a quality ready for use i.e fuel of a grade and quality that meet the specification required by the equipment manufacturer. A service tank is to be declared as such and not to be used for any other purpose.

10.3 For "one fuel ship", where main and auxiliary engines and boiler(s) are operated with Heavy Fuel Oil (HFO), the arrangements complying with this regulation or acceptable "equivalent arrangements" shall be provided.

The arrangements complying with this regulation shall comprise at least the following tanks:

- Two (2) HFO service tanks, each of a capacity sufficient for at least 8 h operation of main engine(s), auxiliary engines and auxiliary boiler(s), and
- One (1) Marine Diesel Oil (MDO) service tank for initial cold starting or repair work of engines or boilers.

Acceptable "equivalent arrangements" shall comprise at least:

- One (1) HFO service tank with a capacity sufficient for at least 8 h operation of main engine(s), auxiliary engines and auxiliary boiler(s), and
- One (1) MDO service tank with a capacity sufficient for at least 8 h operation of main engine(s), auxiliary engines and auxiliary boiler(s), and
- For pilot burners of auxiliary boilers, if provided, an additional MDO service tank for 8 h may be required.

This arrangement only applies where main and auxiliary engines can operate with HFO under all load conditions and, in the case of main engines, during manoeuvring.

For pilot burners of Auxiliary Boilers if provided, an additional MDO tank for 8 hours may be necessary.

10.4 Where main engines and auxiliary boiler(s) are operated with Heavy Fuel Oil (HFO) and auxiliary engines are operating with Marine Diesel Oil (MDO), the arrangements complying with this regulation or acceptable "equivalent arrangements" shall be provided.

The arrangements complying with this regulation shall comprise at least the following tanks:

- Two (2) HFO service tanks, each of a capacity sufficient for at least 8 h operation of main engine(s) and auxiliary boiler(s), and
- Two (2) MDO service tanks each of a capacity sufficient for at least 8 h operation of auxiliary engines.

Acceptable "equivalent arrangements" shall comprise at least:

- One (1) HFO service tank with a capacity sufficient for at least 8 h operation of main engine(s) and auxiliary boiler(s), and
- Two (2) MDO service tanks, each of a capacity sufficient for:
- 4 h operation of main engine(s), auxiliary engines and auxiliary boiler(s), or

- 8 h operation of auxiliary engines and auxiliary boiler(s).

10.5 The "equivalent arrangements" in items 10.3 and 10.4 apply, provided the propulsion and vital systems using two types of fuel support rapid fuel change over and are capable of operating in all normal operating conditions at sea with both types of fuel (MDO and HFO).

10.6 The arrangement of oil fuel service tanks is to be such that one tank can continue to supply oil fuel when the other is being cleaned or opened up for repair.

10.7 The use of a settling tank with or without purifiers, or purifiers alone, and one service tank is not acceptable as an "equivalent arrangement" to two service tanks.

11. Operation Using Heavy Fuel Oils (HFO)

11.1 Heating of heavy fuel oil

11.1.1 Heavy fuel oil tanks are to be fitted with a heating system.

The capacity of the tank heating system is to be in accordance with the operating requirements and the quality of fuel oil intended to be used.

With the consent of **BCS**, storage tanks need not be fitted with a heating system provided it can be guaranteed that the proposed quality of fuel oil can be pumped under all ambient and environmental conditions.

For the tank heating system, see V.2.

11.1.2 Heat tracing is to be arranged for pumps, filters and fuel lines as required.

11.1.3 Where it is necessary to preheat injection valves of engines running with heavy fuel oil, the injection valve cooling system is to be provided with additional means of heating.

11.2 Treatment of heavy fuel oil

11.2.1 Settling tanks

Heavy fuel settling tanks or equivalent arrangements

with sufficiently dimensioned heating systems are to be provided.

Settling tanks are to be provided with drains, emptying arrangements and with temperature measuring instruments.

11.2.2 Heavy fuel oil cleaning for diesel engines

For cleaning of heavy fuels, purifiers or purifiers combined with automatic filters are to be provided.

11.2.3 Fuel oil blending and emulsifying equipments

Heavy fuel oil/diesel oil blending and emulsifying equipments require approval by **BCS**.

11.3 Service tanks

11.3.1 For the arrangement and equipment of daily service tanks, see V.2.

11.3.2 The capacity of the tanks shall be such that should be treatment plant fail, the supply to all the connected consumers can be maintained for at least 8 hours.

11.3.3 Where the overflow pipe of the tank is terminated in the settling tanks, suitable means shall be provided to ensure that no untreated heavy fuel oil can penetrate into the daily service tank in case of overfilling of a settling tank.

11.3.4 Daily service tanks are to be provided with drains and with discharge arrangements.

11.4 Change-over arrangement diesel oil/heavy oil

11.4.1 The change-over arrangement of the fuel supply and return lines is to be interlocked so that faulty switching is excluded and to ensure reliable separation of the fuels.

Change-over valves which allow interpositions are not permitted.

11.4.2 The change-over devices are to be accessible and permanently marked. Their respective working position must be clearly indicated.

11.4.3 Remote controlled change-over devices are to be provided with limit position indicators at the control platforms.

11.5 Fuel supply through stand pipes

11.5.1 Where the capacity of stand pipes exceeds 500 litres, the outlet pipe is to be fitted with a remote controlled quick-closing valve operated from outside the engine room. Stand pipes are to be equipped with air/gas vents and with self-closing connections for emptying and draining. Stand pipes are to be fitted with a local temperature indicator.

11.5.2 Atmospheric stand pipes (pressureless)

Having regard to the arrangement and the maximum fuel level in the service tanks, the stand pipes are to be so located and arranged that a sufficient free space for degasification is available inside the stand pipes.

11.5.3 Closed stand pipes (pressurized systems)

Closed stand pipes are to be designed as pressure vessels and are to be fitted with the following equipment:

- A non-return valve in the recirculation lines from the engines;
- An automatic degasser or a gas blanket monitor with manual degasser;
- A local pressure gauge;
- A local temperature indicator;
- A drain/emptying device, which is to be locked in the closed position.

11.5.4 Fuel booster units

Booster units are to be protected against pressure peaks, e.g. by using adequate dampers.

11.6 End preheaters

Two mutually independent end preheaters are to be provided.

The arrangement of only one preheater may be approved where it is ensured that the operation with fuel oil which do not need preheating can be temporary maintained.

A by-pass with shut-off valve is to be provided.

11.7 Viscosity control

11.7.1 Where main and auxiliary engines are operated on heavy fuel oil, automatic viscosity control is to be provided.

11.7.2 Viscosity regulators are to be fitted with a local temperature indicator.

11.7.3 Local control devices

The following local control devices are to be fitted directly before the engine:

- A pressure gauge;
- A temperature indicator.

11.8 The heavy fuel system is to be effectively insulated as necessary.

12. Sampling points

12.1 The fuel oil pipelines should be provided with sampling points.

12.2 The sampling points should meet the requirements of MEPC.1/Circ.864 'Guidelines for on board sampling and verification of the sulphur content of the fuel oil used on board ships' and should be located as follows:

- .1 after the transfer pump discharge,
- .2 before and after the fuel cleaning equipment, and
- .3 after the fuel oil service tank, before any fuel change over valve,
- .4 before fuel enters the oil fuelled machinery.

12.3 Sampling points should be provided at locations within the fuel oil system that enable samples of fuel oil to be taken in a safe manner.

12.4 The position of a sampling point should be such that the sample of the fuel oil is representative of the fuel oil quality passing that location within the system.

12.5 The sampling points should be located in positions as far removed as possible from any heated surface or electrical equipment so as to preclude impingement of fuel oil onto such surfaces on equipment under all operating conditions.

H. Lubricating Oil Systems

1. General Requirements

1.1 Lubricating oil systems are to be constructed to ensure reliable lubrication over the whole range of speed and during run-down of the engines and to ensure adequate heat transfer.

1.2 Priming pumps

Where necessary, priming pumps are to be provided for supplying lubricating oil to the engines.

1.3 Emergency lubrication

A suitable emergency lubricating oil supply (e.g. gravity tank) is to be arranged to come automatically into use in the event of a failure of the supply from the pumps.

1.4 Lubricating oil treatment

1.4.1 The equipment necessary (purifiers, automatic back-flushing filters, filters and free-jet centrifuges) for adequate treatment of lubricating oil is to be provided.

1.4.2 In the case of auxiliary engines running on heavy oil which are supplied from a common lubricating oil tank, suitable equipment is to be fitted to ensure that in case of failure of the common lubricating oil treatment system or ingress of fuel or cooling water into the lubricating oil circuit, the auxiliary engines required to safeguard the power supply in accordance with Chapter 5 - Electrical Installation Section 3, C. remain fully

operational.

2. Lubricating Oil Systems

2.1 Lubricating oil circulating tanks and gravity tanks

2.1.1 For the capacity and location of these tanks see Section V, 3.

2.1.2 For ships where a double bottom is required the minimum distance between shell and circulating tank are to be at least 500 mm and more.

Where an engine lubricating oil circulation tank extends to the bottom shell plating on ships for which a double bottom is required in the engine room shut-off valves are to be fitted in the drain pipes between engine casing and circulating tank. These valves are to be capable of being closed from a level above the lower platform.

2.1.3 The suction connections of lubricating oil pumps are to be located as far as possible from drain pipes.

2.1.4 Where deep well pumps are used for main engine lubrication, they are to be protected against vibration through suitable supports.

2.1.5 The gravity tank is to be fitted with an overflow pipe which leads to the drain tank. Arrangements are to be made for observing the flow of excess oil in the overflow pipe.

2.2 Filling and suction lines

2.2.1 Filling and suction lines of lubricating oil tanks with a capacity of 500 litres and more located above the double bottom and from which in case of their damage lubricating oil may leak, are to be fitted directly on the tanks with shut-off devices according to G.2.1.

The remote operation of shut-off devices according to G.2.1 may be dispensed with.

- For valves which are kept closed during normal operation,

Where an unintended operation of a quick closing valve would endanger the safe operation of the main propulsion plant or

essential auxiliary machinery.

2.2.2 Where lubricating oil lines must be led in the vicinity of hot machinery, e.g. superheated steam turbines, steel pipes which should be in one length and which are protected where necessary are to be used.

2.2.3 For screening arrangements of lubricating oil pipes G.3.4 applies as appropriate.

2.3 Filters

2.3.1 Lubricating oil filters are to be arranged in the delivery pressure of the pumps.

2.3.2 Mesh size and filter capacity are to be in accordance with the requirements of the engine manufacturer.

2.3.3 Uninterrupted supply of filtered lubricating oil has to be ensured under cleaning and maintenance conditions of filter equipment.

In case of automatic back-flushing filters, it is to be ensured that a failure of the automatic back-flushing will not lead to a total loss of filtration.

2.3.4 Back-flushing intervals of automatic filters provided for intermittent back-flushing are to be monitored.

2.3.5 Main lubricating oil filters are to be fitted with differential pressure monitoring. On engines provided for operation with gas oil only, differential pressure monitoring may be dispensed with.

2.3.6 Engines for the exclusive operation of emergency generators and emergency fire pumps may be fitted with simplex filters.

2.3.7 For the protection of the lubricating oil pumps simplex filter of a minimum mesh size of 100 μ may be arranged on the suction side of the pumps.

2.3.8 For the arrangement of filters, see Section 2, G.3

2.3.9 For diesel generator lubricating oil filters see also H.3.4.1.

2.4 Lubricating oil coolers

It is recommended that turbine and large engine plants be provided with more than one oil cooler.

2.5 Oil level indicator

Machines with their own oil charge are to be provided with a means of determining the oil level from outside during operation. This requirement also applies to reduction gears, thrust bearings and shaft bearings.

2.6 Purifiers

The requirements in G.8 apply as appropriate.

3. Lubricating Oil Pumps

3.1 Main engines

3.1.1 Main and independent stand-by pumps are to be arranged.

Main pumps driven by the main engines are to be so designed that the lubricating oil supply is ensured over the whole range of operation.

3.1.2 For plants with more than one main engine, see Section 2, G.4.

3.2 Main turbine plant

3.2.1 Main and independent stand-by lubricating oil pumps are to be provided.

3.2.2 Emergency lubrication

The lubricating oil supply to the main turbine plant for cooling the bearings during the run-down period is to be assured in the event of failure of the power supply. By means of suitable arrangements such as gravity tanks the supply of oil is also to be assured during starting of the emergency lubrication system.

3.3 Main reduction gearing (motor vessels)

3.3.1 Lubricating oil is to be supplied by a main pump and an independent stand-by pump.

3.3.2 Where a reduction gear has been approved

by **BCS** to have adequate self-lubrication at 75 % of the torque of the propelling engine , a stand -by lubricating oil pump for the reduction gear may be dispensed with up to a power ratio of

$$P / n_1 \leq 3.0$$

where

n_1 = the gear input revolution [min^{-1}],

P = the power transmitted to gear [kW].

3.3.3 The regulations under 3.1.2 are to be applied for multi-propeller plants and plants with more than one engine.

3.4 Auxiliary machinery

3.4.1 Diesel generators

Where more than one diesel generator is available, stand-by pumps are not required.

Where only one diesel generator is available (e.g. on turbine-driven vessels where the diesel generator is needed for start up etc.) a complete spare pump is to be carried on board.

Where more than one diesel generator is available, diesel engine of the generator may be fitted with a simplex lubricating oil filter provided the arrangements are such that the cleaning can be readily performed by changeover to a standby unit without the loss of ship's power required for operation.

3.4.2 Auxiliary turbines

Turbo generators and turbines used for driving important auxiliaries such as boiler feedwater pumps etc. are to be equipped with a main pump and an independent auxiliary pump. The auxiliary pump is to be designed to ensure a sufficient supply of lubricating oil during the start up and run-down operation.

I. Cooling Seawater Equipment

1. Sea Connections, Sea Chests

1.1 At least 2 sea chests are to be provided. Wherever possible, the sea chests are to be

arranged as low as possible on either side of the ship.

1.2 For service in shallow waters, it is recommended that an additional high seawater intake should be provided.

1.3 It is to be ensured that the total seawater supply for the engines can be taken from only one sea chest.

1.4 Each sea chest is to be provided with an effective vent. The following venting arrangements will be approved:

- An air pipe of at least 32 mm. ID which can be shut-off and which extends above the bulkhead deck;
- Adequately dimensioned ventilation slots in the shell plating.

1.5 Steam or compressed air connections are to be provided for clearing the sea chest gratings. The steam or compressed air lines are to be fitted with shut-off valves fitted directly to the sea chests. Compressed air for blowing through sea chest gratings may exceed 2 bar only if the sea chests are constructed for higher pressures.

1.6 Where a sea chest is exclusively arranged as chest cooler the steam or compressed airlines for clearing as in 1.5, may with the agreement of **BCS** be dispensed with.

2. Special Rules for Ships with Ice Class

2.1 For one of the sea chests specified in 1.1 the sea inlet is to be located on the ship's centre line and as far aft as possible. The seawater discharge line of the entire engine plant is to be connected to the top of the sea chest.

2.1.1 For ships with ice class ICE-B1 to ICE-B4 the sea chest is to be arranged as follows:

- In calculating the volume of the chest the following value shall be applied as a guide: about 1 m³ for every 750 kW of the

ship's engine output including the output of auxiliary engines;

- The sea chest shall be of sufficient height to allow ice to accumulate above the inlet pipe;
- The free area of the strum holes shall be not less than four times the sectional area of the seawater inlet pipe.

2.1.2 As an alternative, 2 smaller sea chests as specified in 2.1.1. may be arranged.

2.1.3 All discharge valves shall be so arranged that the discharge of water at any draught will not be obstructed by ice.

2.2 Where necessary, a steam connection or a heating coil is to be arranged for de-icing and thawing the sea chests.

2.3 Additionally, cooling water supply to the engine plant may be arranged from ballast water tanks with circulation cooling.

This system does not replace the requirement stated in 2.1.1.

2.4 For the fire pumps, see the requirements of Section 18.

3. Sea Valves

3.1 Sea valves are to be so arranged that they can be operated from above the floor plates. See also item D.5.2.

3.2 Discharge pipes for seawater cooling systems are to be fitted with a shut-off valve at the shell plating.

4. Strainer

The suction lines of the seawater pumps are to be fitted with strainers.

The strainers are to be so arranged that they can be cleaned during operation of the pumps.

Where cooling water is supplied by means of a scoop,

strainers in the main seawater cooling line can be dispensed with.

5. Cooling Seawater Pumps

5.1 Diesel engine plants

5.1.1 Main propulsion plants are to be provided with main and stand-by cooling seawater pumps.

5.1.2 The main cooling seawater pump may be attached to the propulsion plant. It is to be ensured that the attached pump is of sufficient capacity for the cooling seawater required by main and auxiliary engines over the whole speed range of the propulsion plant.

The drive of the stand-by cooling seawater pump is to be independent of the main engine.

5.1.3 Main and stand-by cooling seawater pumps are each to be of sufficient capacity to meet the maximum cooling seawater requirements of the plant.

Alternatively, three cooling seawater pumps of the same capacity and delivery head may be arranged, provided that two of the pumps are sufficient to supply the required cooling water for full load operation of the plant at design temperature.

With this arrangement it is allowable for the second pump to be automatically put into operation only in the higher temperature range by means of a thermostat.

5.1.4 Ballast pumps or other suitable seawater pumps may be used as stand-by cooling water pumps. Pipe connections between those pipe lines need to be approved by **BCS**.

5.1.5 Where cooling water is supplied by means of a scoop, the main and stand-by cooling water pumps are to be of a capacity which will ensure reliable operation of the plant under partial load conditions and astern operation as required in Section 2, E.5. The main cooling water pump is to be automatically started as soon as the speed falls below that required for the operation of the scoop.

5.2 Steam turbine plants

5.2.1 Steam turbine plants are to be provided with a main and a stand-by cooling water pump.

The main cooling water pump is to be of sufficient capacity to supply the maximum cooling water requirements of the turbine plant. The capacity of the stand-by cooling water pump is to be such as to ensure reliable operation of the plant also during astern operation.

5.2.2 Where cooling water is supplied by means of a scoop, the main cooling water pump is to be of sufficient capacity for the cooling water requirements of the turbine plant under conditions of maximum astern output.

The main cooling water pump is to start automatically as soon as the speed falls below that required for the operation of the scoop.

5.3 Multi-propellers and multi-main engines

For plants with more than one engine and with separate cooling water systems, complete spare pumps on board may be accepted instead of stand-by pumps provided that the main seawater cooling pumps are so arranged that they can be replaced with the means available on board.

5.4 Cooling seawater supply for auxiliary engines

Where a common cooling seawater pump is provided to serve more than one auxiliary engine, an independent stand-by cooling seawater pump with the same capacity is to be fitted. Independently operated cooling seawater pumps of the main engine plant may be used to supply cooling water to auxiliary engines while at sea, provided that the capacity of such pumps is sufficient to meet the additional cooling seawater requirement.

If each auxiliary engine is fitted with an attached cooling seawater pump, no stand-by cooling seawater pumps need be provided.

6. Cooling Seawater Supply in Dock

It is recommended that a supply of cooling seawater, e.g. from water ballast tank is to be available so that at least one diesel generator and, if necessary, the domestic refrigerating plant may be run when the ship is in dock.

Cargo and container cooling systems shall conform to the requirements stated in Chapter 15 - Refrigerating Installations, I.4.

K. Cooling Freshwater Systems

1. General

1.1 Fresh water cooling systems are to be so arranged that the engines can be sufficiently cooled under all operating conditions.

1.2 Depending on the requirements of the engine plant, the following fresh water cooling systems are allowed:

A single cooling circuit for the entire plant;

- Separate cooling circuits for the main and auxiliary plant;
- Several independent cooling circuits for the main engine components which need cooling (e.g. cylinders, pistons and fuel valves) and for the auxiliary engines;
- Separate cooling circuits for various temperature ranges.

1.3 The cooling circuits are to be so divided that, should one part of the system fail, operation of the auxiliary systems can be maintained.

Change-over arrangements are to be provided for this purpose if necessary.

1.4 As far as possible, the temperature controls of main and auxiliary engines as well as of different circuits are to be independent of each other.

1.5 Where, in automated engine plants, heat exchanges for fuel or lubricating oil are incorporated in

the cylinder cooling water circuit of main engines, the entire cooling water system is to be monitored for fuel and oil leakage.

1.6 Common cooling water systems for main and auxiliary plants are to be fitted with shut-off valves to enable repairs to be performed without taking the entire plant out of service.

2. Heat Exchangers, Coolers

2.1 The construction and equipment of heat exchangers and coolers are subject to the Rules of Section 14.

2.2 The coolers of cooling water systems, engines and equipment are to be designed to ensure that the specified cooling water temperatures can be maintained under all operating conditions. Cooling water temperatures are to be adjusted to meet the requirements of engines and equipment.

2.3 Heat exchangers for auxiliary equipment in the main cooling water circuit are to be provided with by-passes if by this means it is possible, in the event of a failure of the heat exchanger, to keep the system in operation.

2.4 It is to be ensured that auxiliary machinery can be maintained in operation while repairing the main coolers. If necessary, means are to be provided for changing over to other heat exchangers, machinery or equipment through which a temporary heat transfer can be achieved.

2.5 Shut-off valves are to be provided at the inlet and outlet of all heat exchangers.

2.6 Every heat exchanger and cooler is to be provided with a vent and a drain.

2.7 Keel coolers, chest coolers

2.7.1 Arrangement and construction drawings of keel and chest coolers are to be submitted for approval.

2.7.2 Permanent vents for fresh water are to be provided at the top of keel coolers and chest coolers.

2.7.3 Keel coolers are to be fitted with pressure gauge connections at the fresh water inlet and outlet.

3. Expansion Tanks

3.1 Expansion tanks are to be arranged at sufficient height for every cooling water circuit.

Different cooling circuits may only be connected to a common expansion tank if they do not interfere with each other. Care must be taken here to ensure that damage to or faults in one system cannot affect the other system.

3.2 Expansion tanks are to be fitted with filling connections, aeration/de-aeration devices, water level indicators and drains.

4. Fresh Water Cooling Pumps

4.1 Main and stand-by cooling water pumps are to be provided for each fresh water cooling system.

4.2 Main cooling water pumps may be driven directly by the main or auxiliary engines which they are intended to cool provided that a sufficient supply of cooling water is assured under all operating conditions.

4.3 The drives of stand-by cooling water pumps are to be independent of the main engines.

4.4 Stand-by cooling water pumps are to have the same capacity as main cooling water pumps.

4.5 Main engines are to be fitted with at least one main and one stand-by cooling water pump. Where according to the construction of the engines more than one water cooling circuit is necessary, a stand-by pump is to be fitted for each main cooling water pump.

4.6 For fresh cooling water pumps of essential auxiliary engines the rules for sea cooling water pumps in I.5.4 may be applied.

4.7 A stand-by cooling water pump of a cooling water system may be used as a stand-by pump for another system provided that the necessary pipe connections are arranged. The shut-off valves in these connections are to be secured against unintended operation.

4.8 Equipment providing for emergency cooling from another system can be approved if the plant and system are suitable for this purpose.

4.9 For plants with more than one main engine, the rules for sea cooling water pumps in I.5.3 may be applied.

5. Temperature Control

Cooling water circuits are to be provided with temperature controls in accordance with the requirement. Control devices whose failure may impair the functional reliability of the engine are to be equipped for manual operation.

6. Preheating for Cooling Water

Means are to be provided for preheating fresh cooling water. Exceptions are to be approved by **BCS**.

7. Emergency Generating Units

Internal combustion engines driving emergency generating units are to be fitted with independent cooling systems. Such cooling systems are to be made proof against freezing.

8. Cooling water supply for electrical main propulsion plants

For the cooling water supply for converters of electrical main propulsion systems, the Chapter 5 - Electrical Installations, Section 13 have to be observed.

L. Compressed Air Lines

1. General

1.1 Pressure lines connected to air compressors are to be fitted with non-return valves at the compressor outlet.

1.2 Oil and water separators, see Section 2, L.4.3.

1.3 Starting air lines may not be used as filling lines for air receivers.

1.4 Only type-tested hose assemblies made of metallic materials may be used in starting air lines of diesel engines which are permanently kept under pressure.

1.5 The starting air line to each engine is to be fitted with a non-return valve and a drain.

1.6 Tyfons are to be connected to at least two compressed air receivers.

1.7 A safety valve is to be fitted behind each pressure-reducing valve. See Section 18, G.1.1.6.

1.8 Pressure water tanks and other tanks connected to the compressed air system are to be considered as pressure vessels and must comply with the requirements in Section 14 relating to the working pressure of the compressed air system.

1.9 For compressed air connections for blowing through sea chests refer to I.1.5.

1.10 For the compressed air supply to pneumatically operated valves and quick-closing valves refer to D.6.

1.11 Requirements for starting engines with compressed air, see Section 2, H.2.

1.12 For compressed air operated fire flaps of the engine room, D.6.5 is to be used analogously. These fire flaps are not to close automatically in case of loss of energy

2. Control Air Systems

2.1 Control air systems for essential consumers are to be provided with the necessary means of air treatment.

2.2 Pressure reducing valves in the control air system of main engines are to be redundant.

M. Exhaust Gas Lines

1. Pipe Layout

1.1 Engine exhaust gas pipes are to be installed separately from each other, taking the structural fire protection into account. Other designs are to be submitted for approval. The same applies to boiler exhaust gas pipes.

1.2 Account is to be taken of thermal expansion when laying out and suspending the lines.

1.3 Where exhaust gas lines discharge near water level, provisions are to be taken to prevent water from entering the engines.

1.4 Openings of exhaust gas pipes of emergency generator diesel engines shall have a height above deck that is satisfactory to meet the requirements of the LLC 1966 as amended 1988, Reg. 19(3).

2. Silencers

2.1 Engine exhaust pipes are to be fitted with effective silencers or other suitable means are to be provided.

3. Water Drains

Exhaust lines and silencers are to be provided with suitable drains of adequate size.

4. Insulation

Insulation of exhaust gas lines inside machinery spaces, see the requirements of Section 18.

5. Additional Requirements for Tankers

For special Rules for tankers refer to Section 20, B.9.3.

Engine exhaust gas lines are additionally subject to Section 2, G.

For special requirements for exhaust gas cleaning system see Section 2, N.

N. Bilge Systems

A bilge system is intended to dispose of water which may accumulate in spaces within the vessel due to condensation, leakage, washing, fire fighting, etc. It is to be capable of controlling flooding in the propulsion machinery space as a result of limited damage to piping systems. Oily bilge water system in engine room is out of the scope of this section.

1. Bilge Lines

The system is to be designed to avoid the possibility of cross-flooding between spaces.

To enhance system availability, bilge pump integrity is to be assured through testing and certification; at least two bilge pumps are to be provided, and bilge suction control valves are to be accessible for maintenance at all times.

1.1 Layout of bilge lines

1.1.1 Bilge lines and bilge suction are to be so arranged that the bilges can be completely pumped even under disadvantageous trim conditions. Bilge pumping systems are to be capable of draining the spaces when the vessel is on even keel and either upright or listed 5 degrees on either side.

1.1.2 Bilge suction are normally to be located on both sides of the ship. For compartments located fore and aft in the ship, on bilge suction may be considered sufficient provided that it is capable of completely draining the relevant compartment.

1.1.3 Spaces located forward of the collision bulkhead and aft of the stern tube bulkhead and not connected to the general bilge system are to be drained by other suitable means of adequate capacity.

1.1.4 The required pipe thicknesses of bilge lines are to be in accordance with Table 16.7.

1.2 Pipes laid through tanks

1.2.1 Bilge pipes may not be led through tanks for lubricating oil, thermal oil, drinking water or feedwater.

1.2.2 Bilge pipes from spaces not accessible during the voyage if running through fuel tanks located above double bottom are to be fitted with a non-return valve directly at the point of entry into the tank.

1.2.3 Where passing through deep tanks, unless being led through a pipe tunnel, bilge suction lines are to be of steel having a thickness at least as required by column D of Table 16.7. Pipes of other materials having dimensions properly accounting for corrosion and mechanical strength may be accepted. The number of joints in these lines is to be kept to a minimum. Pipe joints are to be welded or heavy flanged (e.g., one

pressure rating higher). The line within the tank is to be installed with expansion bends. Slip joints are not permitted. A non-return valve is to be fitted at the open end of the bilge line. These requirements are intended to protect the space served by the bilge line from being flooded by liquid from the deep tank in the event of a leak in the bilge line.

1.3 Bilge suctions and strums / mud boxes

1.3.1 Bilge suctions are to be so arranged as not to impede the cleaning of bilges and bilge wells. They are to be fitted with easily detachable, corrosion-resistant strums.

1.3.2 Emergency bilge suctions are to be arranged in such a manner that they are accessible, with free flow and the hand wheel is not less than 460 mm above the bottom platform.

1.3.3 For the size and design of bilge wells see Chapter 1 - Hull, Section 8, B.3.

1.3.4 Bilge alarms of main and auxiliary machinery spaces, see Section 1, E.5 and Chapter 4-1 - Automation, Section 6, H.

1.3.5 Mud boxes

In machinery spaces and shaft tunnels other than emergency suctions, termination pipes of bilge suctions are to be straight and vertical and are to be led to mud boxes so arranged as to be easily inspected and cleaned.

The lower end of the termination pipe is not to be fitted with a strum box.

1.3.6 Strum boxes

- In compartments other than machinery spaces and shaft tunnels, the open ends of bilge suction pipes are to be fitted with strum boxes or strainers having holes not more than 10 mm in diameter. The total area of such holes is to be not less than twice the required cross-sectional area of the suction pipe.
- Strum boxes are to be so designed that they can be cleaned without having to remove any joint of the suction pipe.

1.4 Bilge valves

1.4.1 Valves in connecting pipes between the bilge and the seawater and ballast water system, as well as between the bilge connections of different compartments, are to be so arranged that even in the event of faulty operation or intermediate positions of the valves, penetration of seawater through the bilge system will be safely prevented.

1.4.2 Bilge discharge pipes are to be fitted with shut-off valves at the ship's side.

1.4.3 Bilge valves are to be arranged so as to be always accessible irrespective of the ballast and loading condition of the ship.

1.4.4 Open end of the bilge line is to be fitted with a non-return valve.

1.5 Reverse-flow protection

1.5.1 A screw-down non-return valve or; a combination of a non-return valve without positive means of closing and a shut-off valve are recognized as reverse flow protection.

1.6 Pipe layout

1.6.1 To prevent the ingress of ballast and seawater into the ship through the bilge system, two means of reverse-flow protection are to be fitted in the bilge connections.

One of such means of protection is to be fitted in each suction line.

1.6.2 The direct bilge suction and the emergency injection need only have one means of reverse-flow protection as specified in 1.5.1.

1.6.3 Where a direct seawater connection is arranged for attached bilge pumps to protect them against running dry, the bilge suctions are also to be fitted with two screw-down non-return valves.

1.6.4 The discharge lines of oily water separators are to be fitted with a reverse flow protection at the ships side.

2. Calculation of Pipe Diameters

2.1 The calculated values according to formulae (4) to (6) are to be rounded up to the next higher nominal diameter.

2.2 Dry cargo and passenger ships

2.2.1 Main bilge pipes

The diameter of the main bilge line suction is to be determined by the equation 4. The actual internal diameter of the bilge main may be rounded off to the nearest pipe size of recognised standard. However, no bilge main suction pipe is to be less than 63 mm internal diameter.

$$d_H = 25.0 + 1.68 \cdot \sqrt{L(B + H)} \quad (4)$$

2.2.2 Branched bilge pipes

The diameter of the bilge branch suction for a compartment is to be determined by the equation 5. The actual internal diameter of the bilge main may be rounded off to the nearest pipe size of recognised standard. If the compartment is served by more than one branch suction, the combined area of all branch suction pipes is not to be less than the area corresponding to the diameter determined by the equation 5. However, no branch suction pipe needs to be more than 100 mm internal diameter, nor is to be less than 50 mm internal diameter, except that for pumping out small pockets or spaces, 38 mm internal diameter pipe may be used.

$$d_Z = 25.0 + 2.16 \sqrt{\ell \cdot (B + H)} \quad (5)$$

d_H = Calculated inside diameter of main bilge pipe, [mm]

d_Z = Calculated inside diameter of branch bilge pipe, [mm]

L = Length of ship between perpendiculars, [m]

B = Moulded breadth of ship (4), [m]

H = Depth of ship to the bulkhead deck, [m]

ℓ = Length of the watertight compartment [m].

2.3 Tankers

The diameter of the main bilge pipe in the engine rooms of tankers and bulk cargo/oil carriers is calculated using the formula:

$$d_H = 35.0 + 3.0 \cdot \sqrt{\ell_1 \cdot (B + H)} \quad (6)$$

where:

ℓ_1 = Total length of spaces between cofferdam or pump-room bulkhead and stern tube bulkhead [m].

Other terms as in formulae (4) and (5).

Branch bilge pipes are to be dimensioned with equation 5. For bilge installations for spaces in the cargo area of tankers and bulk cargo/oil carriers see Section 20.

2.4 Minimum diameter

For ships under 25 meters length, the diameter may be reduced to 40 mm.

2.5 Maximum diameter

2.5.1 The diameter of the main bilge line calculated from equation 4 need not exceed 200 mm.

2.5.2 The branch bilge pipes diameter calculated from equation 5 need not exceed that of the main bilge pipe.

2.6 Deviations

Where in individual cases that the values from equation 5 greater than that of equation 4, the bilge pipe diameter does not need to be bigger than the value from equation 4.

3. Bilge Pumps

3.1 Capacity of bilge pumps

The minimum capacity Q of the required bilge pump may be determined from the following equation:

$$Q = 5.75 \cdot 10^{-3} \cdot d_H^2 \quad (7)$$

(4) For ships other than passenger ships, which have side ballast tanks forming a double hull, the diameter of suction pipes in holds may be determined by introducing as B the actual breadth of the holds amidships.

Where

Q = Minimum capacity [m³/h],

d_H = Calculated inside diameter of main bilge pipe [mm].

3.2 Where centrifugal pumps are used for bilge pumping, they must be self-priming or connected to an air extracting device.

3.3 One bilge pump with a smaller capacity than that required according to formula (7) is acceptable provided that the other pump is designed for a correspondingly larger capacity. However, the capacity of the smaller bilge pump shall not be less than 85 % of the calculated capacity.

3.4 Use of other pumps for bilge pumping

3.4.1 Ballast pumps, stand-by seawater cooling pumps and general service pumps may also be used as independent bilge pumps provided they are self-priming and of the required capacity according to formula (7).

3.4.2 In the event of failure of one of the required bilge pumps, one pump each must be available for fire fighting and bilge pumping.

3.4.3 Fuel and oil pumps may not be connected to the bilge system.

3.4.4 Bilge ejectors are acceptable as bilge pumping arrangements provided that there is an independent supply of driving water.

3.5 Number of bilge pumps for cargo ships

Cargo ships are to be provided with two independent, power bilge pumps. On ships up to 2000 tons gross, one of these pumps may be attached to the main engine.

On ships of less than 100 tons gross, one engine-driven bilge pump is sufficient. The second independent bilge pump may be a permanently installed manual bilge pump. The engine-driven bilge pump may be coupled to the main propulsion plant.

3.6 Number of bilge pumps for passenger ships

At least three pumps are to be provided. One pump may be coupled to the main propulsion plant. Where the criterion of service numeral is 30 **(5)** or more, a further bilge pump is to be provided. Each power bilge pump shall be capable of pumping water through the required main bilge pipe at a speed of not less than 2 m/s.

4. Bilge Pumping for Various Spaces

Note:

For above/below bulkhead deck drainages on passenger and cargo ships, see MSC.1/Circ.1320.

4.1 Machinery spaces

4.1.1 On ships of more than 100 tons gross, the bilges of every main machinery space must be capable of being pumped as follows:

4.1.1.1 Through the bilge suction connected to the main bilge system;

4.1.1.2 Through one direct suction connected to the largest independent bilge pump; and

4.1.1.3 Through an emergency bilge suction connected to the sea cooling water pump of the main propulsion plant or through another suitable emergency bilge system.

4.1.1.4 When a direct suction is active, all secondary bilge pumps should be also capable to pump through bilge main line at same time.

4.1.1.5 Inlet diameter of the direct suction pump is not to be less than the diameter of bilge main line.

4.1.2 If the ships propulsion plant is located in several spaces, a direct suction in accordance with 4.1.1.2 is to be provided in each watertight compartment in addition to branch bilge suction in accordance with 4.1.1.1.

(5) See SOLAS 74/88 as amended Chapter II-1, Part C, Regulation 35-I, 3.2.

4.1.3 On steam ships the diameter of the emergency bilge suction in accordance with 4.1.1.3 is to be at least 2/3 of the diameter and on motor ships equal to the diameter of the cooling water pump suction line. Exceptions to this Rule require the approval of **BCS**. The emergency bilge suction must be connected to the cooling water pump suction line by a reverse-flow protection, according to 1.5.

This valve is to be provided with a plate with the notice:

Emergency bilge valve!
To be opened in an emergency only!

4.1.4 Rooms and decks in engine rooms are to be provided with drains to the engine room bilge. A drain pipe which passes through a watertight bulkhead is to be fitted with a self-closing valve.

4.1.5 On ships with > 500 GT, in periodically unattended machinery spaces, for the controls of sea inlet and discharge valves see Chapter 4-1 - Automation, Section 6. I.

4.2 Shaft tunnel

Bilge suction is to be arranged at the after end of the shaft tunnel. Where the shape of the bottom or the length of the tunnel requires, additional bilge suction is to be provided at the forward end. Bilge valves for the shaft tunnel are to be arranged outside the tunnel in the engine room.

4.3 Cargo holds

4.3.1 Cargo holds are to be normally fitted with bilge suctions fore and aft.

For water ingress protection systems, see Chapter 5 - Electrical Installations, Section 18, B.4.1.9.

4.3.2 Cargo holds having a length less than 30 meters may be provided with only one bilge suction on each side.

4.3.3 On ship's with only one cargo hold, bilge wells of sufficient size are to be provided fore and aft.

4.3.4 For cargo holds for the transport of dangerous goods, see Section 18, P.7.

4.3.5 In all Ro/Ro cargo spaces below the bulkhead deck where a pressure water spraying system according to the requirements of Section 18, L.2.3 provided, the following is to be complied with:

- The drainage system on each side shall have a capacity of not less than 1.25 times of the capacity of both the water spraying system pumps and required number of fire hose nozzles,
- The valves of the drainage arrangement shall be operable from outside the protected space at a position in the vicinity of the drencher system controls,
- At least 4 bilge wells shall be of sufficient holding capacity and shall be arranged on either side directly at the longitudinal bulkhead, not more than 40 meters longitudinally apart from each other.
- 4.4.8 is to be observed in addition

For a bilge system the following criteria are to be satisfied:

- $Q_B = 1,25 Q$
- $A_M = 0,625 Q$ and
 $\text{Sum } A_B = 0,625 Q$

Where:

- Q_B = Combined capacity of all bilge pumps [m^3/s]
- Q = Combined water flow from the fixed fire extinguishing system and the required fire hoses [m^3/s]
- A_M = The sectional area of the main bilge pipe of the protected space [m^2]

Sum A_B = Total cross section of the branch bilge pipes for each side [m^2]

If the drainage arrangement is based on gravity drains the area of the drains and pipes are to be determined according to 4.4.2.

The reservoir tank, shall have a capacity for at least 20 minutes operation at the required drainage capacity of the affected space.

If in cargo ships these requirements cannot be complied with, the additional weight of water and the influence of the free surfaces is to be taken into account in the ship's stability information. For this purpose the depth of the water on each deck shall be calculated by multiplying Q by an operating time of 30 minutes.

4.4 Closed cargo holds and ro-ro spaces above bulkhead decks and above freeboard decks

4.4.1 Cargo holds above bulkhead decks of passenger ships or freeboard decks of cargo ships are to be fitted with drainage arrangement.

4.4.2 The drainage arrangements shall have a capacity that under consideration of a 5° list of the ship, at least 1.25 times both the capacity of the water spraying systems pumps and required number of fire hose nozzles can be drained from one side of the deck.

At least 4 drains shall be located at each side of the protected space, uniformly distributed fore and aft. The distance between the single drains shall not exceed 40 meters.

The minimum required area of scuppers and connected pipes shall be determined by the following formula.

$$A = \frac{Q}{0,5 \cdot \sqrt{19,62(h-H)}}$$

Where:

A = Total required sectional area on each side of the deck [m^2],

Q = Combined water flow from the fixed fire extinguishing system and the required number of fire hoses [m^3/s],

h = Elevation head difference between bottom of scupper well or suction level and the overboard discharge opening or highest approved load line [m],

H = Summation of head losses corresponding to scupper piping, fitting and valves [m].

Each individual drain should not be less than a NB 125 piping.

If in cargo ships these requirements cannot be complied with, the additional weight of water and the influence of the free surfaces is to be taken into account in the ship's stability information. For this purpose the depth of the water on each deck shall be calculated by multiplying Q by an operating time of 30 minutes.

4.4.3 Closed cargo holds may be drained directly towards overboard, only when at a heel of the ship of 5°, the edge of the bulkhead deck or freeboard deck shall not be immersed.

Drains from scuppers to overboard are to be fitted with reverse flow protecting devices according to Chapter 1 - Hull, Section 16.

The drainage of such enclosed spaces to suitable spaces below deck is also permitted provided such drainage is arranged in accordance with the provisions of the Regulation 22(2), ICLL 1966 (1988 Protocol).

4.4.4 Where the edge of the deck, when the ship heels 5° is located at or below the summer load line (SLL) the drainage shall be led to bilge wells or drain tanks with adequate capacity.

4.4.5 The bilge wells or drainage tanks are to be fitted with high level alarms and are to be provided with draining arrangements with a capacity according to 4.4.2.

4.4.6 It is to be ensured that;

- Bilge well arrangements prevent excessive accumulation of free water.
- Water contaminated with petrol or other dangerous substances is not drained to machinery spaces or other spaces where sources of ignition may be present.

Where the enclosed cargo space is protected by a carbon dioxide fire extinguishing system the deck scuppers are fitted with means to prevent the escape of the smothering gas.

4.4.7 The operating facilities of the relevant bilge valves have to be located outside the space and as far as possible near to the operating facilities of the pressure water spraying system for fire fighting.

4.4.8 Means shall be provided to prevent the blockage of drainage arrangements.

The means shall be designed such that the free cross-section is at least 6 times the free cross-section of the drain. Individual holes shall not be bigger than 25 mm. Warning signs are to be provided 1500 mm above the drain opening stating "Drain openings, do not cover or obstruct".

4.4.9 The discharge valves for the scuppers shall be kept open while the ship is at sea.

4.5 Spaces which may be used for ballast water, oil or dry cargo

Where dry-cargo holds are also intended for carrying ballast water or oils, the branch bilge pipes from these spaces are to be connected to the ballast or cargo pipe system only by change-over valves.

The change-over valves must be so arranged that intermediate positioning does not connect the different piping systems. Change-over connections are to be such that the pipe not connected to the cargo hold is to be blanked off.

For spaces which are used for dry cargo and ballast water the change over connection shall be so that the system (bilge or ballast system) not connected to the

cargo hold can be blanked off.

4.6 Refrigerated cargo spaces

Refrigerated cargo spaces and thawing trays are to be provided with drains which cannot be shut-off. Each drain pipe is to be fitted at its discharge end with a trap to prevent the transfer of heat and odours.

4.7 Spaces for transporting livestock

Spaces intended for the transport of livestock are to be additionally fitted with pumps or ejectors for discharging the waste overboard.

4.8 Spaces above fore and aft peaks

These spaces may either be connected to the bilge system or are to be drained by means of hand-operated bilge pumps. Spaces located above the after peak may be drained to the shaft tunnel or to the engine room bilge, provided that the drain line is fitted with a self-closing shut-off valve at a clearly visible and easily accessible position. The drain pipes shall have an inside diameter of at least 40 mm.

4.9 Cofferdams, pipe tunnels and void spaces

Cofferdams, pipe tunnels and void spaces adjoining the ships shell are to be connected to the bilge system.

Where the aft peak is adjoining the engine room, it may be drained over a self-closing valve to the engine room bilge.

For cofferdams, pipe tunnels and void spaces located above the deepest load water line equivalent means may be accepted by **BCS** after special agreement.

4.10 Drainage systems of spaces between bow doors and inner doors on Ro-Ro ships

A drainage system is to be arranged in the area between bow doors and ramp, as well as in the area between the ramp and inner door where fitted. The system is to be equipped with an audible alarm function to the navigation bridge for water level in these areas exceeding 0.5 m. above the car deck level.

For bow doors and inner doors, see Chapter 1 - Hull, Section 23, B.

4.11 Chain lockers

Chain lockers are to be drained by means of appropriate arrangements.

4.12 Condensate drain tanks of charge air coolers

4.12.1 If condensate from a drain tank of a charge air cooler shall be pumped overboard directly or indirectly, the discharge line is to be provided with an approved 15 ppm alarm. If the oil content exceeds 15 ppm an alarm is to be released and the pump shall stop automatically.

The 15 ppm alarm is to be arranged so that the bilge pump will not be stopped during bilge pumping from engine room to overboard.

4.12.2 Additionally the tank is to be provided with a connection to the oily water separator.

4.13 Dewatering of forward spaces of bulk carriers

4.13.1 On bulk carriers means for dewatering and pumping of ballast tanks forward of the collision bulkhead and bilges of dry spaces forward of the foremost cargo hold are to be provided.

For chain lockers or spaces with a volume < 0.1 % of the maximum displacement these rules need not to be applied.

4.13.2 The means are to be controlled from the navigation bridge, the propulsion machinery control position or an enclosed space which is readily accessible from the navigation bridge or the propulsion machinery control position without travelling exposed free-board or superstructure decks.

A position which is accessible via an under deck passage, a pipe trunk or other similar means of access is not to be taken is readily accessible.

4.13.3 Where pipes serving such tanks or bilges pierce the collision bulkhead, valve operation by means of remotely operated actuators may be accepted, as an alternative to the valve control specified in 4.13.2, provided that the location of such valve controls complies with 4.13.2.

4.13.4 The valve is not to move from the demanded position in the case of failure of the control system power or actuator power;

4.13.5 Where piping arrangements for dewatering of forward spaces are connected to the ballast system 2 non-return valves are to be fitted to prevent water entering dry spaces from the ballast system.

One of these non-return valves shall have positive means of closure.

The valve shall be operated from a position as stated in 4.13.2.

4.13.6 Local hand operation from above freeboard deck is required for the valve required in P.1.3.3. However, a remote operation according to 4.13.2 may be accepted if all requirements of 4.13 are met.

4.13.7 The dewatering arrangements are to be such that any accumulated water can be drained directly by a pump or eductor.

4.13.8 It must be recognizable by positive indication at the control stand whether valves are fully open or closed. In case of failure of the valve control system valves shall not move from the demanded position.

4.13.9 Bilge wells shall comply with 1.3.1.

4.13.10 Dewatering and pumping arrangements shall be such that when they are in operation the following shall be available:

- The bilge system shall remain ready for use for any compartment.
- The immediate start of the fire fighting pumps and supply of fire fighting water shall remain available

- The system for normal operation of electric power supply, propulsion and steering shall not be affected by operating the drainage and pumping system.

For water ingress detection systems see Chapter 5 - Electrical Installations, Section 18.

4.13.11 The capacity of the dewatering system according 4.13.1 is to be calculated according following formula:

$$Q = 320 A \text{ [m}^3\text{/h]}$$

A = Is the free cross sectional area of the largest air pipe or ventilation opening connecting the exposed deck with the space for which dewatering is required. [m²].

However, vent openings at the aft bulkhead of the forecastle need not to be considered for calculating the capacity of the drainage facilities.

5. Additional Rules for Passenger Vessels

5.1 Bilge pipe arrangement and bilge valves

5.1.1 The arrangement of bilge pipes;

- Within 0.2 B of the ship's side measured at the level of the subdivision load line,
- In the double bottom lower than 460 mm. above the base line, or
- Below the horizontal level specified in Chapter 1 - Hull, Section 30, E.1.2.

is permitted only if a non-return valve is fitted in the compartment in which the corresponding bilge suction is located.

5.1.2 Valve boxes and valves of the bilge system are to be installed in such a way that each compartment can be emptied by at least one pump in the event of ingress of water.

Where parts of the bilge arrangement (pump with suction connections) are situated less than 0.2 B from the ship's shell, damage to one part of the arrangement must not result in the rest of the bilge arrangement being rendered inoperable.

5.1.3 Where only one common piping system is provided for all pumps, all the shut-off and change-over valves necessary for bilge pumping must be arranged for operating from above the bulkhead deck. Where an emergency bilge pumping system is provided in addition to the main bilge system, this is to be independent of the latter and must be so arranged as to permit pumping of any flooded compartment. In this case, only the shut-off and change over valves of the emergency system need be capable of being operated from above the bulkhead deck.

5.1.4 Shut-off and change-over valves which must be capable of being operated from above the bulkhead deck should be clearly marked, accessible and fitted with a position indicator at the control stand of the bilge system.

5.2 Bilge suction

Bilge pumps in the machinery spaces must be provided with direct bilge suction in these spaces, but not more than two direct suction need be provided in any one space.

Bilge pumps located in other spaces are to have direct suction to the space in which they are installed.

5.3 Arrangement of bilge pumps

5.3.1 Bilge pumps must be installed in separate watertight compartments which are to be so arranged that they are unlikely to be simultaneously flooded in the event of damage to the ship.

Ships with a length of 91.5 meters and upwards or having a bilge pump numeral, calculated in accordance with SOLAS Regulation II-1/35-1.3.2, of 30 or more, the arrangements are to be such that at least one power

bilge pump is to be available for use in all flooding conditions which the ship is required to withstand and in all flooding conditions derived from consideration of minor damages as follows:

- One of the required pumps is to be an emergency bilge pump of a reliable submersible type having a source located above the bulkhead deck, or
- The pumps and their sources of power are to be distributed throughout the length of the ship the buoyancy of which in damaged condition is ascertained by calculation for each individual compartment or group of compartments, at least one pump being available in an undamaged compartment.

5.3.2 The bilge pumps specified in 3.6 and their energy sources may not be located forward of the collision bulkhead.

5.4 Passenger vessels for limited range of service

The range of bilge pumping for passenger vessels with limited range of service, e.g. navigation on harbour service, can be agreed with **BCS**.

6. Additional Rules for Tankers

See Section 20, B.4.

7. Bilge Testing

All bilge arrangements are to be tested under the supervision of **BCS**.

(6) *With regard to the installation on ships of oily water separators, filter plants, oil collecting tanks, oil discharge lines and a monitoring and control system or a 15 ppm alarm device in the water outlet of oily water separators, compliance is required with the provisions of the International Convention for the Prevention of Pollution from Ships, 1973, (MARPOL) and the Protocol of 1978. Also if existed national Regulations are to be considered.*

O. Equipment for the Treatment and Storage of Bilge Water and Fuel and Residues (6)

1. Oily Water Separating Equipment

1.1 Ships of 400 tons gross and above in accordance with MARPOL 73/78 Annex 1 shall be fitted with an oily water separator or a filter plant for the separation of oil/water mixtures.

1.2 Ships of 10,000 tons gross and above shall be fitted, in addition to the equipment required in 1.1, with an oil discharge monitoring and control system or with a 15 ppm alarm system.

1.3 A sampling device is to be arranged in the discharge line of oily water separating equipment/ filtering systems.
1.4 By-pass lines are not permitted for oily water separating equipment/filtering systems.

1.5 Recirculation facilities have to be provided to enable the oil filtering equipment to be tested with the overboard discharge closed.

2. Discharge of Fuel and Oil Residues

2.1 A oil residue (sludge) tank is to be provided. For the fittings and mountings of sludge tanks, see V.

2.2 The oil residue (sludge) tanks:

2.2.1 shall be of adequate capacity, having regard to the type of machinery and length of voyage, to receive the oil residues (sludge) which cannot be dealt with otherwise in accordance with the requirements of MARPOL 73/78 Annex I

2.2.2 shall be provided with a designated self-priming pump that is capable of taking suction from the oil residue (sludge) tanks for disposal of oil residue (sludge) by means as described in regulation 12.2 of MARPOL 73/78 Annex I. The capacity of the pump shall be such that the sludge tank can be emptied in a reasonable time.

2.2.3 shall have no discharge connection to the bilge system, oily bilge water holding tank(s), tank top or oily water separator, except that:

- the tank(s) may be fitted with drains, with manually operated self-closing valves and arrangements for subsequent visual monitoring of the settled water, that lead to an oily bilge water holding tank or bilge well, or an alternative arrangement, provided such arrangement does not connect directly to the bilge discharge piping system; and
- the sludge tank discharge piping and bilge-water piping may be connected to a common piping leading to the standard discharge connection referred to in regulation 13 of MARPOL 73/78 Annex I; the connection of both systems to the possible common piping leading to the standard discharge connection referred to in regulation 13 of MARPOL 73/78 Annex I shall not allow for the transfer of sludge to the bilge system;

2.2.4 shall not arranged with any piping that has direct connection overboard, other than the standard discharge connection referred to in regulation 13 of MARPOL 73/78 Annex I

2.2.5 shall designed and constructed so as to facilitate their cleaning and discharge of residues to reception facilities.

Note:

BCS Technical Circular S.P 35/13 covers interpretations of item 2.2 and also refer to BCS -G 121 for uniform application of MARPOL Annex I, revised regulation 12 as a guidance.

2.3 A separate discharge line is to be provided for discharge of fuel and oil residues to reception facilities. Discharge connection shall comply with MARPOL 73/78 Annex I Reg.13.

2.4 Where incinerating plants are used for fuel and oil residues, compliance is required with Section 15 and with the Resolution MEPC.244(66) "Standard Specification for Shipboard Incinerators".

P. Ballast Systems

1. Ballast Lines

1.1 Arrangement of piping – general

1.1.1 Suctions in ballast water tanks are to be so arranged that the tanks can be emptied despite unfavourable conditions of trim and list.

1.1.2 Ships having very wide double bottom tanks are also to be provided with suction at the outer sides of the tanks. Where the length of the ballast water tanks exceeds 30 meters, **BCS** may require suction to be provided in the forward part of the tanks.

1.2 Pipes passing through tanks

Ballast water pipes may not pass through drinking water, feedwater, thermal oil or lubricating oil tanks.

1.3 Piping systems

1.3.1 Where a tank is used alternately for ballast water and fuel (change-over tank), the suction in this tank is to be connected to the respective system by three-way cocks with L-type plugs, cocks with open bottom or change-over piston valves. These must be arranged so that there is no connection between the ballast water and the fuel systems when the valve or cock is in an intermediate position. Change-over pipe connections may be used instead of the above mentioned valves. Each change-over tank is to be individually connected to its respective system. For remotely controlled valves see D.6.

1.3.2 Where ballast water tanks may be used exceptionally as dry cargo holds, such tanks are also to be connected to the bilge system. The requirements specified in N.4.5 are applicable.

1.3.3 Where, on cargo ships, pipelines are led through the collision bulkhead below the freeboard deck, a shut-off valve is to be fitted directly at the collision bulkhead inside the fore peak.

The valve must be capable of being remotely operated from above the freeboard deck.

Where the fore peak is immediately adjacent to a permanently accessible room (e.g. bow thruster room) which is separated from the cargo space, this shut-off valve may be fitted directly at the collision bulkhead inside this room without provision for remote control, provided this valve is always well accessible.

1.3.4 On passenger ships, only one pipeline may be led through the collision bulkhead below the freeboard deck.

The pipeline is to be fitted with a remote controlled shut-off inside the forepeak directly at the collision bulkhead. The remote control must be operated from above the freeboard deck.

Where the forepeak is divided into two compartments, two pipelines may in exceptional cases be passed through the collision bulkhead below freeboard deck.

1.3.5 Ballast water tanks on ships with ice class ICE-B1 to ICE-B4 which are arranged above the ballast load line, shall be equipped with means to prevent the water from freezing (See Chapter 1- Hull, Section 14, B.4).

1.3.6 Sample points are to be provided to take samples from the discharge lines, as near to the point of discharge as practicable, during ballast water discharge whenever possible (See MEPC.173(58)).

1.4 Anti-heeling arrangements

Anti-heeling arrangements, which may produce heeling moments of more than 10° according to Chapter 1 - Hull, Section 1, E.3, are to be performed as follows:

- A shut-off device is to be provided in the cross channel between the tanks destined for this purpose before and after the anti-heeling pump;
- These shut-off devices and the pump are to be remotely operated. The control devices are to be arranged in one control stand;
- At least one of the arranged remote controlled shut-off devices shall automatically

shut down in the case of power supply failure;

- The position "closed" of the shut-off devices shall be indicated on the control stand by type approved end position indicators;
- Additionally, Chapter 5 - Electrical Installations, Section 7, G is to be observed.

1.5 Exchange of ballast water

1.5.1 For the "overflow method" separate overflow pipes or by-passes at the air pipe heads have to be provided. Overflow through the air pipe heads is to be avoided. Closures according to ICLL, but at least blind flanges are to be provided. The efficiency of the arrangement to by-pass the air pipe heads is to be checked by a functional test during the sea trials.

1.5.2 For the "Dilution method" the full tank content is to be guaranteed for the duration of the ballast water exchange. Adequately located level alarms are to be provided (e.g. at abt. 90 % volume at side tanks, at abt. 95 % at double bottom tanks).

1.6 Ballast water treatment plants

Ballast water treatment plants are to be approved by a flag administration acc. to Code for Approval of Ballast Water Management Systems (BWMS Code) (Res. MEPC 300(72))* . All ships shall install a ballast water treatment plant to provide standards in Regulation D-2 of International Convention for the Control and Management of Ship's Ballast Water and Sediments, 2004. (See also **BCS** Additional Rule for Installation of Ballast Water Management Systems.)

() BWMS approved taking into account Guidelines for approval of ballast water management systems (G8) adopted by resolution MEPC.279(70) shall be deemed to be in accordance with the BWMS Code.*

2. Ballast Pumps

At least two power driven ballast pumps are to be provided. Bilge pumps may be used for ballast water transfer provided the provisions of Sec.16.N are fulfilled.

3. Cross-Flooding Arrangements

3.1 Passenger ships

As far as possible, cross-flooding arrangements for equalizing of asymmetrical flooding in case of damage should operate automatically. Where the arrangement does not operate automatically, any shut-off valves must be capable of being operated from the bridge or another central location above the bulkhead deck. The position of each closing device has to be indicated on the bridge and at the central operating location (see also Chapter 1 - Hull, Section 26, E.6 and Chapter 5 - Electrical Installations, Section 7, H.).

The cross-flooding arrangements must ensure that in case of flooding, equalization is achieved within 15 minutes.

3.2 Cargo ships

As far possible, cross-flooding arrangements for equalizing of asymmetrical flooding in case of damage should operate automatically. Where the arrangement does not operate automatically, any shut-off valves must be capable of being operated from the bridge or another central location. The position of each closing device has to be indicated on the bridge and at the central operating location (see also Chapter 1 - Hull, Section 26, E.6 and Chapter 5 - Electrical Installations Section 7, H.).

The cross-flooding arrangements must ensure that in case of flooding equalization is achieved within 10 minutes.

3.3 Cross-flooding arrangements for equalizing of asymmetrical flooding in case of damage are to be submitted to **BCS** for approval.

4. Additional Rules for Tankers

See Section 20.B.4 and **BCS** Additional Rule for Installation of Ballast Water Management Systems, Item 3.2.

5. Operational Testing

The ballast arrangement is to be subjected to operational testing under the **BCS** supervision.

Q. Thermal Oil Systems

Thermal oil systems shall be installed in accordance with Section 13.

The pipelines, pumps and valves belonging to these systems are also subject to the following requirements.

1. Pumps

1.1 Two circulating pumps which are to be independent of each other are to be provided.

1.2 A transfer pump is to be installed for filling the expansion tank and for graining the medium.

1.3 The pumps are to be so mounted that any oil leakage can be safely disposed of.

1.4 For emergency stopping, see the requirements of Section 18, Fire Protection and Fire Fighting Equipment.

2. Valves

2.1 Only valves made of ductile materials may be used.

2.2 Valves shall be designed for a nominal pressure of PN 16.

2.3 Valves are to be mounted in accessible positions.

2.4 Non-return valves are to be fitted in the pressure lines of the pumps.

2.5 Valves in return pipes are to be secured in the open position.

2.6 Bellow sealed valves are to be preferably used.

3. Piping

3.1 Pipes in accordance with Table 16.1 or B.2.1 are to be used.

3.2 The material of the sealing joints is to be suitable for permanent operation at the design temperature and resistant to the thermal oil.

3.3 Provision is to be made for thermal expansion by an appropriate pipe layout and the use of suitable compensators.

3.4 The pipelines are to be preferably connected by means of welding. The number of detachable pipe connections is to be minimized.

3.5 The laying of pipes through accommodation, public or service spaces is not permitted.

3.6 Pipelines passing through cargo holds are to be installed in such a way that they cannot be damaged.

3.7 Pipe penetrations through bulkheads and decks are to be insulated against conduction of heat into the bulkhead. See also the requirements of Section 18, B.7.

3.8 Means of bleeding (of any air), i.e. the venting are to be so arranged that air/oil mixtures can be carried away without danger. Bleeder screws for venting are not permitted.

3.9 For screening arrangements of thermal oil pipes G.3.4 applies as appropriate.

4. Drainage and Storage Tanks

4.1 Drainage and storage tanks shall be equipped with air vents and drains. For storage tanks see also V. 4.

4.2 The air vents for the drainage tanks shall terminate above open deck. Air pipe closing device, see R, 1.3.

4.3 Drains shall be of self closing type if the tanks are located above double bottom.

5. Pressure Testing

See B.4.

6. Tightness and Operational Testing

After installation, the entire arrangement is to be subjected to tightness and operational testing under the supervision of **BCS**.

R. Air, Overflow and Sounding Pipes

The laying of air, overflow and sounding pipes is permitted only in places where the laying of the corresponding piping system is also permitted (see Table 16.6).

1. Air and Overflow Pipes

1.1 Arrangement

1.1.1 All tanks, void spaces etc. are to be fitted at their highest position with air pipes or overflow pipes which must normally terminate above the open deck.

1.1.2 Air and overflow pipes are to be laid vertically.

1.1.3 Air and overflow pipes passing through cargo holds are to be protected against damage.

1.1.4 The wall thickness of air pipes on the exposed deck is to be accordance with Table 16.22 and 16.23.

For the height above deck of air/overflow pipes and necessity of fitting brackets on air pipes, see Chapter 1 - Hull, Section 16, D.

1.1.5 Air pipes from unheated leakage oil tanks and lubricating oil tanks may terminate at clearly visible positions in the engine room. Where these tanks form part of the ship's hull, the air pipes are to terminate above the free board deck, on passenger ships above the bulkhead decks. It must be ensured that no leaking oil can spread onto heated surfaces where it may ignite.

1.1.6 Air pipes from lubricating oil tanks and leakage oil tanks which terminate in the engine room are to be provided with funnels and pipes for safe drainage in the event of possible overflow.

1.1.7 On cargo ships of 500 gross tons or above and on all passenger ships air pipes of lubricating oil tanks which terminate on open deck are to be arranged such that in the event of a broken air pipe this shall not directly lead to the risk of ingress of sea or rain water.

Table 16.22 Choice of minimum wall thicknesses

Piping system or position of open pipe outlets	Location								
	Tanks with same media	Tanks with disparate-media	Drain lines and scupper pipes			Air escape, sounding and overflow pipes		Cargo holds	Machinery spaces
			below freeboard deck on bulkhead deck		above free board deck	above weather deck	below weather deck		
			without shut-off on ship's side	with shut-off on ship's side					
Air, Overflow and sounding pipe	A	C	-	-	-	C	A	A	A
Scupper pipes from open deck		B	-	A	A	-	-	B	
Discharge and scupper pipes leading directly overboard			B		-				
Discharge pipes of pumps for sanitary systems			-		A				

1.1.8 Wherever possible, the air pipes of feedwater and distillate tanks should not extend into the open.

1.1.9 Where these tanks form part of the ship's shell the air pipes are to terminate within the engine room casing above the freeboard deck, in passenger ships above the bulkhead deck.

1.1.10 Air pipes for cofferdams and void spaces with bilge connections are to be extended above the open deck respectively on passenger vessels above the bulkhead deck.

1.1.11 On cargo ships of 500 gross tons or above and on all passenger ships air pipes of fuel service and settling tanks which terminate on open deck are to be arranged such that in the event of a broken air pipe this shall not directly lead to the risk of ingress of sea-or rainwater (see also V.2).

1.1.12 Where fuel day tanks are fitted with change-over overflow pipes, the change-over devices are to be so arranged that the overflow is led to one of the storage tanks.

1.1.13 The overflow pipes of tanks used alternatively for oil fuel and ballast water must be capable of being separated from the fuel overflow system.

1.1.14 Where the air and overflow pipes of several tanks situated at the ship's shell lead to a common line, the connections to this line are to be above the freeboard deck if possible but at least so high above the deepest load water line that should a leakage occur in one tank due to damage to the hull or listing of the ship, fuel or water cannot flow into another tank.

1.1.15 The air and overflow pipes of lubricating oil and fuel tanks shall not be led to a common line.

Table 16.23 Minimum wall thicknesses of air, overflow, sounding and sanitary pipes

Pipe outside diameter [mm]	Minimum wall thickness [mm]		
	A	B	C
38 - 82.5	4.5	7.1	6.3
88.9	4.5	8	7.1
108	4.5	8	7.1
114.3	4.5	8	8
127 - 139.7	4.5	8.8	8
152.4 - 168.3	4.5	10	8.8
177.8	5	10	8.8
193.7	5.4	12.5	8.8
219.1	5.9	12.5	8.8
244.5-457.2	6.3	12.5	8.8

1.1.16 For the connection to a common line of air and overflow pipes on ships with classification mark **FS**, see D.9.

1.1.17 For the cross-sectional area of air pipes and air/overflow pipes, see Table 16.24.

1.2 Number of air and overflow pipes

1.2.1 The number and arrangement of the air pipes is to be so performed that the tanks can be aerated and de-aerated without exceeding the tank design pressure by over- or under-pressure.

1.2.2 Tanks which extend from side to side of the ship must be fitted with an air/overflow pipe at each corner. At the narrow ends of double bottom tanks in the forward and after parts of the ship, only one air/overflow pipe is sufficient.

1.3 Air pipe closing devices

Air/overflow pipes terminating above the open deck are to be fitted with approved air pipe heads.

To prevent blocking of the air pipe head openings by their floats during tank discharge the maximum allowable air velocity determined by the manufacturer is to be observed.

1.4 Overflow systems

1.4.1 Ballast water tanks

Proof by calculation is to be provided for the system concerned that under the specified operating conditions the design pressures of all the tanks connected to the overflow system cannot be exceeded.

1.4.2 Fuel oil tanks

The requirements to be met by overflow systems of heavy oil tanks are specified in the **BCS** "Regulation for the Construction, Fitting and Testing of Closed Fuel Overflow Systems".

Table 16.24 Cross-Sectional areas of air and overflow pipes

Tank filling systems		Cross-sectional areas of air and overflow pipes	
		HB	HTB
Filling	by gravity	1/3 f per tank	-
	Pumping	-	1.25 f per tank (1)
<p>Explanatory note: HB = Air pipe HTB = Air/overflow pipe f = Cross-sectional area of tank filling pipe</p> <p>(1) 1.25 f as the total cross-sectional area is sufficient if it can be proved that the resistance to flow of the air and overflow pipes including the air pipe closing devices at the proposed flow rate cannot cause unacceptably high pressures in the tanks in the event of overflow.</p>			

For more details about air pipe closing devices see "Technical Circulars, Machinery, S-P 36/13 Air Pipe Closing Devices".

1.4.3 The overflow collecting manifolds of fuel tanks are to be led at a sufficient gradient to an overflow tank of sufficient capacity.

The overflow tank is to be fitted with a level alarm which operates when the tank is about 1/3 full.

1.4.4 For the size of the air and overflow pipes see Table 16.25.

1.4.5 The use of a fuel storage tank as overflow tank is allowable but requires the installation of a high level alarm and an air pipe with 1.25 times the cross-sectional area of the main bunkering line.

1.5. Determination of the pipe cross-sectional areas

1.5.1 For the cross-sectional areas of air and overflow pipes, see Tables 16.24 and 16.25.

The minimum outside diameter of air and overflow pipes shall not be smaller than 60.3 mm.

On ships > 80 meters in length, in the forward quarter only air/overflow pipes with an outer diameter ≥ 76.1 mm. may be used. See also Chapter 1 - Hull, Section 16.

1.5.2 The clear cross-sectional area of air pipes on passenger ships with cross-flooding arrangement must be so large that the water can pass from one side of the ship to the other within 15 minutes. See also P.3.

1.6 The minimum wall thicknesses of air and overflow pipes are to be in accordance with Tables 16.22 and 16.23, whereby A, B and C are the groups for the minimum wall thickness.

1.7 For pipe material are to be selected according to B.

2. Sounding Pipes

2.1 General

2.1.1 Sounding pipes are to be provided for tanks, cofferdams and void spaces with bilge connections and for bilges and bilge wells in spaces which are not accessible at all times.

On application, the provision of sounding pipes for bilge wells in permanently accessible spaces may be dispensed with.

2.1.2 Where the tanks are fitted with remote level indicators which are type -approved by **BCS** the arrangement of sounding pipes can be dispensed with.

2.1.3 As far as possible, sounding pipes are to be laid straight and are to extend as near as possible to the bottom.

2.1.4 Sounding pipes which terminate below the deepest load waterline are to be fitted with self-closing shut-off devices. Such sounding pipes are only allowable in spaces which are accessible at all times.

All other sounding pipes are to be extended to the open deck. The sounding pipe openings must always be accessible and fitted with watertight closures.

2.1.5 Sounding pipes of tanks are to be provided close to the top of the tank with holes for equalizing the pressure.

2.1.6 In cargo holds, a sounding pipe is to be fitted to each bilge well.

2.1.7 Where level alarms are arranged in each bilge well of cargo holds, the sounding pipes may be dispensed with. The level alarms are to be separate from each other and are to be type approved by **BCS (7)**.

2.1.8 In cargo holds, fitted with non weather tight hatch covers, 2 level alarm are to be provided in each cargo holds, irrespective if sounding pipes are fitted. The level alarms are to be independent from each other and are to be type approved by **BCS**.

2.1.9 Sounding pipes passing through cargo holds are to be laid in protected spaces or they are to be protected against damage.

(7) *National Rules, if exist are to be observed.*

2.2 Sounding pipes for fuel, lubricating oil and thermal oil tanks

2.2.1 Sounding pipes which terminate below the open deck are to be provided with self-closing devices as well as with self-closing test valves, see also V.2.

2.2.2 Sounding pipes shall not to be located in the vicinity of firing plants, machine components with high surface temperatures or electrical equipment.

2.2.3 Sounding pipes must not terminate in accommodation or service spaces.

2.2.4 Sounding pipes are not to be used as filling pipes.

2.3 Cross-sections of pipes

2.3.1 Sounding pipes shall have a nominal inside diameter of at least 32 mm.

2.3.2 The nominal diameters of sounding pipes which pass through refrigerated holds at temperatures below 0°C are to be increased to an inside diameter of 50 mm.

2.4 The minimum wall thicknesses of sounding pipes are to be in accordance with Tables 16.22 and 16.23.

2.5 For pipe materials see B.

S. Drinking Water Systems (8)

1. Drinking water tanks

1.1 For the design and arrangement of drinking water tanks see Chapter 1 - Hull, Section 12.

(8) National requirements, if any, are to be observed.

Table 16.25 Cross-sectional areas of air and overflow pipes (closed overflow systems)

Tank filling and overflow systems		Cross-sectional areas of air and overflow pipes			Remarks
		HB	TB (2)	BB	
Filling	Stand-pipe	1/3 f	-	-	cross-sectional area of stand-pipe $\geq 1.25 F$
	Relief valve	1/3 f (1)	min. 1.25 F	-	nominal diameter of relief valve $\geq 1.25 F$
Overflow system	Overflow chest	1/3 F at chest	min. 1.25 F	1.25 F	-
	Manifold	1/3 F	min. 1.25 F	-	-
	Overflow tank	1/3 F	-	-	-
Explanatory notes: <i>HB</i> = Air pipe <i>TB</i> = Overflow pipe <i>BB</i> = Drainage line <i>f</i> = Cross-sectional area of tank filling pipe <i>F</i> = Cross-sectional area of main filling pipe (1) 1/3 f only for tanks in which an overflow is prevented by structural arrangements. (2) Determined in accordance with 1.4.					

1.2 On ships with ice class ICE-B1 and higher drinking water tanks located at the ship's side above the ballast waterline are to be provided with means for tank heating to prevent freezing.

2. Drinking Water Tank Connections

2.1 Filling connections are to be located sufficiently high above deck and are to be fitted with a closing device.

2.1.1 Filling connections are not to be fitted to air pipes.

2.2 Air/overflow pipes are to be extended above the open deck and are to be protected against the entry to insects by a fine mesh screen.

Air pipe closing devices, see R.1.3.

2.3 Sounding pipes must terminate sufficiently high above deck.

3. Drinking Water Pipe Lines

3.1 Drinking water pipe lines are not to be connected to pipe lines carrying other media.

3.2 Drinking water pipe lines are not to be laid through tanks which do not contain drinking water.

3.3 Drinking water supply to tanks which do not contain drinking water (e.g. expansion tanks of the fresh water cooling system) is to be made by means of an open funnel or with means of preventing flow-back

4. Pressure Water Tanks / Calorifiers

For design, equipment, installation and testing of pressure water tanks and calorifiers, Section 14, A. and E. are to be observed.

5. Drinking Water Pumps

5.1 Separate drinking water pumps are to be provided for drinking water systems.

5.2 The pressure lines of the pumps of drinking water pressure tanks are to be fitted with screw-down non-return valves.

6. Drinking Water Generation

Where the distillate produced by the ships own evaporator units is used for the drinking water supply, the treatment of the distillate has to comply with current regulations of national health authorities.

T. Sewage and Gravity Drain Systems

1. General

1.1 Ships of 400 GT and above and ships of less than 400 GT which are certified to carry more than 15 persons are to be fitted with the following equipment:

- A sewage treatment plant approved according to Resolution MEPC.227(64), as amended, or
- A sewage comminuting and disinfecting system (facilities for the temporary storage of sewage when the ship is less than 3 nautical miles from the nearest land, to be provided), or
- A sewage holding tank

1.2 All ships subject to Annex IV, irrespective of their size and of the presence of a sewage treatment plant or sewage holding tank, shall be provided with a pipeline and the relevant shore connection flange for discharging sewage to port sewage treatment facility. The pipeline is to be provided with a standard discharge connection according to MARPOL 73/78, Annex IV, Regulation 10.

1.3 The holding tank shall have means to indicate visually the content. The use of a sounding pipe is not allowed because of hygienic reasons.

2. Arrangement

2.1 For scuppers and overboard discharges see Chapter 1 -Hull, Section 16.

2.2 The minimum wall thicknesses of sanitary discharge pipes below freeboard and bulkhead decks are specified in Tables 16.22 and 16.23.

2.3 For discharge lines above freeboard deck/bulkhead deck the following pipes may be used:

- Steel pipes according to Table 16.5, Group N,
- Pipes having smaller thicknesses which are specially protected against corrosion after special approval,
- Special types of pipes according to recognized standards, e.g. socketed pipes, after special approval.

2.4 For sanitary discharge lines below freeboard deck/bulkhead deck within a watertight compartment, which terminate in a sewage tank or in a sanitary treatment plant, pipes according to 2.3 may be used.

2.5 Penetrations of pipes of smaller thickness pipes of special types and plastic pipes through bulkheads of type A are to be approved by **BCS**.

2.6 If sanitary discharge pipes are led through cargo holds, they are to be protected against damage by cargo.

2.7 Sewage tank and sewage treatment systems

2.7.1 Sewage tanks are to be fitted with air pipes leading to the open deck. For air pipe closing devices see Section 16, R.1.3.

2.7.2 Sewage tank are to be fitted with a filling connection, a rinsing connection and a level alarm.

2.7.3 The discharge lines of sewage tanks and sewage treatment tanks are to be fitted at the ships' side with screw-down non-return valves.

When the valve is not arranged directly at the ships' side, the thickness of the pipe is to be according to Table 16.23, column B.

2.7.4 A second means of reverse flow protection is to be fitted in the suction or delivery line of the sewage pump from sewage tanks or sewage treatment plants if, in the event of a 5° heel to port or starboard, the lowest internal opening of the discharge system is less than 200 mm. above the summer load line. **(9)**

The second means of reverse-flow protection may be a pipe loop having an overflow height above the summer load line of at least 200 mm. at a 5° list. The pipe loop is to be fitted with an automatic ventilation device located at 45° below the crest of the loop.

2.7.5 Where at a heeling of the ship of 5° at port or starboard, the lowest inside opening of the sewage system lies on the summer load line or below, the discharge line of the sewage collecting tank is to be fitted in addition to the required reverse-flow protection device according to 2.7.4 with a gate valve directly on the ships' side. In this case the reverse-flow protection device needs not to be of screw-down type.

2.7.6 Ballast and bilge pumps may not be used for emptying sewage tanks.

3. Additional Rules for Ships with Classification Mark FS

3.1 The sanitary arrangement and their discharge lines are to be so located that in the event of damage of one compartment no other compartments can be flooded.

(9) *Where sanitary treatment arrangements are fitted with emergency drains to the bilge or with openings for chemicals, these will be considered as internal openings in the sense of these Rules.*

3.2 If this condition cannot be fulfilled, e.g. When:

- Watertight compartments are connected with each other through internal openings of the sanitary discharge lines, or
- Sanitary discharge lines from several watertight compartments are led to a common drain tank, or
- Parts of the sanitary discharge system are located within the damage zone (see D.9.) and these are connected to other compartments over internal openings,

The water tightness is to be ensured by means of remote controlled shut-off device at the watertight bulkheads.

The operation of the shut-off devices must be possible from an always accessible position above the bulkhead deck on passenger ships and above the unsuitable leak water line on other ships. The position of the shut-off devices must be monitored at the remote control position.

3.3 Where the lowest inside opening of the sanitary discharge system is below the bulkhead deck, a screw-down non-return valve and a second reverse-flow protection device are to be fitted in the discharge line of the sanitary water treatment arrangement. In this case, the discharge line of sanitary collecting tanks is to be fitted with a gate valve and two reverse-flow protection devices. Concerning the shut-off devices and reverse-flow protection devices, 2.7.3 and 2.7.4 and 2.7.5 are to be applied.

4. Gravity Drain Systems

4.1 Application

These requirements apply to gravity drain systems from watertight and non-watertight spaces located either above or below the freeboard deck.

4.2 Definitions

4.2.1 Gravity drain system

A gravity drain system is a piping system in which flow is accomplished solely by the difference between the

height of the inlet end and the outlet end. For the purposes of the requirements, gravity drain systems include those which discharge both inside and outside the vessel.

4.2.2 Gravity discharge

A gravity discharge is an overboard drain from a watertight space such as spaces below freeboard deck or within enclosed superstructures or deckhouses. Back flooding through a gravity discharge would affect the reserve buoyancy of the vessel.

4.2.3 Inboard end

The inboard end of an overboard gravity discharge pipe is that part of the pipe at which the discharge originates. The inboard end to be considered for these requirements is the lowest inboard end where water would enter the vessel if back-flooding would occur.

4.2.4 Scupper

A scupper is an overboard drain from a non-watertight space or deck area. Back-flooding through a scupper would not affect the reserve buoyancy of the vessel.

4.3 Basic Principles

Enclosed watertight spaces (spaces below freeboard deck or within enclosed superstructures or deckhouses) are to be provided with means of draining. This may be achieved by connection to the bilge system or by gravity drain. In general, a gravity drain is permitted wherever the position of the space allows liquid to be discharged by gravity through an appropriate opening in the boundary of the space. Unless specifically demanded by **BCS** (see 4.5.2 or the following paragraph), the discharge can be directed overboard or inboard. Where directed overboard, means are to be provided to prevent entry of sea water through the openings in accordance with 4.4. Where directed inboard, suitable arrangements are to be provided to collect and dispose of the drainage.

Non-watertight spaces (open superstructures or deckhouses) and open decks, where liquid can accumulate, are also to be provided with means of

draining. In general, a gravity drain is permitted for all non-watertight spaces. All such drains are to be directed overboard.

Gravity drains are to be capable of draining the space when the vessel is on even keel and either upright or listed 5 degrees on either side.

In addition to the requirements identified below, for gas carriers see Chapter 10, Section 2, 2.3, for chemical carriers see Chapter 8, Section 2, 2.3 and for passenger vessels see Chapter 1, Section 30, K.

4.4 Protection from Sea Water Entry

4.4.1 Overboard Gravity Discharges – Normally Open

4.4.1.1 General

Gravity discharge pipes led overboard from any watertight space are to be fitted with an effective and accessible means, as described below, to prevent backflow of water from the sea into that space. The requirements for non-return valves in this subparagraph are applicable only to those discharges which remain open during the normal operation of the vessel.

Normally, each separate discharge is to have one non-return valve with a positive means of closing it from a position above the freeboard deck. The means for operating the positive closing valve is to be readily accessible and provided with an indicator showing whether the valve is open or closed. Alternatively, one non-return valve and one positive closing valve controlled from above the freeboard deck may be accepted.

Where, however, the vertical distance from the summer load waterline (or, where assigned, timber summer load waterline) to the inboard end of the discharge pipe exceeds 1% of the freeboard length of vessel, the discharge may have two non-return valves without positive means of closing, provided that the inboard non-return valve is always accessible for examination under all service conditions, that is, above the tropical load waterline (or, where assigned, timber tropical load waterline.) If this is impracticable, a locally operated positive closing valve may be provided between the two non-return valves, in which case, the inboard non-return valve need not be located above the specified tropical load waterline.

Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 2% of the freeboard length of vessel, a single non-return valve without positive means of closing is acceptable, provided it is located above the tropical load waterline (or, where assigned, timber tropical load waterline.) If this is impracticable, a locally operated positive closing valve may be provided below the single non-return valve, in which case, the non-return valve need not be located above the specified tropical load waterline.

4.4.1.2 Manned Machinery Space

Where sanitary discharges and scuppers lead overboard through the shell in way of machinery spaces, the fitting to the shell of a locally operated positive closing valve, together with a non-return valve inboard, will be acceptable.

See Table 16.26 for the acceptable arrangements of scuppers, inlets and discharges.

4.4.2 Overboard Gravity Discharges – Normally Closed

For overboard discharges which are closed at sea, such as gravity drains from topside ballast tanks, a single screw down valve operated from above the freeboard deck is acceptable.

4.4.3 Overboard Gravity Discharges from Spaces below the Freeboard Deck on Vessels Subject to SOLAS Requirements

For vessels subject to SOLAS requirements, instead of the requirements identified in 7.4.1 above, each separate gravity discharge led through the shell plating from spaces below the freeboard deck is to be provided with either one automatic non–return valve fitted with a positive means of closing it from above the freeboard deck or with two automatic non–return valves without positive means of closing, provided that the inboard valve is situated above the deepest subdivision load line (DSL) and is always accessible for examination under service conditions.

Where a valve with positive means of closing is fitted, the operating position above the freeboard deck shall always be readily accessible and means shall be provided for indicating whether the valve is open or closed.

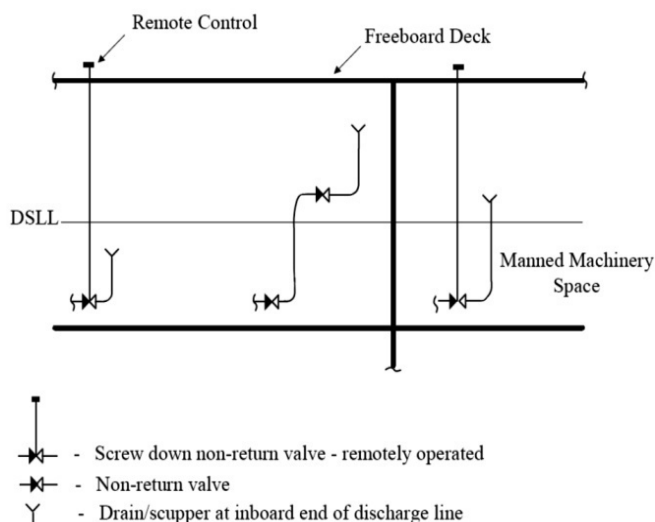


Figure 16.4 Overboard discharges from spaces below freeboard deck and valve arrangements according to SOLAS

4.4.4 Scuppers and Discharges Below the Freeboard Deck – Shell Penetration

Scuppers and discharge pipes originating at any level and penetrating the shell either more than 450 mm. below the freeboard deck or less than 600 mm. above the summer load waterline is to be provided with a non-return valve at the shell.

This valve, unless required above may be omitted if the length of piping from the shell to freeboard deck has a wall thickness in accordance with Tables 16.22 and 16.23. Interpolation is applicable for any interval points.

4.5 Gravity Drains of Cargo Spaces on or Above Freeboard Deck

4.5.1 Overboard Drains

Enclosed cargo spaces of a vessel, whose summer freeboard is such that the deck edge of the cargo spaces being drained is not immersed when the vessel

heels 5 degrees, may be drained by means of a sufficient number of suitably sized gravity drains discharging directly overboard. These drains are to be fitted with protection complying with 4.4.

4.5.2 Inboard Drains

Where the summer freeboard is such that the deck edge of the cargo space being drained is immersed when the vessel heels 5 degrees, the drains from these enclosed cargo spaces are to be led to a suitable space, or spaces, of adequate capacity, having a high water level alarm and provided with fixed pumping arrangement for discharge overboard. In addition, the system is to be designed such that:

- The number, size and disposition of the drain pipes are to prevent unreasonable accumulation of free water and drain tanks should be fitted high level alarm systems.
- A overboard discharge pipe line should be considered for preventing any overflowing from any fulfilled drain tanks into the machinery spaces. The pumping Arrangements are to take into account the requirements for any fixed pressure water-spraying fire-extinguishing system;
- Water contaminated with substances having flash point of 60°C or below is not to be drained to machinery spaces or other spaces where sources of ignition may be present; and
- Where the enclosed cargo space is protected by a fixed gas fire-extinguishing system, the drain pipes are to be fitted with means to prevent the escape of the smothering gas. The U-tube water seal arrangement should not be used due to possible evaporation of water and the difficulty in assuring its effectiveness.

Table 16.26 Overboard Discharges – Valve Requirements

Discharges coming from enclosed spaces below the freeboard deck or on the freeboard deck				Discharges coming from other spaces		
General requirement where inboard end < 0.01L above SWL	Discharges through manned machinery space		Alternatives where inboard end > 0.01L above SWL		outboard end > 450 mm below FB deck or < 600 mm above SWL	otherwise
	> 0.01L above SWL		> 0.02L above SWL			
Superstructure or Deckhouse Deck						
FB Deck					FB Deck	
SWL					SWL	

4.5.3 Cargo Spaces Fitted with Fixed Water-Spray System

Where the cargo space is fitted with a fixed water-spray fire extinguishing system, the drainage arrangements are to be such as to prevent the build-up of free surfaces. If this is not possible, the adverse effects upon stability of the added weight and free surface of water are to be taken into account for the approval of the stability information. See N.4.3.5.

4.6 Gravity Drains of Spaces Other than Cargo Spaces

4.6.1 Gravity Drains Terminating in Machinery Space

Watertight spaces such as a steering gear compartment, accommodations, voids, etc. may be drained to the main machinery space; all such drains are to be fitted with a valve operable from above the freeboard deck or a quick-acting, self closing valve. The valve is to be located in an accessible and visible location and preferably in the main machinery spaces.

4.6.2 Gravity Drains Terminating in Cargo Holds

When gravity drains from other spaces are terminated in cargo holds, the cargo hold bilge well is to be fitted with high level alarm.

4.6.3 Gravity Drains Terminating in a Drain Tank

Where several watertight compartments are drained into the same drain tank, each drain pipe is to be provided with a stop-check valve.

4.6.4 Escape of Fire Extinguishing Medium

Gravity drains which terminate in spaces protected by fixed gas extinguishing systems are to be fitted with means to prevent the escape of the extinguishing medium. See also 4.5.2.

4.7 Gravity Drains of Non-Watertight Spaces

4.7.1 General

Scuppers leading from open deck and non-watertight superstructures or deckhouses are to be led overboard.

The requirements of 4.4.4 also apply.

4.7.2 Helicopter Decks

Drainage piping of helicopter decks is to be constructed of steel. The piping is to be independent of any other piping system and is to be led directly overboard close to the waterline. The drain is not to discharge onto any part of the vessel.

4.8 Vessels Subject to Damage Stability

Gravity drain piping where affected by damage stability considerations is to meet D.9.

4.9 Vessels Receiving Subdivision Loadlines

For vessel receiving subdivision loadlines, the bulkhead deck is to apply to provisions given in 4.4 when it is higher than the freeboard deck.

U. Hose Assemblies and Compensators (See also Section 16, D.10 and 11)

1. Scope

1.1 The following Rules are applicable for hose assemblies and compensators made of non-metallic and metallic materials.

1.1.1 Hose assemblies and compensators made of non-metallic and metallic materials may be used according to their suitability in fuel-, lubricating oil-, hydraulic oil-, bilge-, ballast-, fresh water cooling-, sea water cooling-, compressed air- auxiliary steam **(10)** exhaust gas and thermal oil systems as well as in secondary piping systems.

1.2 Hose assemblies and compensators made of non-metallic materials are not permitted in permanently pressurized starting air lines.

Furthermore, it is not permitted to use hose assemblies and compensators in fuel injection piping systems of combustion engines.

(10) *Metallic hose assemblies and compensators only.*

1.3 Compensators made of non-metallic materials are not approved for the use in cargo lines of tankers

2. Definitions

- **Hose assemblies** consist of metallic or non-metallic hoses completed with end fittings ready for installation.
- **Compensators** consist of bellows with end fittings as well as anchors for absorption of axial loads where angular or lateral flexibility is to be ensured. End fittings may be flanges, welding ends or approved pipe unions.
- **Burst pressure** is the internal static pressure at which a hose assembly or compensator will be destroyed.

2.1 High-pressure hose assemblies made of non-metallic materials

Hose assemblies which are suitable for use in systems with distinct dynamic load characteristic.

2.2 Low-pressure hose assemblies and compensators made of non-metallic materials

Hose assemblies or compensators which are suitable for use in systems with predominant static load characteristics.

2.3 Maximum allowable working pressure

2.3.1 The maximum allowable working pressure of high pressure hose assemblies is the maximum dynamic internal pressure permitted to be imposed on the components.

2.3.2 The maximum allowable working pressure respectively nominal pressure for low pressure hose assemblies and compensators is the maximum static internal pressure permitted to be imposed on the components.

2.4 Test pressure

2.4.1 For non-metallic high pressure hose assemblies the test pressure is 2 times the maximum

allowable working pressure.

2.4.2 For non-metallic low pressure hose assemblies and compensators the test pressure is 1.5 times the maximum allowable working pressure or 1.5 times the nominal pressure.

2.4.3 For metallic hose assemblies and compensators, the test pressure is 1.5 times the maximum allowable working pressure or 1.5 times the nominal pressure.

2.5 Burst Pressure

For non-metallic as well as metallic hose assemblies and compensators the burst pressure is required to be at least 4 times the maximum allowable working pressure or 4 times the nominal pressure.

Excepted hereof are non-metallic hose assemblies and compensators with a maximum allowable working pressure respectively nominal pressure of not more than 20 bar. For such components the burst pressure has to be at least 3 times the maximum allowable working pressure or three times the nominal pressure.

For hose assemblies and compensators in process and cargo piping for gas and chemical tankers the burst pressure is required to be at least 5 times the maximum allowable working pressure.

3. Requirements

3.1 Hose and compensators used in the systems mentioned in 1.1.1 are to be of approved type **(11)**.

3.2 Manufacturers of hose assemblies and compensators **(12)** must be recognized by **BCS**.

3.3 Hose assemblies and compensators including their couplings are to be suitable for media, pressures and temperatures they are designed for.

3.4 The selection of hose assemblies and compensators is to be based on the maximum allowable working pressure of the system concerned. A pressure of 5 bar is to be considered as the minimum working pressure.

3.5 Hose assemblies and compensators for the use in fuel-, lubricating oil-, hydraulic oil-, bilge- and sea water systems are to be flame-resistant **(12)**.

4. Installations

4.1 Hose assemblies shall only be used at locations where they are required for compensation of relative movements. They shall be kept as short as possible under consideration of the installation instruction of the hose manufacturer. The number of hose assemblies and compensators is to be kept to minimum.

4.2 The minimum bending radius of installed hose assemblies shall not be less than specified by the manufacturers.

4.3 Non-metallic hose assemblies and compensators are to be located at visible and accessible positions.

4.4 In fresh water systems with a working pressure of ≤ 5 bar and in charging and scavenging air lines, hoses may be fastened to the pipe and with double clips.

4.5 Where hose assemblies and compensators are installed in the vicinity of hot components they must be provided with approved heat-resistant sleeves.

4.6 Hose assemblies and compensators conveying flammable liquids that are in close proximity of heated surface are to be provided with screens or other similar protection to avoid the risk of ignition due to failure at the hose assembly or compensator according to the G.3.4.5.1. Hose assemblies and compensators are to be subjected in the manufacturer's works to a pressure test in accordance with 2.4 under the supervision of **BCS**.

5.2 For compensators intended to be used in exhaust gas pipes the pressure test according 5.1 may be omitted.

6. Ship Cargo Hoses

6.1 Ship cargo hoses for cargo-handling on

chemical tankers and gas tankers shall be type **(11)** approved.

Mounting of end fittings is to be carried out only by approved manufacturers **(12)**.

6.2 Ship cargo hoses are to be subjected to final inspection at the manufacturer under supervision of **BCS** surveyor as follows:

- Visual inspection,
- Hydrostatic pressure test with 1.5 times the maximum allowable working pressure or 1.5 times the nominal pressure. The nominal pressure shall be at least 10 bar.

Measuring of the electrical resistance between the end fittings. The resistance shall not exceed 1 k Ω .

6.3 Cargo hoses on gas tankers are additionally subject to the **BCS** Rules for Liquefied Gas Carriers, Section 20.

6.4 Cargo hoses on chemical tankers are additionally subject to the **BCS** Rules for Chemical Tankers, Section 20.

7. Marking

Hose assemblies and compensators must be permanently marked with the following particulars:

- Manufacturer's mark or symbol,
- Date of manufacturing,
- Type,
- Nominal diameter,

(11) See "Regulations for the Performance of Type Tests, Part 7- Test Requirements for Mechanical Components and Equipment"

(12) See "Regulations for the Recognition of Manufacturers of Hose Assemblies and Compensators."

- Maximum allowable working pressure respectively nominal pressure,
- Test certificate number and sign of the responsible **BCS** inspection office.

V. Storage of Liquid Fuels, Lubricating, Hydraulic and Thermal Oils and Oil Residues

1. General

1.1 Scope

The following requirements apply to the storage of liquid fuels, lubricating, hydraulic and thermal oils as well as to oily residues.

1.2 Definitions

- **Service tanks** are settling tanks and daily service tanks which supply consumers directly.
- **Changeable tanks** are tanks which may be used alternatively for liquid fuels or ballast water. Changeable tanks are to be treated as fuel tanks.

1.3 Tank plan

A tank plan is to be submitted in triplicate. Particulars regarding arrangement, medium and volume of the tanks are to be included.

2. Storage of Liquid Fuels

2.1 General safety precautions for liquid fuels

Tanks and pipes are to be so located and equipped that fuel may not spread either inside the ship or on deck and may not be ignited by hot surfaces or electrical equipment. The tanks are to be fitted with air and overflow pipes as safeguards against overpressure, see R.

2.2 Distribution, location and capacity of fuel tanks

2.2.1 Distribution of fuel tanks

2.2.1.1 The fuel supply is to be stored in several tanks so that, even in the event of damage of one of the tanks, the fuel supply will not be lost entirely. On passenger ships and on cargo ships of 400 GRT and over, no fuel tanks or tanks for the carriage of flammable liquids may be arranged forward of the collision bulkhead.

2.2.1.2 Provision is to be made to ensure that internal combustion engines and boiler plants operating on heavy fuel oil can be operated temporarily on fuel which does not need to be preheated. Appropriate tanks are to be provided for this purpose. This requirement does not apply where cooling water of the main or auxiliary engines is used for preheating of heavy fuel tanks. Other arrangements are subject to the approval of **BCS**.

2.2.1.3 Fuel tanks are to be separated by cofferdams from tanks containing lubricating, hydraulic, thermal or edible oil as well as from tanks containing boiler feed water, condensate or drinking water. This does not apply the used lubricating oil which will not be used on board anymore.

2.2.1.4 On small ships the arrangement of cofferdams according to 2.2.1.3 may, with the approval of **BCS** be dispensed with, provided that the common boundaries between the tanks are arranged in accordance with Chapter 1 - Hull, Section 12, A.

2.2.1.5 Fuel oil tanks adjacent to lubricating oil circulating tanks are not permitted.

2.2.2 Arrangements of fuel tanks

2.2.2.1 Fuel tanks may be located above engines, boilers, turbines and other equipment with a high surface temperature (above 220 °C) only if adequate spill trays are provided below such tanks and they are protected against heat radiation. Surface temperature of the elements without insulation and lagging shall be considered.

2.2.2.2 Fuel tanks shall be an integral part of the ship's structure. If this is not practicable, the tanks shall be located adjacent to an engine room bulkhead and the tank top of the double bottom. The arrangement of free-standing fuel tanks inside engine rooms is to be avoided. Tank arrangements which do not conform to the preceding rules require the approval of **BCS**.

2.2.2.3 Tanks adjacent to refrigerated cargo holds are subject to Chapter 15 – Refrigerating Installations, Section 1, M.

2.2.2.4 An independent fuel supply is to be provided for the prime movers of the emergency source of electrical power:

- On cargo ships, the fuel capacity is to be sufficient for at least 18 hours. This applies in analogous manner to the engines driving the emergency fire pumps.
- On passenger ships, the fuel capacity is to be sufficient for at least 36 hours. A reduction may be approved for passenger ships employed in short voyages only (in territorial waters), but the capacity is to be sufficient for at least 12 hours. On passenger ships, the fuel tank is to be located above the bulkhead deck and on cargo ships above the uppermost continuous deck, and in both cases outside the engine and boiler rooms and aft of the collision bulkhead. By the arrangement and/or heating of the fuel tank, the emergency diesel equipment is to be kept in a state of readiness even when the outside temperature is low.

2.2.2.5 Fuel oil service tanks provided for emergency diesel generators which are approved for operation in port for the main power supply shall be so designed that the capacity required under 2.2.2.4 is available at any time. An appropriate low level alarm is to be provided, see Chapter 5 – Electrical Installations, Section 3, D.

2.2.2.6 Fuel oil tanks and bunkers are not to be situated immediately above boilers or in locations where they could be subjected to high temperatures, unless specially agreed by the Society. In general, the distance between fuel oil tanks and boilers is not to be less than

450 mm. Where boilers are situated above double bottom fuel oil tanks, the distance between the double bottom tank top and the lower metallic part of the boilers is not to be less than:

- 750 mm for water tube boilers
- 600 mm for cylindrical boilers.

2.2.2.7 Protection against oil pollution in the event of collision or grounding

2.2.2.7.1 Application

The provisions of the present requirement apply to all ships with an aggregate oil fuel capacity of 600 m³ and above:

- For which the building contract is placed on or after 1 August 2007; or
- In the absence of a building contract, the keels of which are laid or which are at a similar stage of construction on or after 1 February 2008; or
- The delivery of which is on or after 1 August 2010.

The provisions of this requirement apply to all oil fuel tanks except small oil fuel tanks with a maximum individual capacity not exceeding 30 m³, provided that the aggregate capacity of such excluded tanks is not greater than 600 m³.

Note:

- 1) *For the purpose of application of this requirement, tanks containing oil residues (sludges) are to be considered as oil fuel tanks.*
- 2) *The provisions of this requirement apply to oil fuel overflow tanks except if they are provided with an alarm for detection of oil and kept empty according to the operational procedures.*

2.2.2.7.2 Maximum capacity of oil fuel tanks

Individual oil fuel tanks are not to have a capacity of

over 2500 m³.

2.2.2.7.3 Oil fuel tank protection

For ships having an aggregate oil fuel capacity 600 m³ and above, oil fuel tanks are to be located at a sufficient distance from the bottom shell plating *h* and from the side shell plating *w* in accordance with the relevant provisions of MARPOL 73/78, Annex I, Regulation 12A.

2.2.2.7.4 Suction wells

Suction wells in oil fuel tanks may protrude in the double bottom provided that the conditions stated in MARPOL 73/78, Annex I, Regulation 12A.10 are satisfied.

2.2.2.7.5 Valves

Lines of fuel oil piping located at a distance from the ship's bottom or from the ship's side less than *h* or *w* referred to in item 2.2.2.7.3 are to be fitted with valves or similar closing devices within, or immediately adjacent to, the oil fuel tank. These valves are to be capable of being brought into operation from a readily accessible enclosed space the location of which is accessible from the navigation bridge or propulsion machinery control position without traversing exposed freeboard or superstructure decks. The valves are to close in case of remote control system failure and are to be kept closed at sea at any time when the tank contains oil fuel except that they may be opened during oil fuel transfer operations.

- Valves for oil fuel tanks located in accordance with item 2.2.2.7.3 may be treated in a manner similar to the treatment of suction wells as per item 2.2.2.7.4 and therefore arranged at a distance from the ship's bottom of not less than 0.5 *h* referred to in item 2.2.2.7.3 (see the figure 16.5) (*)
- Valves for tanks which are permitted to be located at a distance from the ship's bottom or side at a distance less than *h* or *w* referred to in item 2.2.2.7, respectively, in accordance with the accidental oil fuel outflow performance standard of MARPOL 73/78, Annex I, Regulation 12A.11 may be arranged at the distance less than *h* or *w* referred to in

item 2.2.2.7, respectively(*)

-
- Fuel tank air escape pipes and overflow pipes are not considered as part of 'lines of fuel oil piping' and therefore may be located at a distance from the ship's side of less than *w*(*).

(*) BCS- *IMPC* 87.

2.2.2.8 For number and capacity of fuel oil service tanks, see G.

2.3 Fuel tank fittings and mountings

2.3.1 For filling and suction lines see G.; for air, overflow and sounding pipes, see R.

2.3.2 Service tanks are to be so arranged that water and residues can deposit despite of ship movement. Fuel tanks located above the double bottom are to be fitted with water drains with self-closing shut-off valves.

2.3.3 Tank gauges

2.3.3.1 The following tank gauges are permitted:

-
- Sounding pipes,
- Oil-level indicating devices (type approved),
- Oil-level gauges with flat glasses and self closing shut-off valves at the connections to the tank and protected against external damage.

2.3.3.2 For fuel storage tanks the provision of sounding pipes is sufficient. The sounding pipes may be dispensed with, if the tanks are fitted with oil-level indicating devices which have been type approved by **BCS**.

2.3.3.3 Fuel oil settling and daily service tanks are to be fitted with oil-level indicating devices or oil-level gauges according to 2.3.3.1.

2.3.3.4 Sight glasses and oil gauges fitted directly on the side of the tank and cylindrical glass oil gauges are

not permitted.

2.3.3.5. Sounding pipes of fuel tanks may not terminate in accommodation or passenger spaces, nor shall they terminate in spaces where the risk of ignition of spillage from the sounding pipes consists.

2.3.3.6 On passenger ships, sounding pipes and oil level indicating devices are permitted only where they do not require penetration below the tank top and where their failure or over-filling of the tanks cannot result in the release of fuel.

2.3.3.7 Sounding pipes should terminate outside machinery spaces. Where this is not possible, the following requirements are to be met:

- Oil-level gauges are to be provided in addition to the sounding pipes.
- Sounding pipes are to be located in a safe distance from ignition hazards or they are to be effectively screened to prevent that spillage through the sounding pipes may come into contact with a source of ignition.
- The sounding pipes are to be fitted with self closing shut-off devices and self-closing test cocks.

2.4 Fastening of appliances and fittings on fuel tanks

2.4.1 Appliances, mountings and fittings not forming part of the fuel tank equipment may be fitted to tank walls only by means of intermediate supports. To free-standing tanks only components forming part of the tank equipment may be fitted.

2.4.2 Valves and pipe connections are to be attached to doubler flanges welded to the tank wall. Holes for attachment bolts are not to be drilled in the tank wall. Instead of doubler flanges, thick walled pipe stubs with flange connections may be welded into the tank walls.

2.5 Tank heating system

2.5.1 Tanks are to be provided with a system for warming up viscous fuels. It has to be possible to control the heating of each individual tank. Heating coils are to be appropriately subdivided or arranged in groups with their own shut-off valves. Where necessary, suction pipes are to be provided with trace heating arrangement.

2.5.2 Fuel oil in storage tanks is not to be heated to temperatures within 10°C below the flash point of the fuel oil. In service tanks, settling tanks and any other tanks of supply systems fuel oil may be heated to higher temperatures if the following arrangements are to be provided:

- The length of the vent pipes from such tanks and/or cooling device is sufficient for cooling the vapours to below 60°C, or the outlet of the vent pipes is located 3 meters away from sources of ignition.
- Air pipe heads are fitted with flame screens.
- There are no openings from the vapour space of the fuel tanks into machinery spaces, bolted manholes are acceptable.
- Enclosed spaces are not to be located directly above such fuel tanks, except for vented cofferdams.
- Electrical equipment fitted in the vapour space has to be of certified type to be intrinsically safe.

2.5.3 For ships with ice class the tank heating is to be so designed that the fuel oil remains capable of being pumped under all ambient conditions.

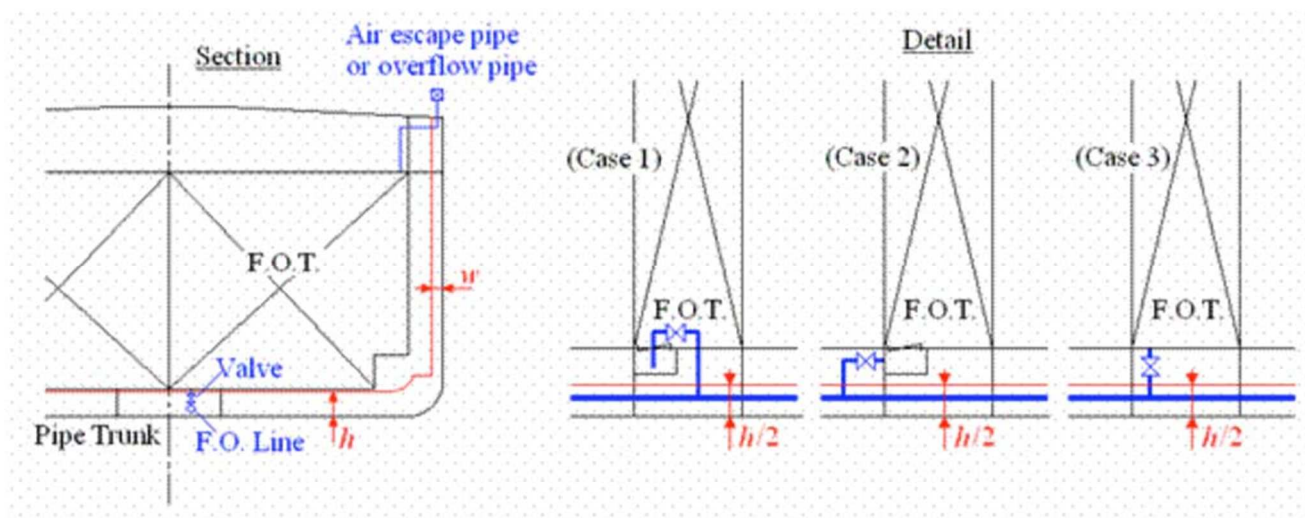


Figure 16.5 Fuel tank air escape pipes, overflow pipes and valves for oil fuel tanks

2.5.4 At tank outlets, heating coils are to be fitted with means of closing. Steam heating coils are to be provided with means for testing the condensate for oil between tank outlet and closing device. Heating coil connections in tanks normally are to be welded. The provision of detachable connections is permitted only in exceptional cases. Inside tanks, heating coils are to be supported in such a way that they are not subjected to impermissible stresses due to vibration, particularly at their points of clamping.

2.5.5 Tanks for fuel which requires preheating are to be fitted with thermometers and, where necessary, with thermal insulation.

2.5.6 For the materials, wall thickness and pressure testing of heating coils, see B.

2.6 Hydraulic pressure tests

Fuel tanks are to be tested for tightness in accordance with Chapter 1 - Hull, Section 12, H.

2.7 Fuels with a flash point of $\leq 60^{\circ}\text{C}$

For the storage of liquid fuels with a flash point of $\leq 60^{\circ}\text{C}$, see Section 1, D.16.

3. Storage of Lubricating and Hydraulic Oils

3.1 Tank arrangement

For the arrangement of the tanks 2.2.2.1 and analogously Chapter 1 - Hull, Section 8, B.5.1 are to be applied.

3.2 Tank fittings and mountings

3.2.1 For filling and suction lines of lubricating oil and hydraulic oil tanks, see H.2.2.

3.2.2 For tank sounding devices for oil tanks, see 2.3.3.1, 2.3.3.4 and 2.3.3.6.

3.2.3 For the fastening of appliances and fittings on the tanks, 2.4. is to be applied analogously.

3.2.4 For tank heating systems the requirements of 2.5.4 are to be observed.

3.3 Capacity and construction of tanks

3.3.1 Lubricating oil circulation tanks are to be sufficiently dimensioned to ensure that the dwell time is long enough for settling out of air bubbles, residues, etc.

With a maximum permissible filling level of about 85 %, the tanks are to be large enough to hold at least the lubricating oil contained in the entire circulation system including the contents of gravity tanks.

3.3.2 Measures, such as the provision of baffles or limber holes consistent with structural strength requirements, particularly relating to the machinery bed plate, are to be provided to ensure that the entire content of the tank remains in circulation. Limber holes are to be located as near to the bottom of the tank as possible. Suction pipe connections are to be placed as far as practicable away from the oil drain pipe so that neither air nor sludge may be sucked in irrespective of the heeling angle of the ship likely to be encountered during service.

3.3.3 Lubricating oil circulating tanks are to be equipped with sufficiently dimensioned vents.

4. Storage of Thermal Oils

4.1 Arrangement of tanks

For the arrangement of the tanks 2.2.2.1 and Chapter 1 - Hull, Section 8, B.5 are to be applied analogously.

4.2 Tank fittings and mountings

4.2.1 For tank measuring devices for thermal oil tanks, see 2.3.3 and Section 13. Expansion tanks are to be fitted with type approved level indicating devices.

4.2.2 For the mounting of appliances and fittings on the tanks, 2.4 is to be applied analogously.

4.2.3 For filling and suction lines of thermal oil tanks see H.2.2.

5. Storage of Oil Residues

5.1 Tank heating system

To ensure the pumpability of the oil residues a tank heating system in accordance with 2.5. is to be provided, if considered necessary. Sludge tanks are generally to be fitted with means of heating which are to be so designed that the content of the sludge tank may

be heated up to 60°C.

5.2 Sludge tanks

5.2.1 Capacity of sludge tanks

The capacity of sludge tanks shall be such that they are able to hold the residues arising from the operation of the ship having regard to the scheduled duration of a voyage **(13),(14)**.

5.2.2 Fittings and mountings of sludge tanks

5.2.2.1 For tank sounding devices 2.3.3.2 and 2.3.3.5 are to be applied analogously.

5.2.2.2 For air pipes, see R.

6. Storage of Gas Bottles for Domestic Purposes

6.1 Storage of gas bottles shall be located on open deck or in well ventilated spaces which only having access to open deck only.

6.2 Gaseous fuel systems for domestic purposes shall comply with a recognized standard **(13)**.

A portion of open deck, recessed into a deck structure, machinery casing, deck house, etc., utilized for the exclusive storage of gas bottles is considered acceptable for the purpose of 6.1 and 6.2 provided that:

- Such a recess has an unobstructed opening, except for small appurtenant structures, such as opening corner radii, small sills, pillars, etc. The opening may be provided with grating walls and door;
- The depth of such a recess is not greater than 1 m.

A portion of open deck meeting the above shall be considered as open deck in applying tables 9.1 to 9.8 of SOLAS Chapter II-2.

(13) *National requirements, if any, are to be observed.*

(14) *Reference is made to MEPC Circular 642 as amended by MEPC.1/Circ.676 and MEPC.1/Circ.760*

SECTION 17
SPARE PARTS

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B. LISTS OF MINIMUM RECOMMENDED SPARE PARTS	17- 2

A. General

1. Spare parts in general are not mandatory for retention of class. It is, however, assumed that an inventory of spare parts for main drive and the operationally important auxiliary machinery is maintained on board every ship together with the necessary tools; sufficient to meet the needs posed by the ship's plans of operation. Its content should be decided taking into consideration:

- The probability of need as a consequence of likely failures,
- The likely failures and effect on the main functions,
- The possibility of the ship's staff effecting the necessary repairs.

2. For systems and components related to main functions, depending on the design and arrangement of the engine plant, the intended service and operation of the ship, the recommendations of the manufacturer shall also be taken into account.

3. Any applicable statutory requirement of the country of registration of the ship is also to be considered.

4. **BCS** may require specific spare parts to be carried, if deemed necessary as a mandatory requirement. The extent and amount is to be decided on a case by case basis.

5. Minimum recommended spare parts lists, from Table 17.1 to Table 17.5, including the necessary tools and instructions for replacement, specified in this document are related to the ships for unrestricted services.

Spare parts lists for ships with restricted service are to be agreed between the ship owner and **BCS** by taking into consideration e.g. ship type, capacity, range, travel time, the intended area of operation, availability of rescue facilities in the area and proximity to a place of refuge.

Spare parts lists specified in this document can be used as a basis document for the preparation of the spare parts lists for ships with restricted service.

B. Lists of Minimum Recommended Spare Parts

1. Spare parts for main internal combustion engines, see Table 17.1.

2. Spare parts for each type of auxiliary internal combustion engine driving electric generators for essential services, see Table 17.2.

3. Spare parts for auxiliary steam turbines driving electric generators for essential services, see Table 17.3.

4. Spare parts for main steam turbines, see Table 17.4.

5. Spare parts for essential auxiliary machinery, see Table 17.5.

Table 17.1 List of minimum recommended spare parts for main internal combustion engines of ships for unrestricted services

Item	Spare part	Number recommended
1. Main bearings	Main bearings or shells for one bearing of each size and type fitted, complete with shims, bolts and nuts	1
2. Main thrust block	Pads for one face of Michell type thrust block, or	1 set
	Complete white metal thrust shoe of solid ring type, or	1
	Inner and outer race with rollers, where roller thrust bearings are fitted	1
3. Cylinder liner	Cylinder liner, complete with joint rings and gaskets	1
4. Cylinder cover	Cylinder cover, complete with valves, joint rings and gaskets	1
	Cylinder cover bolts and nuts, for one cylinder	½ set
5. Cylinder valves	Exhaust valves, complete with casings, seats, springs and other fittings for one cylinder	2 sets
	Air inlet valves, complete with casings, seats, springs and other fittings for one cylinder	1 set
	Starting air valve, complete with casings, seat springs and other fittings	1
	Cylinder overpressure sentinel valve, complete	1
	Fuel valves of each size and type fitted, complete with all fittings, for one engine	1 set (1)
6. Connecting rod bearings	Bottom end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder	1 set
	Top end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder	1 set
7. Pistons	Crosshead type; piston of each type fitted, complete with piston rod, stuffing box, skirt, rings, studs and nuts	1
	Trunk piston type; piston of each type fitted, complete with skirt, rings, studs, nuts, gudgeon pin and connecting rod	1
8. Piston rings	Piston rings, for one cylinder	1 set
9. Piston cooling	Telescopic cooling pipes and fittings or their equivalent, for one cylinder unit	1 set
10. Cylinder lubricators	Lubricator, complete, of the largest size, with its chain drive or gear wheels, or equivalent spare part kit	1
11. Fuel injection pumps	Fuel pump complete, or when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valves, springs, etc.), or equivalent high pressure fuel pump	1
12. Fuel injection piping	High pressure double wall fuel pipe of each size and shape fitted, complete with couplings	1
13. Scavenge blower (including turbo chargers)	Rotors, rotor shafts, bearings, nozzle rings, and gear wheels or equivalent working parts of other types	1 set (2)
14. Scavenging system	Suction and delivery valves for one pump of each type fitted	1 set
15. Reduction and/or reverse gear	Complete bearing bush, of each size fitted in the gear case assembly	1 set
	Roller or ball race, of each size fitted in the gear case assembly	1 set

Footnotes

1. *a) Engines with one or two fuel valves per cylinder: one set of fuel valves, complete.*
b) Engines with three or more fuel valves per cylinder: two fuel valves complete per cylinder, and a sufficient number of valve parts, excluding the body, to form, with those fitted in the complete valves, a full engine set.
2. *The spare parts may be omitted where it has been demonstrated, at the builder's test bench for one engine of the type concerned, that the engine can be manoeuvred satisfactorily with one blower out of action.*
The requisite blanking and blocking arrangements for running with one blower out of action are to be available on board.

Notes

1. *The availability of other spare parts, such as gears and chains for camshaft drive, should be specially considered and decided upon by the owner.*
2. *It is assumed that the crew has on board the necessary tools and equipment.*
3. *When the recommended spares are utilized, it is recommended that new spares are supplied as soon as possible.*
4. *In case of multi-engine installations, the minimum recommended spares are only necessary for one engine.*
5. *For electronically controlled engines spare parts as recommended by the engine designer/manufacture.*

Table 17.2 List of minimum recommended spare parts for each type of auxiliary internal combustion engine driving electric generators for essential services on board ships for unrestricted service

Item	Spare part	Number recommended
1. Main bearings	Main bearings or shells for one bearing of each size and type fitted, complete with shims, bolts and nuts	1
2. Cylinder valves	Exhaust valves, complete with casings, seats, springs and other fittings for one cylinder	2 sets
	Air inlet valves, complete with casings, seats, springs and other fittings for one cylinder	1 set
	Starting air valve, complete with casings, seat springs and other fittings	1
	Cylinder overpressure sentinel valve, complete	1
	Fuel valves of each size and type fitted, complete with all fittings, for one engine	1/2 set
3. Connecting rod bearings	Bottom end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder	1 set
	Trunk piston type: gudgeon pin with bush for one cylinder	1 set
4. Piston rings	Piston rings, for one cylinder	1 set
5. Piston cooling	Telescopic cooling pipes and fittings or their equivalent, for one cylinder	1 set
6. Fuel injection pumps	Fuel pump complete, or when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valves, springs, etc.), or equivalent high pressure fuel pump	1
7. Fuel injection piping	High pressure double wall fuel pipe of each size and shape fitted, complete with couplings	1
8. Gaskets and packings	Special gaskets and packings of each size and type fitted, for cylinder covers and cylinder liners for one cylinder	1 set
Notes 1. The availability of other spare parts should be specially considered and decided upon by the owner. 2. It is assumed that the crew has on board the necessary tools and equipment. 3. When the recommended spares are utilized, it is recommended that new spares are supplied as soon as possible. 4. Where the number of generators of adequate capacity fitted for essential services exceeds the required number, spare parts may be omitted. 5. For electronically controlled engines spare parts as recommended by the engine designer/manufacturer.		

Table 17.3 List of minimum recommended spare parts for auxiliary steam turbines driving electric generators for essential services of ships for unrestricted service

Item	Spare part	Number recommended
1. Turbine shaft	Carbon sealing rings, where fitted, with springs, for each size sealing rings and type of gland, for one turbine	1 set
2. Oil filters	Strainer baskets or inserts, for filters of special design, of each type and size	1 set
Notes 1. The availability of other spare parts should be specially considered and decided upon by the owner. 2. It is assumed that the crew has on board the necessary tools and equipment. 3. When the recommended spares are utilized, it is recommended that new spares are supplied as soon as possible. 4. Where the number of generators of adequate capacity fitted for essential services exceeds the required number, spare parts may be omitted.		

Table 17.4 List of minimum recommended spare parts for main steam turbines of ships for unrestricted service

Item	Spare part	Number recommended
1. Turbine shaft	Carbon sealing rings, where fitted, with springs, for each size sealing rings type of gland	1 set
2. Oil filters	Strainer baskets or inserts, for filters of special design, of each type and size	1 set
Notes 1. The availability of other spare parts should be specially considered and decided upon by the owner. 2. It is assumed that the crew has on board the necessary tools and equipment. 3. When the recommended spares are utilized, it is recommended that new spares are supplied as soon as possible. 4. In case of multi-engine installations, the minimum recommended spares are only necessary for one engine.		

Table 17.5 List of minimum recommended spare parts for essential auxiliary machinery of ships for unrestricted service

1. Auxiliary internal combustion engines and steam turbines driving essential service machinery other than generators

The number of minimum recommended spare parts for auxiliary internal combustion engines and steam turbines driving essential service machinery is to be in accordance with that recommended for internal combustion engines and turbines driving electric generators. When an additional unit for the same purpose and of adequate capacity is fitted, spare parts may be omitted.

2. Pumps (1)

Spare parts	Number recommended
1. Piston pumps	
1.1 Valve with seats and springs, each size fitted	1 set
1.2 Piston rings, each type and size for one piston	1 set
2. Centrifugal pumps	
2.1 Bearing of each type and size	1
2.2 Rotor sealing of each type and size	1
3. Gear type pumps	
3.1 Bearing of each type and size	1
3.2 Rotor sealing of each type and size	1
(1) When a sufficiently rated standby pump is available, the spare parts may be dispensed with.	

3. Compressors for essential service

Spare parts	Number recommended
1. Suction and delivery valves complete of each size fitted in one unit	½ set
2. Piston rings of each type and size fitted for one piston	1 set

4. General

It is recommended that where, for maintenance or repair work of the essential machinery, special tools or equipment are to be used, these are available on board. When the recommended spares are utilized, it is recommended that new spare are supplied as soon as possible.

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A. General**1. Scope**

1.1 The rules in this section apply to fire protection in the machinery and boiler spaces of passenger and cargo vessels and to fire extinguishing equipment throughout the ship.

1.2 Firefighting ships to which the notation FF is to be allocated are also subject to the "Chapter 11 - Fire Fighting Ships".

2. Document for Approval

Diagrammatic plans, drawings and documents covering the following are to be submitted in triplicate for approval:

- Water fire extinguishing equipment, including details of the capacities and pressure heads of the fire pumps and hydraulic calculations of the minimum pressure at the fire hose nozzles specified in Table 18.3.
- CO₂ or alternative gas fire extinguishing system with arrangement drawing, operating diagram, CO₂ room, tripping devices alarm diagram, calculation, operating instructions
- Foam extinguishing system, including drawings of storage tanks for foam concentrate, monitors, foam generators and foam applicators and the calculations and details relating to the supply of foam concentrate,
- Pressure water spraying system, automatic, including drawings for pressurized water tank, spray nozzles and alarms, with calculation,
- Pressure water spraying system, manually operated, including calculations of water demand and pressure drop, spray nozzles, remote control, for pressure water spraying systems in ro/ro decks/special category spaces, also documentary proof of water drainage system,

- Pressure water spraying system for exhaust gas fired thermal oil heaters, including a drawing of the heater showing the arrangement of the spray nozzles and a diagram and calculation of the water supply and drainage,
- Dry powder fire extinguishing system, including the powder vessels, propellant containers and the relevant calculations,
- Fire extinguishing equipment for galley range exhaust ducts and deep-fat cooking equipment,
- Fixed local fire extinguishing arrangement for fuel oil purifiers for heated fuel oil,
- Fixed local application fire-fighting systems for category A machinery spaces,
- For passenger ships: arrangement of smoke detectors and manually operated call points in accommodations including service spaces, as well as in machinery spaces and cargo spaces,
- For arrangements for the carriage of dangerous goods in packaged form according to Class Notation DG, see P.1.2,
- For arrangements for the carriage of solid dangerous goods in bulk according to Class Notations DG and DBC, see Q.1.2.

3. Further Rules Applicable

- 3.1** Structural fire protection
Chapter 1 - Hull, Section 21
- 3.2** Relevant Rules for ships carrying liquefied gases in bulk
Chapter 10 - Liquefied Gas Tankers
- 3.3** Relevant Rules for the ships carrying dangerous chemicals in bulk
Chapter 8 - Chemical Tankers
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- 3.9** Additional fire protection and fire extinguishing equipment in automated plant
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- 3.10** Electrical plant
Chapter 5 - Electrical Installations
- 3.11** Rules for the firefighting ships,
Chapter 11 - Fire Fighting Ships

4. Definitions

For definitions of terms used in this Section, SOLAS - International Convention for the Safety of Life at Sea - Chapter II-2 - Construction - Fire protection, fire detection and fire extinction - Part A - General - Regulation 3 – Definitions is to be referred to.

5. Alternative Design and Arrangements

The fire safety design and arrangements may differ from the prescriptive requirements of this Section, provided that the design and arrangements meet the fire safety objectives and functional requirements **(1)**.

B. Fire Protection

1. Machinery Space Arrangement

1.1 The arrangement of machinery spaces shall be so that safe storage and handling of flammable liquids is ensured.

1.2 All spaces in which internal combustion engines, oil burners or fuel settling or service tanks are located must be easily accessible and sufficiently ventilated.

1.3 Where leakage of flammable liquids may

occur during operation or routine maintenance work, special precautions are to be taken to prevent these liquids from coming into contact with sources of ignition.

1.4 Materials used in machinery spaces shall not normally have properties increasing the fire potential of these rooms.

1.5 Materials used as flooring, bulkhead lining, ceiling or deck in control rooms, machinery spaces or rooms with oil tanks must be non-combustible. Where there is a danger that oil may penetrate insulating materials, these must be protected against the penetration of oil or oil vapours.

1.6 To ensure the application of current installation and construction standards and to safeguard the observance of precautions for preventing the occurrence of fires during assembly, inspection and maintenance works, reference is made to the guidelines for measures to prevent fires in engine rooms and cargo pump rooms as set out in MSC.1/Circ.1321 and **BCS-G 58**.

1.7 Level switches may be used below the tank top provided they are contained in a steel enclosure or other enclosures not capable of being destroyed by fire.

1.8 Hose clamps and similar types of attachments for flexible pipes should not be permitted.

2. Fuel Oil Purifiers

2.1 Enclosed spaces

Fuel oil purifiers for heated fuel oil, should preferably be installed in a separate room. This room must be enclosed by steel divisions, be fitted with a self-closing steel door and be provided with the following:

- Separate mechanical ventilation **(2)**,

(1) Reference is made to the “Guidelines on Alternative Design and Arrangements for Fire Safety” adopted by IMO by MSC/Circ. 1002, as amended by MSC.1/Circ.1552.

(2) See Rules in Chapter 28- Ventilation, Section 1, E.10.

- Fire detection and alarm system,
- Fixed fire extinguishing system,

This system may form part of the machinery space fire extinguishing system.

In the event of a fire in the machinery space, the fire extinguishing system must be capable of being actuated together with the fire extinguishing system of the machinery space.

If the fuel oil purifiers are arranged in a separate machinery space of category A, this space shall be provided with a fixed fire extinguishing system with independent release.

2.2 Open purifier station (area) within the machinery space

2.2.1 If it is impracticable to place the fuel oil purifiers in a separate room, precautions against fire are to be taken by means of a suitable arrangement of the main components and by shielding and containment of leaks and to ventilation (2).

3. Arrangement of Boiler Plants

3.1 Boilers are to be located at a sufficient distance from fuel and lubricating oil tanks and from cargo space bulkheads in order to prevent undue heating of the tank contents or the cargo. Alternatively, the tank sides or bulkheads are to be insulated.

Where boilers are located in machinery spaces on tween decks and boiler rooms are not separated from the machinery space by watertight bulkheads, the tween decks shall be provided with coamings at least 200 mm in height. This area may be drained to the bilges. The drain tank shall not form part of an overflow system.

4. Insulation of Piping and Equipment with High Surface Temperatures

4.1 Surfaces, having temperature exceeding 60°C, with which the crew are likely to come into contact during operation are to be suitably protected or insulated.

All parts with surface temperatures above 220°C, e.g.

steam, thermal oil and exhaust gas lines, exhaust gas boilers and silencers, turbochargers etc., are to be effectively insulated with non-combustible materials. The insulation must be such that oil or fuel cannot penetrate into the insulating material.

Metal cladding or approved hard jacketing of the insulation is considered to afford effective protection against such penetration.

4.2 Boilers are to be provided with non-combustible insulation which is to be clad with steel sheet or the equivalent.

4.3 Insulation must be such that it will not crack or deteriorate when subject to vibration.

5. Fuel and Lubricating Oil Tanks

The requirements of Section 16.V are to be observed.

6. Protection Against Fuel and Oil Leakages

6.1 Drip trays or other Suitable means of collection are to be fitted below hydraulic valves and cylinders as well as below potential leakage points in lub oil and fuel oil systems.

Oil-tight drip trays of ample size having suitable drainage arrangements should be provided at pipes, pumps, valves and other fittings where there is a possibility of leakage. Valves should be located in well lighted and readily visible positions. Drip trays will not be required where pumps, valves and other fittings are placed in special compartments either inside or outside the machinery space with approved overall drainage arrangements.

Where drainage arrangements are provided from collected leakages, they are to be led to a suitable oil drain tank not forming part of an overflow system.

Fuel oil separation tanks, fuel oil overflow tanks are to be placed in an oil-tight spill tray of ample size having drainage arrangements leading to a drain tank of suitable size.

6.2 The arrangement of piping systems and their components intended for combustible liquids, shall be such

that leakage of these liquids cannot come into contact with heated surfaces or other sources of ignition. Where this cannot be precluded by structural design, suitable precautionary measures are to be taken.

6.3 Tanks, pipelines, filters, preheaters etc. containing combustible liquids may not be placed directly above heat sources such as boilers, steam lines, exhaust gas manifolds and silencers or items of equipment which have to be insulated in accordance with 4.1 and may also not be placed above electrical switch gear.

6.4 The fuel injection pipes of the engines are to be shielded or installed that any fuel leaking out can be safely drained away (see also Section 2, G.2.2 and Section 16, G.3.3).

6.5 All parts of the oil fuel system containing heated oil under pressure exceeding 1,8 bar, as far as practicable, shall be arranged such that the defects an leakage can readily be observed. The machinery spaces in way of such parts of the fuel oil system shall be adequately illuminated.

7. Bulkhead Penetrations

Pipe penetrations through class A or B divisions in accordance with SOLAS 1974 must be able to withstand the temperature for which the divisions were designed.

Where steam, exhaust gas and thermal oil lines pass through bulkheads, the bulkhead must be suitably insulated to protect it against excessive heating.

8. Means of Closure

Means must be provided for reasonable gastight sealing of boiler rooms and machinery spaces. The air ducts to these spaces are to be fitted with fire closure made of non-combustible material which can be closed from the deck. Machinery space skylights, equipment hatches, doors and other openings are to be so arranged that they can be closed from outside the rooms.

9. Emergency Stops

Electrically powered fuel pumps, lubricating oil pumps,

oil burner plants, purifiers, fan motors, boiler fans, thermal oil and cargo pumps are to be equipped with emergency stops which, as far as practicable, are to be grouped together outside the spaces in which the equipment is installed and which are to remain accessible even in the event of a fire breaking out. Emergency stops are also to be provided inside the compartments in which the equipment is installed.

10. Remotely Operated Shutoff Devices

Steam-driven fuel pumps, boiler fans, cargo pumps, the fuel supply lines to boilers and the outlet pipes of fuel tanks located above the double bottom are to be fitted with remotely controlled shutoff devices.

The controls for remote operation of the valve for the emergency generator fuel tank have to be in a separate location from the controls for remote operation of other valves for tanks located in machinery spaces.

The location and grouping of the shutoff devices are subject to the appropriate requirements specified in 9.

10.1 Machinery space safety station

It is recommended that the following safety devices to be grouped together in a central, at all times easily accessible location outside the machinery space:

- Cut-off switches for engine room ventilation fans, boiler blowers, fuel transfer pumps, purifiers, thermal oil pumps;
- Means for closing the,
 - Quick-closing fuel valves,
 - Remote controlled water tight doors and sky-lights in the machinery space area;
- Actuation of the machinery space fire extinguishing system.

In passenger ships, all controls indicated in B.8., B.9., B.10. and B.10.1 of this Section as well as means of control for permitting release of smoke from machinery spaces and means of control for closing power-operated doors or actuating release mechanisms on doors other

than power-operated watertight doors in machinery space boundaries, are to be located at one control position or grouped in as few positions as possible.

Such positions are to have a safe access from the open deck.

When releasing the machinery space fire extinguishing system or opening the door of its release box for test purposes exclusively, an automatic shutoff of machinery aggregates and auxiliary systems indicated in 9. and 10. is not permitted (see also Chapter 5 - Electrical Installations, Section 9, C.).

10.2 Passenger ship safety station

On passenger ships carrying more than 36 passengers, the following safety devices are to be grouped together in a permanently manned central control station:

- The alarm panels of the pressure water spraying system required in accordance with C.2.4 of this Section and the fire detection and alarm system;
- The controls and status indicators for the remotely operated fire doors;
- The emergency cut-offs of the ventilation fans (except machinery space fans) plus their starters and running lights.

As regards the design of the alarm- and operating panels see Chapter 5 - Electric Installation, Section 9.

11. Cargo Spaces for the Carriage of Vehicles with Fuel in Their Tanks and Cargo Spaces of Ro-Ro Ships

11.1 The cargo spaces of passenger ships carrying more than 36 passengers are to be provided with forced ventilation capable of effecting at least 10 air changes per hour.

11.2 The cargo spaces of passenger ships carrying less than 36 passengers are to be provided with forced ventilation capable of effecting at least 6 air changes per hour.

11.3 On passenger ships special category spaces **(3)** are to be equipped with forced ventilation capable of 10 air changes per hour.

11.4 The cargo spaces of cargo ships and ro-ro ships are to be provided with forced ventilation capable of at least 6 air changes per hour, if the electrical equipment is of certified safe type in the entire space, or at least 10 air changes per hour, if the electrical equipment is of certified safe type up to a height of 450 mm above the deck (see Chapter 5 – Electrical Installations, Section 16).

11.5 Design

11.5.1 An independent power ventilation system is to be provided for the removal of gases and vapours from the upper and lower part of the cargo space. This requirement is considered to be met if the ducting is arranged such that approximately 1/3 of the air volume is removed from the upper part and 2/3 from the lower part.

11.5.2 The ventilation system must be capable of being run during loading and unloading of vehicles as well as during the voyage.

Arrangements shall be provided to permit a rapid shutdown and effective closure of the ventilation system from outside of the space in case of fire, taking into account the weather and sea conditions **(4)**

11.5.3 The design of mechanical exhaust ventilators is to be comply with Section 20, B.5.3.

For the type of protection of electrical motors and other electrical equipment located in the exhaust air stream, see Chapter 5 - Electrical Installations, Section 16, H.

11.5.4 Reference is made to the ventilation requirements in Chapter 28 - Ventilation, Section 1, H. and I.

(3) For definition see Table 18.1, Note 4.

(4) Reference is made to BCS- I SC 243.

11.6 Monitoring

The failure of a fan shall actuate a visual / audible alarm on the bridge.

11.7 Other requirements

11.7.1 Drains from vehicle decks may not be led to machinery spaces or other spaces containing sources of ignition.

11.7.2 A fire detection and alarm system according to part C is to be provided for the cargo spaces and vehicle decks.

11.7.3 For the fire extinguishing equipment see F.2.6, F.2.7 and Table 18.1 of this Section.

11.8 Electrical equipment is to comply with the Rules in Chapter 5 - Electrical Installations, Section 16.

11.9 The requirements for a fixed fire extinguishing system, fire detection, foam applicators and portable extinguishers need not apply to weather decks used for the carriage of vehicle with fuel in their tanks.

11.10 For the structural fire protection requirements see Chapter 1 – Hull, Section 21 item B.19

11.11 Vehicles with fuel in their tanks for their own propulsion may be carried in cargo spaces other than vehicle, special category or ro-ro spaces, provided that all the following conditions are met:

- the vehicles do not use their own propulsion within the cargo spaces;
- the cargo spaces are in compliance with the appropriate requirements of SOLAS Reg. II-2/19; and
- the vehicles are carried in accordance with the IMDG Code, as defined in SOLAS Reg. VII/1.1.

12. Requirements for vehicle carriers carrying motor vehicles with compressed hydrogen or natural gas in their tanks for their own propulsion as cargo

12.1 Purpose

The purpose of this item is to provide additional safety measures for vehicle carriers with vehicle and ro-ro

spaces intended for carriage of motor vehicles with compressed hydrogen or compressed natural gas in their tanks for their own propulsion as cargo.

12.2 Application

12.2.1 In addition to complying with the requirements of item 11, as appropriate, vehicle spaces of vehicle carriers intended for the carriage of motor vehicles with compressed hydrogen or compressed natural gas in their tanks for their own propulsion as cargo shall comply with the requirements in items 12.3 to 12.5.

12.3 Requirements for spaces intended for carriage of motor vehicles with compressed natural gas in their tanks for their own propulsion as cargo

12.3.1 Electrical equipment and wiring

All electrical equipment and wiring shall be of a certified safe type for use in an explosive methane and air mixture (refer to IEC 60079).

12.3.2 Ventilation arrangement

12.3.2.1 Electrical equipment and wiring, if installed in any ventilation duct, shall be of a certified safe type for use in explosive methane and air mixtures.

12.3.2.2 The fans shall be such as to avoid the possibility of ignition of methane and air mixtures. Suitable wire mesh guards shall be fitted over inlet and outlet ventilation openings.

12.3.3 Other ignition sources

Other equipment which may constitute a source of ignition of methane and air mixtures shall not be permitted.

12.4 Requirements for spaces intended for carriage of motor vehicles with compressed hydrogen in their tanks for their own propulsion as cargo

12.4.1 Electrical equipment and wiring

All electrical equipment and wiring shall be of a certified safe type for use in an explosive hydrogen and air mixture (refer to IEC 60079).

12.4.2 Ventilation arrangement

12.4.2.1 Electrical equipment and wiring, if installed in any ventilation duct, shall be of a certified safe type for use in explosive hydrogen and air mixtures and the outlet from any exhaust duct shall be sited in a safe position, having regard to other possible sources of ignition.

12.4.2.2 The fans shall be designed such as to avoid the possibility of ignition of hydrogen and air mixtures. Suitable wire mesh guards shall be fitted over inlet and outlet ventilation openings.

12.4.3 Other ignition sources

Other equipment which may constitute a source of ignition of hydrogen and air mixtures shall not be permitted.

12.5 Detection

When a vehicle carrier carries as cargo one or more motor vehicles with either compressed hydrogen or compressed natural gas in their tanks for their own propulsion, at least two portable gas detectors shall be provided. Such detectors shall be suitable for the detection of the gas fuel and be of a certified safe type for use in the explosive gas and air mixture.

13. Ro-Ro Cargo Spaces in Passenger Ships not Intended for the Carriage of Vehicles with Fuel in their Tanks

13.1 For closed ro-ro cargo spaces which are not intended for the carriage of vehicles with fuel in their tanks nor are special category spaces the requirements as per B.11 of this section, with the exception of clauses 11.5.3, 11.7.1 and 11.8, as well as the requirements of Section 16, N.4.4 are to be applied.

13.2 For open ro-ro cargo spaces which are not intended for the carriage of vehicles with fuel in their tanks nor are special category spaces the requirements applicable to a conventional cargo space shall be observed with the exception that a sample extraction smoke detection system is not permitted and that additionally the requirements of Section 16, N.4.4 are to be applied.

14. Fire Resistance of Components in Fixed Fire-Extinguishing Systems

14.1 All discharge piping, fittings and nozzles in the

protected spaces shall be constructed of materials having a melting temperature which exceeds 925°C. The piping and associated equipment shall be adequately supported.

C. Fire Detection

1. General

Fire detection and alarm systems and sample extraction smoke detection systems are subject to approval. For the design of the systems, see Chapter 5 - Electrical Installations, Section 9 and for manual operated call point see Chapter 5 - Electrical Installations, Section 9.D.3.1.23.

2. Fire Detection in Passenger Ships

2.1 In passenger ships carrying not more than 36 passengers, a fire detection and alarm system in accordance with Chapter 5 - Electrical Installations, Section 9 is to be provided in all accommodation - and service spaces and, if considered necessary by **BCS**, in control stations **(5)**.

Spaces where there is no substantial fire risk are excluded from this Rule.

2.2 Instead of a fire detection and alarm system in accordance with 2.1, an approved automatic pressure water spraying system in accordance with L.1, in this Section or an approved equivalent pressure water spraying system **(6)** may be provided.

In this case, additionally an approved fire detection and alarm system in accordance with Chapter 5 - Electrical Installations, Section 9 is to be installed in corridors, stairways and escape routes within the accommodation area. This system is to be designed for smoke detection.

2.3 Where in passenger ships a public space comprises three or more decks (atrium) containing combustible furnishings, shops, offices or restaurants, the entire vertical fire zone is to be equipped with fire protection arrangements in accordance with 2.4.

(5) For definition see SOLAS II-2, Reg. 3.

(6) See IMO-Resolution A.800(19)), A Revised Guidelines for Approval of Sprinkler Systems Equivalent to that Referred to in Regulation II-2/12 of SOLAS, as amended by Res. MSC.265(84) as amended by Resolution MSC.284(86).

In this case however, deviating from Chapter 5 - Electrical Installations, Section 9, D.3.1.11 and L.1.8.2 of this Section, all decks within this public space may be monitored or protected by a common fire detection - or spraying section.

2.4 In passenger ships carrying more than 36 passengers, an approved automatic pressure water spraying system in accordance with L.1 in this Section or an equivalent approved pressure water spraying system **(6)** is to be provided in all accommodation - and service spaces including corridors and stairways, and in control stations.

Refrigerated chambers may be fitted with dry pipe sprinkler systems.

All the above-mentioned spaces except for sanitary spaces and galleys are additionally to be monitored for smoke by means of a fire detection and alarm system in accordance with Chapter 5 - Electrical Installations, Section 9.

Heat detectors are acceptable in refrigerated chambers and in other spaces where steam and fumes are produced such as saunas and laundries.

In spaces a little fire risk, e.g. void spaces, public toilets, CO₂ rooms, etc., installations of a pressure water spraying system or a fire detection and alarm system may be omitted.

In control stations, instead of a pressure water spraying system some other suitable fixed fire extinguishing system may be provided if essential equipment installed in these spaces could be damaged by water.

2.5 Closed cargo spaces for the carriage of motor vehicles with fuel in their tanks, closed ro/ro cargo spaces and inaccessible cargo spaces are to be equipped with a fire detection and alarm system or with a sample extraction smoke detection system.

The conditions of ventilation in the cargo spaces shall be specially taken into account when designing and installing these systems.

The fire detection and alarm system prescribed for inaccessible cargo spaces may be dispensed with if the ship only makes journeys of short duration.

2.6 Special category spaces (see also Table

18.1) are to be provided with manually operated call points such that no part of the space is more than 20 m. from a manually operated call point. One manually operated call point is to be mounted at each exit.

2.8 Special category spaces without a permanent patrol system are to be equipped with a fire detection and alarm system.

The conditions of ventilation are to be especially taken into account in selecting and positioning the detectors.

After installation, the system is to be tested under normal conditions of ventilation.

2.8 The cabin balconies are to be provided with a fire detection and alarm system in accordance with Chapter 5 - Electrical Installations, Section 9, D., if the furniture and furnishings on such balconies are not of restricted fire risk **(7)**.

3. Fire Detection in the Accommodation Spaces of Cargo Ships

Depending on the structural fire protection of the accommodation spaces, cargo ships are to be provided with the following fire detection systems:

3.1 Structural fire protection method IC

A fire detection and alarm system including manually operated alarms is to be provided for corridors, stairways and escape routes within the accommodation areas. The system is to be designed to detect smoke.

3.2 Structural fire protection method IIC

An automatic pressure water spraying system conforming to L.1. of this Section or approved equivalent pressure water spraying system **(5)** is to be provided for accommodation and service spaces. Corridors, stairways and escape routes within the accommodation spaces are subject to 3.1.

(7) Definitions for restricted fire risk are given in SOLAS II-2, regulations 3.40.1, 3.40.2, 3.40.3, 3.40.6 and 3.40.7.

Table 18.1 Fixed fire extinguishing systems

Spaces and areas to be protected		Type of vessel	
		Cargo ships ≥ 500 GT	Passenger ships
Machinery spaces with internal combustion machinery used for the main propulsion and machinery spaces containing oil-fired plants (boilers, incinerators etc.) or oil fuel units (10)		For all ships CO ₂ , high-expansion foam or BCS approved pressure water system (1) (2)	
Machinery spaces of category A containing internal combustion engines not used for propelling the ships		≥ 375 kW CO ₂ , high-expansion foam or BCS approved pressure water system (2)	≥ 375 kW CO ₂ , high-expansion foam or BCS approved pressure water system (2)
Machinery spaces containing steam engines		≥ 375 kW CO ₂ , high-expansion foam or BCS approved pressure water system (2)	≥ 375 kW CO ₂ , high-expansion foam or BCS approved pressure water system (2)
Fire hazard areas of category A machinery spaces above 500 m ³ in volume acc. to L.3		Fixed water-based local application fire fighting systems (3) (FWBLAFFS)	
Fuel oil purifiers in acc. with B.2.		Fixed local fire extinguishing arrangement Low expansion foam-, pressure water spraying-, dry powder system	
Exhaust gas fired thermal oil heaters acc. to L.2.2		Pressure water spraying system	
Scavenge trunks of two-stroke engines acc. to Section 2, G.6.3.		CO ₂ system or other equivalent extinguishing system	
Paint lockers and flammable liquid lockers acc. to M.1.		CO ₂ , dry powder extinguishing or pressure water spraying system (2)	
Deep-fat cooking equipment acc. to M.3		Automatic or manual fire extinguishing system of BCS approved type	
Accommodation-, service spaces and control stations, incl. Corridors and stairways		Only in the case of structural fire protection method IIC automatic sprinkler system, see C.3.2	Automatic sprinkler system, see C.2.4; if less than 37 passengers, see C.2.1/C.2.2
Cabin balconies		-	Pressure water-spraying system (7)
Galley range exhaust ducts acc. to M.2.		CO ₂ system or other equivalent extinguishing system	
Incinerator spaces and waste storage spaces		Automatic sprinkler system or manually released fire extinguishing system, for details refer to N.	
Helicopter landing deck acc. to O.		Low-expansion foam system	
Cargo spaces	1. Special category spaces on passenger ships (4)	-	Pressure water spraying system
	2. For motor vehicles with fuel in their tanks	For all ships CO ₂ or high-expansion - or pressure water spraying system	
	3. For dangerous goods	For all ships CO ₂ , inert gas fire extinguishing system (5) (6) (9) (11)	
	4. On ro/ro-ships a) closed b) open c) not capable of being sealed	CO ₂ , high-expansion foam, or pressure water spraying system pressure water spraying water pressure water spraying water	-
	5. Cargo spaces not included in 1-4	≥ 2000 GT (6) CO ₂ or inert gas systems	≥ 1000 GT CO ₂ , inert gas or high-expansion foam extinguishing system

Table 18.1 Fixed fire extinguishing systems (cont.)

Spaces and areas to be protected	Type of vessel	
	Cargo ships ≥ 500 GT	Passenger ships
Cargo area and cargo tanks	<p>Tankers acc. to D. 2:</p> <p>Low-expansion foam system and inert gas system</p> <p>Chemical tankers to Chapter 8 - Chemical Tankers, Section 11:</p> <p>Low-expansion foam, dry powder, pressure water spraying and inert gas system</p> <p>Ships for the carriage of liquefied gases to Chapter 10 - Liquefied Gas Tankers, Section 11:</p> <p>Pressure water spraying, dry powder system (8) and inert gas systems.</p>	-
Cargo pump spaces	<p>Tankers and chemical tankers:</p> <p>CO₂, high-expansion foam or pressure water spraying system (2)</p>	-
Cargo pump and compressor rooms:	<p>Ships for the carriage of liquefied gases:</p> <p>CO₂, system (2)</p>	-
<p>(1) Also applies to < 500 GT in the case of ships with class notation AUT and in the case of chemical tankers.</p> <p>(2) Approved systems using gases other than CO₂, may be applied-see, I.</p> <p>(3) Applies to passenger ships of 500 GT and above and cargo ships of 2000 GT and above.</p> <p>(4) Special category spaces are closed vehicle decks on passenger ships to which the passengers have access.</p> <p>(5) Pressure water spraying system in ro/ro spaces (open or not capable of being sealed), in open top container cargo spaces and in special category spaces.</p> <p>(6) May be dispensed with on request where only coal, ore, grain, unseasoned timber, non-combustible cargoes or cargoes resending a low fire risk are carried. Reference is made to MSC.1/Circ. 1395/Rev.4.</p> <p>(7) May be dispensed with, if the furniture and furnishings are only of restricted fire risk, see L.4.</p> <p>(8) Details see J.3.</p> <p>(9) For ships of less than 500 GT the requirement may be dispensed with subject to acceptance by the Administration.</p> <p>(10) Oil fuel unit includes any equipment used for the preparation and delivery of oil fuel, heated or not, to boilers (including inert gas generators) and engines (including gas turbines) at a pressure of more than 0.18 N/mm². Oil fuel transfer pumps are not considered as oil fuel units</p> <p>(11) Fixed CO₂ fire-extinguishing systems or inert gas systems installed on board dedicated to the protection of cargo spaces can be used for the control of the self-heating of the cargo within the cargo holds (See Q.2.1).</p>		

Spaces where there is no fire e.g. void spaces, sanitary spaces, etc., need not be monitored.

3.3 Structural fire protection method IIIC

A fire detection and alarm system including manually operated alarms is to be provided for the entire accommodation spaces, with the exception of spaces where there is no fire risk

In corridors, staircases and escape routes, the system must be designed to detect smoke

The detection system is only relevant to the accommodation block. Service spaces built away from the accommodation block need not be fitted with a fixed fire detection system.

4. Fire Detection and Alarm Systems for Machinery Spaces

4.1 Machinery spaces of category A **(8)** of ships with class notation AUT or AUT-C are to be equipped with a fire detection and alarm system. The system must be designed to detect smoke.

4.2 Spaces for emergency generators which are used in port for serving the main source of electrical powers are to be provided with a fire detection system regardless of the output of the diesel engine.

4.3 Exhaust gas fired thermal oil heaters are to be fitted with a fire alarm on the exhaust gas side.

4.4 Enclosed spaces containing incinerators are to be equipped with a fixed fire detection and alarm system.

4.5 For fire detection in unmanned machinery spaces, BCS- I SC129 (SOLAS Reg. II-2/7.4) is to be complied with.

(8) For definition see *Seagoing Ships, Chapter 1 - Hull, Section 21, B.4.3.2 [6] (applicable to all ships in the scope of this Section).*

5. Fire Detection and Fire Alarm Systems for the Cargo Spaces of Cargo Ships

5.1 Closed ro/ro cargo spaces are to be equipped with a fire detection and alarm system.

5.2 Closed cargo spaces for the carriage of motor vehicles with fuel in their tanks are to be equipped with a fire detection and alarm system or a sample extraction smoke detection system.

5.3 Cargo spaces for the carriage of dangerous goods as specified in P. are to be equipped with a fire detection and alarm system or a sample extraction smoke detection system. However, closed ro/ro cargo spaces are subject to 5.1.

5.4 The provision of a fire detection and alarm system or a sample extraction smoke detection system in cargo spaces not mentioned in 5.1 to 5.3 is recommended.

6. Design of Fire Detection and Fire Alarm Systems

6.1 For the design and installation of fire detection and alarm systems, see Chapter 5 - Electrical Installations, Section 9 and additionally 6.2 and L.1. of this Section.

6.2 Sample extraction smoke detection systems

6.2.1 The main components of a sample extraction smoke detection system are sampling pipes, smoke accumulators and a control panel, as well as three-way valves, if the system is interconnected to a carbon dioxide fire-extinguishing system.

The control panel shall permit observation of smoke in the individual sampling pipes and indicate which space is on fire.

6.2.2 The sampling pipes shall have an internal diameter of at least 12 mm. Two switchover sample extraction fans are to be provided. In considering the ventilation conditions in the protected spaces, the suction capacity of each fan and the size of the

sampling pipes shall be adequate to ensure the detection of smoke within the time criteria required in 6.2.8. Means to monitor the airflow shall be provided in each sampling line.

The sampling pipes shall be so designed as to ensure that, as far as practicable, equal quantities of airflow are extracted from each interconnected smoke accumulator.

6.2.3 The smoke accumulators are to be located as high as possible in the protected space and shall be so arranged that no part of the overhead deck area is more than 12 m horizontally away from a smoke accumulator.

At least one additional smoke accumulator has to be provided in the upper part of each exhaust ventilation duct. An adequate filtering system shall be fitted at the additional accumulator to avoid dust contamination.

6.2.4 Smoke accumulators from more than one monitored space shall not be connected to the same sampling pipe. The number of smoke accumulators connected to each sampling pipe shall satisfy the conditions indicated in 6.2.8.

6.2.5 The sampling pipes shall be self-draining and be provided with an arrangement for periodically purging with compressed air.

6.2.6 In cargo holds where non-gastight tween deck panels (movable stowage platforms) are provided, separate sampling pipes with smoke accumulators are to be provided for the upper and lower parts of the cargo holds.

6.2.7 In the case of cargo spaces intended for dangerous cargo steps are to be taken to ensure that the air drawn in by a sample extraction smoke detection system is discharged directly into the open air.

6.2.8 After installation, the system shall be functionally tested using smoke generating machines or equivalent as a smoke source. An alarm shall be received at the control panel in not more than 180 sec for vehicle and ro-ro spaces, and in not more than 300 sec for container and general cargo holds, after smoke

is introduced at the most remote smoke accumulator.

6.2.9 See Chapter 5 - Electrical Installations, Section 9 D3.7.2 for further information about sample extraction smoke detection systems.

D. Scope of Fire Extinguishing Equipment

1. Purpose and Application

1.1 The purpose of this subsection is to suppress and swiftly extinguish a fire in the space of origin, except for item 1.2. For this purpose, the following functional requirements shall be met:

- Fixed fire-extinguishing systems shall be installed having due regard to the fire growth potential of the protected spaces; and
- Fire-extinguishing appliances shall be readily available.

1.2 For open-top container holds (refer to MSC/Circ.608/Rev.1) and on deck container stowage areas on ships designed to carry containers on or above the weather deck, constructed on or after 1 July 2016, fire protection arrangements shall be provided for the purpose of containing a fire in the space or area of origin and cooling adjacent areas to prevent fire spread and structural damage.

1.3 Any ship is to be equipped with a general water fire extinguishing system in accordance with E. and with portable and mobile extinguishers as specified under F.

1.4 In addition, depending on their nature, size and the propulsion power installed, spaces subject to a fire hazard are to be provided with fire extinguishing equipment in accordance with Table 18.1. The design of this equipment is described in E. to Q.

For design of equipment and medium of fixed gas fire-extinguishing systems, see also FSS Code Chapter 5.2.1.1.

Cargo spaces for the carriage of dangerous goods are also required to comply with P. and Q., as applicable.

Unless otherwise specified, this equipment is normally to be sited outside the spaces and areas to be protected and, in the event of a fire, must be capable of being actuated from points which are always accessible.

1.5 Approval of fire extinguishing appliances and equipment

Approvals of Administrations or other Classification Societies are generally accepted for fire fighting equipment and components such as fire extinguishers, fire hoses, foam concentrates, etc. unless **BCS** approved equipment is expressly required in the Rules of this Section.

2. Protection of the cargo area of tankers

2.1 The cargo area and the cargo pump rooms of tankers are to be equipped with a fixed fire extinguishing system in accordance with Table 18.1

2.2 Tankers equipped with crude oil washing and tankers of 20 000 dwt and above carrying flammable liquids with a flash point of 60°C or less are to be additionally equipped with a fixed inert gas system (see Section 20. D).

2.3 Pump room alarms:

Where audible alarms are fitted to warn of the release of fire extinguishing medium into pump rooms, they may be of the pneumatic type or electric type.

(a) Pneumatically operated alarms

In cases where the periodic testing of such alarms is required, CO₂ operated alarms should not be used owing to the possibility of the generation of static electricity in the CO₂ cloud. Air operated alarms may be used provided the air supply is clean and dry.

(b) Electrically operated alarms

When electrically operated alarms are used, the

arrangements are to be such that the electric actuating mechanism is located outside the pump room except where the alarms are certified intrinsically safe.

It was further agreed that the use of CO₂ operated alarms should be discouraged.

3. Ships designed to carry containers on or above the weather deck

3.1 For open-top container holds **(9)** and on deck container stowage areas on ships designed to carry containers on or above the weather deck, constructed on or after 1 July 2016, fire protection arrangements shall be provided for the purpose of containing a fire in the space or area of origin and cooling adjacent areas to prevent fire spread and structural damage.

3.2 Ships shall carry, in addition to the equipment and arrangements required by this section for cargo holds, at least one water mist lance.

3.2.1 The water mist lance shall consist of a tube with a piercing nozzle which is capable of penetrating a container wall and producing water mist inside a confined space (container, etc.) when connected to the fire main.

3.2.2 Ships designed to carry five or more tiers of containers on or above the weather deck shall carry, in addition to the requirements of paragraph 3.2.1 mobile water monitors (also refer to MSC.1/Circ.1472 for design, performance, testing and approval of mobile water monitors used for the protection of on-deck cargo areas of ships designed and constructed to carry five or more tiers of containers on or above the weather deck) as follows:

(9) *For a definition of this term, and further requirements concerning open-top container ships refer to MSC/Circ.608/Rev.1.*

- Ships with breadth less than 30 m: at least two mobile water monitors; or
- Ships with breadth of 30 m or more: at least four mobile water monitors.

3.2.2.1 The mobile water monitors, all necessary hoses, fittings and required fixing hardware shall be kept ready for use in a location outside the cargo space area not likely to be cut-off in the event of a fire in the cargo spaces.

3.2.2.2 A sufficient number of fire hydrants shall be provided such that:

- All provided mobile water monitors can be operated simultaneously for creating effective water barriers forward and aft of each container bay;
- The two jets of water required by item E.2.4.1 can be supplied at the pressure required by paragraph E.2.3.4 and Table 18.3; and
- Each of the required mobile water monitors can be supplied by separate hydrants at the pressure necessary to reach the top tier of containers on deck.

3.2.2.3 The mobile water monitors may be supplied by the fire main, provided the capacity of fire pumps and fire main diameter are adequate to simultaneously operate the mobile water monitors and two jets of water from fire hoses at the required pressure values. If carrying dangerous goods, the capacity of fire pumps and fire main diameter shall also comply with P.3 as far as applicable to on-deck cargo areas.

Note:

1. On board cargo ships designed to carry five or more tiers of containers on or above the weather deck;

.1 in cases where the mobile water monitors are supplied by separate pumps and piping system the total capacity of the main fire pumps need not exceed 180 m³/h (also refer to item E.1.2.4) and the diameter of the fire main and water service pipes (hereinafter referred to “the pipework diameter”) need only be sufficient for the discharge of 140 m³/h.

.2 in cases where the mobile water monitors are supplied by the main fire pumps; the total capacity of required main fire pumps and the pipework diameter shall be sufficient for simultaneously supplying both the required number of fire hoses and mobile water monitors. However, the total capacity shall not be less than the following .1 or .2, whichever is smaller:

.1 four thirds of the quantity required under regulation II-1/35-1 to be dealt with by each of the independent bilge pumps in a passenger ship of the same dimension when employed in bilge pumping; or

.2 180 m³/h

.3 in cases where the mobile water monitors and the “water spray system” (fixed arrangement of spraying nozzles or flooding the cargo space with water) required by SOLAS regulation II-2/19.3.1.3 are supplied by the main fire pumps, the total capacity of the main fire pumps and the pipework diameter need only be sufficient to supply whichever of the following is the greater:

.1 the mobile water monitors and the four nozzles required by SOLAS regulation II-2/19.3.1.2; or

.2 the four nozzles required by SOLAS regulation II-2/19.3.1.2 and the water spray system required by SOLAS regulation II-2/19.3.1.3.

The total capacity, however, is not to be less than 1.2.1 or 1.2.2, whichever is smaller.

2. *On board cargo ships designed to carry five or more tiers of containers on or above the weather deck, the total capacity of the emergency fire pump need not exceed 72 m³/h (also refer to item E.1.4.1).*

3.2.2.4 The operational performance of each mobile water monitor shall be tested during initial survey on board the ship to the satisfaction of the Administration. The test shall verify that:

- The mobile water monitor can be securely fixed to the ship structure ensuring safe and effective operation; and
- The mobile water monitor jet reaches the top tier of containers with all required monitors and water jets from fire hoses operated simultaneously.

4. Ships with natural gas-fuelled engine installations

Fire safety arrangements for ships provided with natural gas-fuelled engine installations shall be in accordance with the **BCS** Rules Chapter 78 – Rules for Classification of Ships Using Gases or Other Low - Flashpoint Fuels.

E. General Water Fire Extinguishing Equipment (Fire and Deckwash System)

1. Fire Pumps

1.1. Number of pumps

1.1.1 Passenger ships of 4000 GT and over are to be equipped with at least three, passenger ships of less than 4000 GT with at least two fire pumps.

In passenger ships of 1000 GT and over, fire pumps, their sea connections and power sources are to be distributed throughout the ship in such a way that an outbreak of fire in one compartment cannot put them out of action simultaneously.

Where, on passenger ships of less than 1000 GT, the main fire pumps are located in one compartment, an additional emergency fire pump is to be provided outside this compartment.

1.1.2 Cargo ships of 500 GT and over are to be equipped with at least two, and cargo ships of less than 500 GT with at least one fire pump.

1.1.3 Cargo ships of 500 GT and over a fixed emergency fire pump is to be provided if an outbreak of fire in one compartment can put all the fire pumps out of action.

An emergency fire pump is also to be provided if the main fire pumps are installed in adjacent compartments, and the division between the compartments is formed by more than one bulkhead or deck.

1.1.4 On cargo ships, in every machinery space containing ballast, bilge or other water pumps, provision shall be made for connecting at least one of these pumps to the fire extinguishing system. Such connection may be dispensed with where none of the pumps is capable of the required capacity or pressure.

1.2 Minimum capacity and pressure head

1.2.1 The minimum capacity and the number of fire pumps shall be as specified in Table 18.2.

1.2.2 Where fire pumps with different capacities are installed, no pump shall supply less than 80 % of the total required capacity divided by the specified number of fire pumps.

1.2.3 Each fire pump must be capable of supplying sufficient water for at least two of the nozzles used on board the ship.

On ships for the carriage of dangerous goods the requirements of P. and Q., shall also be complied with.

The capacity of a fire pump must not be less than 25 m³/h.

On cargo ships of less than 100 GT the fire pump must be capable of supplying water for at least one effective jet of water via a 9 mm. nozzle

1.2.4 The total required capacity of the fire pumps excluding emergency fire pumps - need not exceed 180 m³/h. on cargo ships.

1.2.5 For emergency fire pumps, see 1.4

1.2.6 The pressure head of every fire pump must be so chosen that the requirement of 2.3.4 in this Section is met. On cargo ships and passenger ships of less than 300 GT, instead of the pressures given in Table 18.3 every nozzle must under the conditions of 2.3.4 be capable of delivering water jet of at least 12 m. length horizontally.

1.3 Drive and arrangement of pumps

1.3.1 Each fire pump must have a power source independent of the ship's propulsion machinery.

1.3.2 On cargo ships of less than 1000 GT, one of the fire pumps may be coupled to an engine which is not exclusively intended to drive this pump.

1.3.3 On cargo ships of less than 300 GT, the fire pump may be coupled to the main engine provided that the line shafting can easily be detached from the main engine (e.g. by means of a clutch coupling or reversing gear).

1.3.4 On cargo ships of 2000 GT and over and on passenger ships, fire pumps and their power sources may not be located forward of the collision bulkhead. This requirement may be waived if a suitable fixed installed seawater pump of sufficient pressure and capacity may be connected additionally to the fire main.

1.3.5 Fire pumps and their sea connections are to be located as deep as possible below the ship's light waterline.

Where such an arrangement is impracticable, the pumps must be of self-priming type or must be connected to a priming system.

1.3.6 Provision is to be made for supplying at least one of the fire pumps in the machinery space with water from two sea chests.

On ships with ice class, a suction from the de-iced seawater cooling system is to be provided for the fire pumps.

1.3.7 For emergency fire pumps, see 1.4.

1.3.8 Ballast, bilge and other pumps provided for pumping seawater and having a sufficient capacity may be used as fire pumps provided that at least one pump is immediately available for firefighting purposes.

1.3.9 Centrifugal pumps are to be connected to the fire mains by means of screw-down non-return valves or a combination of a shutoff and a non-return device.

1.3.10 On passenger ships of ≥ 1000 GT, the water fire extinguishing equipment in interior locations is to be installed in such a way that at least one jet of water with the prescribed nozzle discharge pressure is immediately available. The uninterrupted supply of water is to be ensured by the automatic starting of one of the specified fire pumps.

1.3.11 On passenger ships of < 1000 GT the immediate availability of water for fire fighting is to be safeguarded according to either 1.3.10 or 1.3.12.

1.3.12 On ships with the Class Notation "AUT", at least one fire pump is to be provided with remote starting arrangements from the bridge and from the central fire control station, if there is one.

The associated shutoff valves from the sea water inlet to the fire main must be capable of being controlled from the above named positions. Alternatively locally-operated valves may be used; there are to be permanently kept open and provided with appropriate signs, e.g.

"Valve always to be kept open!"

1.3.13 Where on cargo ships of 500 GT and over and on passenger ships the fire pumps are located in different compartments, at least one fire pump must fulfil all requirements of an emergency fire pump specified in 1.4 (i.e. independent power and water supply etc.), with the exception of 1.4.1 first sentence being not applicable.

Table 18.2 Number and minimum capacity of fire pumps

Passenger ships		Cargo ships	
≥ 4000 GT	< 4000 GT	≥ 500 GT	< 500 GT
Number of power-driven fire pumps			
3	2	2	1
Min Q (m³/h) of one fire pump (1)			
$5,1 \cdot 10^{-3} d_H^2 (2)$	$3,8 \cdot 10^{-3} d_H^2$	$7,65 \cdot 10^{-3} d_H^2 (2)$	$5,75 \cdot 10^{-3} d_H^2$
<p>(1) d_H [mm] = theoretical diameter of the bilge main (see Section 16, N. formula 4)</p> <p>(2) Applicable to passenger ships with a criterion numeral of 30 or over in accordance with SOLAS 74/88 as amended, Chapter II-1, Part C, Regulation 35-1, 3.2.</p>			

1.4 Emergency fire pumps

1.4.1 The emergency fire pump must be capable of delivering at least 40% of the total capacity specified for the main fire pumps, but in any case not less than 25 m³/h for passenger ships of less than 1000 GT and for cargo ships of 2000 GT and over, and in any case not less than 15 m³/h for cargo ships of less than 2000 GT.

Only self-priming pumps may be installed

1.4.2 The emergency fire pump must be capable of supplying water to all parts of the ship from two hydrants simultaneously at the pressure stated in Table 18.3; see also 2.2.1.

1.4.3 All the power and water supply equipment required for the operation of the emergency fire pump must be independent of the space where the main fire pumps are installed.

In cargo ships, the room(s) where the pump and prime mover are installed should have adequate space for

maintenance work and inspections.

The electrical cables to the emergency fire pump may not pass through the machinery spaces containing the main fire pumps and their source(s) of power and prime mover(s).

If the electrical cables to the emergency fire pump pass through other high fire risk areas, they are to be of a fire resistant type.

1.4.4 The supply of fuel intended for the operation of the emergency fire pump must be sufficient for at least 18 h at nominal load.

The fuel tank intended for the emergency fire pump power supply must contain sufficient fuel to ensure the operation of the pump for at least the first 6 h without refilling. This period may be reduced to 3 h for cargo ships of less than 5000 GT.

1.4.5 The space where the emergency fire pump and its power source are installed must not be directly adjacent to machinery spaces of Category A

(8) or to the space where the main fire pumps are installed.

Where this is not feasible, the division between the rooms shall be formed by not more than one bulkhead. Recesses should be restricted to a minimum, and doors between the spaces are to be designed as airlocks. The door towards the machinery space shall be of A-60 standard.

The bulkhead is to be constructed in accordance with the insulation requirements for control stations (Chapter 1 - Hull, Section 21).

When a single access to the emergency fire pump room is through another space adjoining a machinery space of category A (8) or the spaces containing the main fire pumps, class A-60 boundary is required between that other space and the machinery space of category A or spaces containing the main fire pumps

1.4.6 The emergency fire pump is to be installed in such a way that the delivery of water at the prescribed rate and pressure is ensured under all conditions of list, trim, roll and pitch likely to be encountered in service.

If the emergency fire pump is installed above the water line in light condition of the ship, the net positive suction head of the pump ($NPSH_{req}$) should be about 1 m. lower than the net positive suction head of the plant ($NPSH_a$) (10).

Upon installation on board, a performance test is to be carried out to verify the required capacity. As far as practicable, the test shall be conducted at lightest sea-going draught at the suction position.

1.4.7 The sea suction is to be located as deep as possible and together with the pump suction and delivery pipes of the pump to be arranged outside the spaces containing the main fire pumps.

In exceptional cases consent may be given for locating of short lengths of the suction and delivery pipes in the spaces containing the main fire pumps provided that the piping is enclosed in a substantial steel casing. Alternatively to the steel casing the piping may be thick-walled acc. to Section 16., Table 16.23, Column B, but not less than 11 mm., all

welded and be insulated equivalent to A-60 standard. (11).

The sea suction may also be located in machinery spaces of category A if otherwise not practicable. In this case the suction piping shall be as short as possible and the valve shall be operable from a position in the immediate vicinity of the pump.

1.4.8 The sea valve is to be permanently kept open and provided with an appropriate sign (see 1.3.12). Alternatively, the sea valve must be operable from a position close to the pump, or close to the pump controls in the case of remote-controlled pumps.

For maintaining the operational readiness of the sea chest, the requirements of Section 16, I.1.4 and I.1.5 shall be complied with.

1.4.9 Where a fixed water-based fire extinguishing system installed for the protection of the machinery space is supplied by the emergency fire pump, the emergency fire pump capacity shall be adequate to supply the fixed fire extinguishing system at the required pressure and two jets of water (12).

1.4.10 The ventilation system of the space in which the emergency fire pump is installed shall be so designed that smoke can not be aspirated in the event of a fire in the engine room. Forced ventilation is to be connected to the emergency power supply.

1.4.11 In case of a diesel as power source for the emergency fire pump, it shall be capable of being started by hand cranking down to a temperature of 0°C.

If this is impracticable or if lower temperatures are likely to be encountered, consideration is to be given to the provision of suitable heating arrangements, e.g. room heating or heating of the cooling water or lubricating oil.

(10) Reference is made to the *BCS Guidelines for the Design, Construction and Testing of Pumps* and *IMO MSC.1/Circ.1388, "Unified Interpretation of Chapter 12 of the International Code for Fire Safety Systems (FSS Code)"* (

11) Reference is made to *BCS- I SC 245 Corr.1.*

(12) Reference is made to *BCS- I SC 163*

If starting by hand-cranking is impracticable an alternative independent means of power (compressed air, electricity, or other sources of stored energy, including hydraulic power or starting cartridges) starting shall be provided. This means shall be such as to enable the diesel to be started at least 6 times within the period of 30 min, and at least twice within the first 10 min.

2. Fire Mains

2.1 International shore connection

Ships of 500 GT and over are to be provided with at least one connector through which water can be pumped from the shore into the ship's fire main. The dimensions of the shore connection flange shall be as shown in Fig.18.1.

It shall be possible to use the shore connection on either side of the ship.

2.2 Arrangement of fire mains

2.2.1 On ships for which an emergency fire pump is specified or on which fire pumps are installed in separate compartments, it must be possible by means of shutoff valves to isolate the sections of the fire main within Category A machinery spaces **(8)** where the main fire pumps are located from the rest of the fire main. The shutoff valves are to be located in a readily accessible position outside the Category A machinery spaces.

With the shutoff valves closed, it must be possible to supply all the hydrants located outside the machinery space where the main fire pumps are located from a pump which is not sited in this space. Piping in the engine room may not normally be used for this purpose. However, in exceptional cases short sections of piping may be laid in the machinery space provided that the integrity is maintained by the enclosure of the piping in a substantial steel casing.

Isolation requirements are not applicable to the piping from fire pumps located in other spaces other than category A machinery spaces.

Alternatively to the steel casing the piping may be thickwalled acc. to Section 16, Table 16.23, Column B,

but not less than 11 mm., all welded and be insulated equivalent to A-60 standard.

2.2.2 On passenger ship of 4000 GT and over, the fire main must be constructed as a ring system equipped with appropriately sited isolating valves.

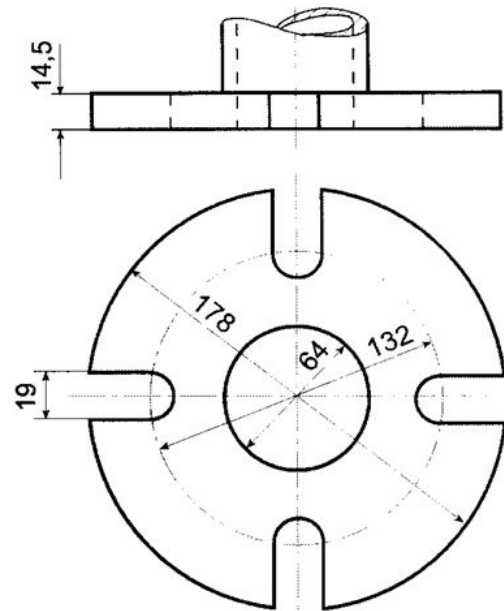


Fig. 18.1 International shore connection

2.2.3 Fire mains are to be provided with drain valves or cocks.

2.2.4 Branch pipes from the fire mains for hawse flushing are to be capable of being shut off in the vicinity of the main fire pump(s) or from the open deck. Other branch pipes not serving fire fighting purposes and which are used only occasionally may be accepted if capable of being shut from the open deck. The shutoff devices are to be fitted with warning signs instructing personnel to close them after use.

Alternatively, the forementioned branch pipes may be provided with electrically operated shutoff devices if the associated remote controls are located in a central position, e.g. in the engine control room or fire control station.

2.2.5 On tankers, the fire main is to be fitted with isolating valves at a protected position at the poop front and on the tank deck at intervals of not more than 40m.

2.2.6 In piping sections where the possibility of freezing exists during operation of the ship in cold climates, suitable provisions are to be made for continuously pressurized pipelines.

2.2.7 Relief valves are to be provided in conjunction with all fire pumps if the pumps are capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.

2.3 Fire main design

2.3.1 The following formula provides a guidance value for the sizing of fire mains:

$$d_F = 0,8d_H$$

$$d_F = \text{Internal diameter of fire main}$$

$$d_H = \text{Theoretical diameter of main bilge pipe in accordance with Section 16, N.2.}$$

$$d_{Fmin} = 50 \text{ mm.}$$

For pipe thicknesses see Section 16, Table 16.7 (Seawater lines).

2.3.2 On passenger ships the diameter d_F does not need to exceed $d_{Fmax} = 175 \text{ mm.}$, on cargo ships $d_{Fmax} = 130 \text{ mm.}$ respectively.

2.3.3 The entire fire main is to be designed for the maximum permissible working pressure of the fire pumps subject to a minimum working pressure of 10 bar.

2.3.4 At no point in the ship shall the discharge pressure at the nozzles be less than the values shown in Table 18.3 when water is drawn simultaneously from two adjacent hydrants. On liquefied gas tankers this requirement is to be met at a minimum pressure at the nozzles of 0,50 N/mm² (refer to Rules of Chapter 10 - Liquefied Gas Tankers, Section 11).

2.4 Hydrants

2.4.1 Hydrants are to be so positioned that water

from two nozzles simultaneously, one of which shall be from a single length of hose, may reach

- Any part of the ship to which passengers and crew normally have access during the voyage,
- Any part of an empty cargo space,

In ro-ro spaces or vehicle spaces it must be possible to reach any part with water from two nozzles simultaneously, each from a single length of hose.

In passenger ships any part of accommodation, service and machinery spaces must be capable of being reached with water from at least two nozzles, one of which shall be from a single length of hose, when all watertight doors and all doors in main vertical zone bulkheads are closed.

Table 18.3 Pressure at nozzles

Type of vessel	GT	Pressure at nozzle [N/mm ²]
Cargo ships	< 6000	0,25
	≥ 6000	0,27
Passenger ships	< 4000	0,30
	≥ 4000	0,40

2.4.2 Deck hydrants are to be arranged such that they remain accessible when carrying deck cargo. Hydrants shall be located near the accesses to spaces. In the case of cargo spaces for the transport of dangerous goods, the additional requirements of Part P and Q. are to be observed.

2.4.3 Hydrants in machinery spaces and boiler rooms:

The number and position of the hydrants are to be in accordance with 2.4.1. On ships of less than 500 GT a single hydrant is sufficient. Hydrants are to be sited at easily accessible points above the floor plates on each side of the ship. One of the hydrants is to be located at the lower entrance to the emergency escape.

2.4.4 Passenger ships are to be additionally equipped with two hydrants in a space adjoining the lower level of the machinery space where this space is intended to serve as an escape route (e.g. the shaft tunnel).

2.5 Fire hoses

2.5.1 Fire hoses must be made of a non-decomposing material.

2.5.2 Fire hoses are to have a length of at least 10 m., but not more than.

- .1** 15 m. in machinery spaces.
- .2** 20 m. in other spaces and open decks and.
- .3** 25 m. for open decks on ships with a maximum breadth in excess of 30 m.

Every hose must be provided with quick - acting couplings of an approved type, a nozzle and a coupling spanner. Fire hoses are to be stowed with nozzles attached in readily accessible positions close to the hydrants. Aluminium alloys may be used for fire hose couplings and nozzles, except in open deck areas of oil tankers and chemical tankers.

2.5.3 On passenger ships, a fire hose with nozzle is to be provided for each hydrant required.

On ships carrying more than 36 passengers, the hoses of hydrants located within the superstructure must be kept permanently coupled to the hydrant.

2.5.4 Cargo ships of 1000 GT and over are to be equipped with a fire hose with nozzle for every 30 m. of the ships length and with one additional hose, but at least five hoses altogether. In addition, for machinery spaces and boiler rooms a fire hose with nozzle is to be provided for each second hydrant required.

2.5.5 Cargo ships of 500 to 1000 GT are to be equipped with at least five fire hoses.

2.5.6 Cargo ships of less than 500 GT are to be equipped with at least three fire hoses.

2.5.7 Ships for the transport of dangerous goods according to Part P and Q. are to be equipped with 3 additional hoses and nozzles.

2.6 Nozzles

2.6.1 Only dual purpose spray/jet nozzles with a shutoff are to be provided.

2.6.2 The nozzle sizes shall be 12, 16 and 19 mm. or as close thereto as possible.

In accommodation and service spaces, a nozzle size of 12 mm. is sufficient.

For machinery spaces and open decks, the nozzle size shall be such that the largest possible volume of water can be delivered at the stipulated pressure by the smallest available fire pump; however, a nozzle size greater than 19 mm. need not be used.

Fire hose nozzles made of plastic type material, e.g. polycarbonate, are considered acceptable provided capacity and serviceability are documented and the nozzles are found suitable for the marine environment.

F. Portable and Mobile Fire Extinguishers, Portable Foam Applicators and Water Fog Applicators

1. Extinguishing Media, Weights of Charge, Fire classes and Spare Charges

1.1 The extinguishing medium for fire extinguishers must be suitable for the potential fire classes (see Table 18.4).

Toxic extinguishing media and extinguishing media liable to generate toxic gases may not be used.

CO₂ fire extinguishers may not be located in accommodation areas and water fire extinguishers not in machinery spaces.

1.2 Fire extinguishers must be approved in accordance with a recognized standard.

For the use in areas with electrical equipment operating at voltages > 1 kV the suitability is to be established.

1.3 The charge in portable dry powder and gas extinguishers should be at least 5 kg. and the content of foam and water extinguishers should be not less than 9 ℓ.

The total weight of a portable fire extinguisher ready for use shall not exceed 23 kg.

Table 18.4 Classification of extinguishing media

Fire class	Fire hazard	Extinguishing media
A	Solid combustible materials of organic nature (e.g. wood, coal, fibre materials, rubber and many plastics)	Water, dry powder/dry chemical, foam
B	Flammable liquids (e.g. oils, tars, petrol, greases and oil-based paints)	Dry powder/ dry chemical, foam, carbon dioxide
C	Flammable gases (e.g. acetylene, propane)	Dry powder/dry chemical
D	Combustible metals (e.g. magnesium, sodium, titanium and lithium)	Special dry powder or dry chemical (metal)
F(K)	Cooking oils, greases or fats	Wet chemical solution
-	Electrical equipment	Carbon dioxide, dry powder /dry chemical

1.4 Mobile extinguisher units are to be designed for a standard dry powder charge of 50 kg. or for a foam solution content of 45 or 135 litres.

It is recommended that only dry powder extinguishers be used.

1.5 For fire extinguishers, capable of being recharged on board, spare charges are to be provided:

- 100 % for the first 10 extinguishers of each type,
- 50 % for the remaining extinguishers of each type, but not more than 60 (fractions to be rounded off).

1.6 For fire extinguishers which cannot be recharged on board, additional portable fire extinguishers of same type and capacity shall be provided. The number is to be determined as per 1.5.

1.7 Portable foam applicators

1.7.1 A portable foam applicator unit has to consist of a foam nozzle / branch pipe, either of a self-inducing type or in combination with a separate inductor, capable of being connected to the fire main by a fire hose, together with two portable tanks each containing at least 20 litres approved foam concentrate **(13)**.

1.7.2 The nozzle / branch pipe and inductor has to be capable of producing effective foam suitable for extinguishing an oil fire, at a foam solution flow rate of at least 200 litres / min at the nominal pressure in the fire main.

2. Number and Location

2.1 General

2.1.1 One of the portable fire extinguishers is to be located at the access to the individual space it is designated for. It is recommended that the remaining portable fire extinguishers in public spaces and workshops are located at or near the main entrances and exits.

If a space is locked when unmanned, portable fire extinguishers required for that space may be kept inside or outside the space.

2.1.2 If the portable fire extinguishers are not suitable for fire-fighting in electrical installations, additional extinguishers are to be provided for this purpose. Fire extinguishers are to be marked with the maximum permissible voltage and with the minimum distance to be maintained when in use.

(13) Refer to IMO MSC.1/Circ.1312, as amended

2.2 Portable fire extinguishers

The minimum number and distribution of portable fire extinguishers shall be selected according to Table 18.5 under consideration of the fire hazards in the respective space **(14)**. The classes of portable fire extinguishers indicated in that table are given only for reference.

2.3 Mobile fire extinguishers, portable foam applicators and water fog applicators

Machinery and special category spaces are to be provided, depending on their purpose, with mobile fire extinguishers, portable foam applicator units and water fog applicators as described hereinafter.

2.3.1 Machinery spaces of category A (8) containing internal combustion machinery (15)

The following is to be provided:

- Mobile fire extinguishers of 50 kg. dry powder or 45 l foam which shall be so located that the extinguishant can be directed onto any part of the fuel and lubricating oil pressure systems, gearing and other fire hazards;
- At least one portable foam applicator unit,
- For smaller spaces on cargo ships (e.g. emergency diesel generator room), above listed equipment may be arranged outside near the entrance to that spaces.

2.3.2 Machinery spaces of category A (8) containing oil fired boilers (15)

At least is to be provided:

- Two portable foam extinguishers or equivalent in each firing space in each boiler room and in each space in which a part of the oil fuel installation is situated. There shall be not less than one approved foam-type extinguisher of at least 135 l capacity or equivalent in each boiler room. These extinguishers shall be provided with hoses on reels suitable for reaching any part of the boiler room. In case of domestic boilers of less than 175 kW, or boilers protected by fixed water-based local application fire-extinguishing

systems as required SOLAS II-2/10.5.6 an approved foam-type extinguisher of at least 135 l capacity is not required.

- A receptacle containing at least 0,1 m³ of sand or sawdust impregnated with soda or one additional portable extinguisher alternatively.
- At least portable foam applicator unit.

2.3.3 Machinery spaces containing steam turbines or enclosed steam engines

In spaces containing steam turbines or enclosed steam engines having in the aggregate a total output of 375 kW and over used for main propulsion or other purposes mobile fire extinguishers of 50 kg dry powder or 45 litres foam shall be provided which are to be so located that the extinguishant can be directed onto any part of the fuel and lubrication oil pressure system, gearing and any other fire hazard. This requirement is not applicable where the space is protected by a fixed fire extinguishing system in accordance with Table 18.1.

2.3.4 Machinery spaces of category A (8) in passenger ships

In addition to the fire fighting equipment specified in 2.2 and 2.3.1 - 2.3.3, machinery spaces of category A in passenger ships carrying more than 36 passengers are to be provided with at least two water fog applicators.

2.3.5 Machinery spaces on small ships

On ships of less than 500 GT, the machinery spaces referred to in 2.3.1 to 2.3.4 need to be equipped with a mobile fire extinguisher and a portable foam applicator unit, unless a fixed fire extinguishing system is not provided in such spaces.

(14) *Reference is made to IMO Res.A.951(23) "Improved Guidelines for Marine Portable Fire Extinguishing"*

(15) *See MSC/Circ. 1120, as amended "Regulation 10.5: Number of Systems, Appliances, and Extinguishers Required in Machinery Spaces" or BCS- I SC30 only for information.*

2.3.6 Special category spaces on passenger ships and ro-ro spaces

Each space is to be provided with one portable foam applicator unit and three water fog applicators. A total of at least two portable foam applicator units are to be supplied.

G. High-Pressure CO₂ Fire Extinguishing Systems

1. Calculation of the Necessary Quantity of CO₂

The calculation of the necessary quantity of CO₂ is to be based on a gas volume of 0,56 m³ per kg of CO₂.

If two or more individually floodable spaces are connected to the CO₂ system, the total CO₂ quantity available need not be more than the largest quantity required for one of these spaces. The system shall be fitted with normally closed control valves arranged to direct the agent into the appropriate space.

Adjacent spaces with independent ventilation systems not separated by at least A-0 class divisions should be considered as the same space.

1.1 Machinery, boiler and cargo pump spaces

1.1.1 The quantity of gas available for spaces containing internal combustion machinery oil-fired boilers other oil-fired equipment, for purifier spaces according to B.2.1 and for cargo pump rooms must be sufficient to give a minimum volume of free gas equal to the larger of the following:

- a) 40 % of the gross volume of the largest space including the casing (e.g. engine room casing) up to the level at which the horizontal area of the casing is less than 40 % of the floor of the space concerned taken midway between the tanktop and the lowest part of the casing,
- b) 35 % of the gross volume of the largest space including the casing.

1.1.2 For cargo ships under 2000 GT, the percentage specified in 1.1.1 a) and b) may be reduced to 35 % and 30 % respectively.

1.1.3 For cargo pump spaces on chemical tankers and for compressor and cargo pump spaces on liquified gas tankers the volume of free gas available is to be calculated as 45 % of the gross volume of the space.

1.1.4 For machinery spaces without casings (e.g. incinerator or inert gas generator spaces) the volume of free gas available is to be calculated as 35 % of the gross volume of the space.

1.1.5 Where two or more spaces containing boilers or internal combustion engines are not entirely separated, they are to be considered as a single space for the purpose of determining the quantity of CO₂ required.

1.1.6 The volume of starting air receivers, converted to free air volume, is to be added to the gross volume of the machinery space when calculating the necessary quantity of extinguishing medium. Alternatively, a discharge pipe, led from the safety valves to the open air, may be fitted.

1.2 Cargo spaces

1.2.1 In cargo spaces, the quantity of CO₂ available must be sufficient to fill at least 30 % of the gross volume of the largest cargo space which is capable of being sealed. Calculation of the gross volume is to be based on the distance from the double bottom (tank top) to the weather deck including the hatchway and the vertical boundaries of the cargo space concerned.

1.2.2 If a container cargo hold is fitted with partially weathertight hatchway covers the quantity of CO₂ for the cargo space is to be increased in accordance with one of the following formulae, as appropriate:

$$CO_{2\ 30\%}^{INC} = 60 \cdot A_T \cdot \sqrt{\frac{B}{2}}$$

Table 18.5 Minimum numbers and distribution of portable fire extinguishers in the various types of spaces

	Type of spaces	Minimum number of extinguishers	Class(es) of extinguisher(s)
Accommodation spaces	Public spaces	1 per 250 m ² of deck area or fraction thereof	A
	Corridors	Ttavel distance to extinguishers should not exceed 25 m. within each deck and main vertical zone.	A
	Stairways	0	
	Lavatories, cabins, offices, pantries containing no cooking appliances	0	
	Hospital	1	A
Service spaces	Laundry, drying rooms, pantries containing cooking appliances	1 (2)	A or B
	Lockers and store rooms (having a deck area of 4 m ² or more), mail and baggage rooms, workshops (not part of machinery spaces, galleys)	1 (2)	B
	Galleys	1 class B and 1 additional class F or K for galleys with deep fat fryers	B, F or K
	Lockers and store rooms (deck area is less than 4 m ²)	0	
	Paint lockers and other spaces in which flammable liquids are stowed	In accordance with Section 18, M.1	
Control stations	Control stations (other than wheelhouse), e.g. battery room (excluding CO ₂ room and foam room)	1	A or C
	Wheelhouse	2, if the wheelhouse is less than 50 m ² only 1 extinguisher is required (3)	A or C
Machinery spaces of category A	Spaces containing internal combustion machinery	No point of space is more than 10 m walking distance from an extinguisher (6)	B
	Spaces containing oil-fired boilers	2 for each firing space	B
	Spaces containing steam turbines or enclosed steam engines	No point of space is more than 10 m walking distance from an extinguisher (6)	B
	Central control station for propulsion machinery	1, and 1 additional extinguisher suitable for electrical fires when main switchboards are arranged in central control station	A and/or C
	Vicinity of the main switchboards	2	C
	Workshops	1	A or B
	Enclosed space with oil-fired inert gas generators, incinerators and waste disposal units	2	B
	Enclosed room with fuel oil purifiers	0	
	Periodically unattended machinery spaces of category A	1 at each entrance (1)	B
Other spaces	Workshops forming part of machinery spaces	1	B or C
	Other machinery spaces (auxiliary spaces, electrical equipment spaces, auto-telephone exchange rooms, air conditioning spaces and other similar spaces)	1 (7)	B or C
	Weater deck	0 (4)	B
	Ro-ro spaces and vehicle spaces	No point of space is more than 20 m walking distance from an extinguisher at each deck level (4) (5)	B
	Cargo spaces	0 (4)	B
	Cargo pump-room and gas compressor room	2	B or C
	Helidecks	In accordance with Section 18, O.1	B

**Table 18.5 Minimum numbers and distribution of portable fire extinguishers in the various types of spaces
(continued)**

- (1) *A portable fire extinguisher required for a small space may be located outside and near the entrance to that space.*
- (2) *For service spaces, a portable fire extinguisher required for that small space placed outside or near the entrance to that space may also be considered as part of the requirement for the space in which it is located.*
- (3) *If the wheelhouse is adjacent with the chartroom and has a door giving direct access to chartroom, no additional fire extinguisher is required in the chart room. The same applies to safety centres if they are within the boundaries of the wheelhouse in passenger ships.*
- (4) *Portable fire extinguishers, having a total capacity of not less than 12 kg of dry powder, should be provided when dangerous goods are carried on the weather deck, in open ro-ro spaces and vehicle spaces, and in cargo spaces as appropriate, see Section 18, P.9. Two portable fire extinguishers, each having a suitable capacity, should be provided on weather deck for tankers.*
- (5) *No portable fire extinguisher needs to be provided in cargo holds of containerships if motor vehicles with fuel in their tank own propulsion are carried in open or closed containers.*
- (6) *Portable fire extinguishers required for oil-fired boilers may be counted.*
- (7) *Portable fire extinguishers located not more than 10 m walking distance outside these spaces, e.g. in corridors, may be taken for meeting this requirement.*

$$CO_{2.45\%}^{INC} = 4 \cdot A_T \cdot \sqrt{\frac{B}{2}}$$

$CC_{2.30\%}^{INC}$ = Increase of CO₂ quantity for cargo spaces not intended for carriage of motor vehicles with fuel in their tanks for their own propulsion [kg]

$CC_{2.45\%}^{INC}$ = Increase of CO₂ quantity for cargo spaces intended for carriage of motor vehicles with fuel in their tanks for their own propulsion [kg]

A_T = Total maximum area of design-related gaps at the hatch covers [m²]

B = Breadth of cargo space protected by the CO₂ system [m]

The non-weathertight gaps shall not exceed 50 mm.

1.2.3 In the case of cargo spaces in ships carrying only coal, ore, grain unseasoned timber, non-combustible cargo or cargo which presents a low fire risk, application may be made to the national authorities for exemption from this requirement (See BCS- ISC197)

1.2.4 For the cargo spaces of ships intended for the transport of motor vehicles with partly filled fuel tanks and for closed ro-ro spaces, the available quantity of CO₂ must be sufficient to fill at least 45 % of the gross volume of the largest enclosed cargo space.

1.2.5 It is recommended that mail rooms, spaces for bonded stores and baggage compartments be connected to the CO₂ fire extinguishing system.

1.2.6 Where cargo spaces connected to a CO₂ system are temporarily used as spaces for the transport of passengers means must be provided for sealing off the relevant connecting lines during such periods by the use of spectacle flanges.

1.3 Protection of spaces against over-/under-pressure

It is to be safeguarded that flooding of a space with CO₂ cannot cause an unacceptable over- or under- pressure in the space concerned. If necessary, suitable means of pressure relief are to be provided.

2. CO₂ Cylinders

2.1 Design and equipment

2.1.1 In respect of their material, manufacture, type and testing, CO₂ cylinders must comply with the requirements of Section 14, G.

2.1.2 CO₂ cylinders may normally only be filled with liquid CO₂ in a ratio of 2 kg CO₂ to every 3 litres of cylinder capacity. Subject to the shipping route concerned, special consideration may be given to a higher filling ratio (3 kg CO₂ to every 4 litres capacity).

2.1.3 Cylinders intended for flooding boiler rooms, machinery spaces, as well as cargo pump and compressor rooms must be equipped with quick-opening valves for group release enabling these spaces to be flooded with 85 % of the required gas volume within two minutes.

Cylinders intended for the flooding of cargo spaces need only be fitted with individual release valves, except for cargo spaces for the transport of reefer containers and for the cases addressed in 3.5 which require cylinders with quick-opening valves for group release.

For cargo spaces for the carriage of motor vehicles with fuel in their tanks and for ro-ro spaces CO₂ cylinders with quick-opening valves suitable for group release are to be provided for flooding of these spaces within 10 minutes with 2/3 of the prescribed quantity of CO₂.

For container and general cargo spaces (primarily intended to carry a variety of cargoes separately secured or packed) the fixed piping system shall be such that at least two thirds of the gas can be discharged into the space within 10 min. For solid bulk cargo spaces the fixed piping system shall be such that at least two thirds of the gas can be discharged into the space within 20 min. The system controls shall be arranged to allow one third, two thirds or the entire quantity of gas to be discharged based on the loading condition of the hold.

2.1.4 Cylinder valves must be approved by a recognized institution and be fitted with an overpressure relief device.

2.1.5 Siphons must securely be connected to the cylinder valve.

2.2 Disposition of CO₂ cylinders

2.2.1 CO₂ cylinders are to be stored in special spaces, securely anchored and connected to a manifold. Check valves are to be fitted between individual cylinders and the main manifold.

If hoses are used to connect the cylinders to the manifold, they must be type-tested.

2.2.2 At least the cylinders intended for the quick flooding of boiler rooms and machinery spaces are to be grouped together in one room.

2.2.3 The cylinders for CO₂ fire extinguishing systems for scavenge trunks and for similar purposes may be stored in the machinery space on condition that an evidence by calculation is provided proving that the concentration of the free CO₂ gas (in case of leakages at all cylinders provided) relative to the net volume of the engine room does not exceed 4 %.

3. Rooms for CO₂ Cylinders

3.1 When stored outside a protected space, rooms for CO₂ cylinders are not to be located forward of the collision bulkhead and shall, wherever possible, be situated on the open deck and are not to be used for other purposes. Access should be possible from the open deck and shall be independent of the protected space. CO₂ cylinder rooms below the open deck must have a stairway or ladder leading directly to the open deck. The CO₂ cylinder room shall not be located more than one deck below the open deck. Direct connections via doors or other openings between cylinder rooms and machinery spaces or accommodation spaces below the open deck are not permitted. In addition to the cabins themselves, other spaces provided for use by passengers and crew such as sanitary spaces, public spaces, stair wells and corridors are also considered to form part of the accommodation space.

The size of the cylinder room and the arrangement of the cylinders must be conducive to efficient operation.

Means are to be provided for

- Conveying cylinders to the open deck, and
- The crew to safely check the quantity of CO₂ in the cylinders, independent of the ambient temperatures. These means shall be so arranged that it is not necessary to move the cylinders completely from their fixing position. This is achieved, for instance, by providing hanging bars above each bottle row for a weighing device or by using suitable surface indicators.

Cylinder rooms shall be lockable. The doors of cylinder rooms must open outwards.

Bulkhead and decks including doors and other means of closing any opening therein which form the boundaries between CO₂ storage rooms and adjacent enclosed spaces shall be gas tight.

Cylinder rooms are to be exclusively used for installation of CO₂ cylinders and associated system components.

For the purpose of the application of Part A Chapter 1 Hull Section 21 Tables 21.1 to 21.8, such cylinder storage rooms complying with this item 3 are to be treated as fire control stations.

3.2 Cylinder rooms are to be protected or insulated against heat and solar radiation in such a way that the room temperature does not exceed 45 °C. The boundaries of the cylinder room must conform to the insulation values prescribed for control stations (Chapter 1 - Hull, Section 21).

Cylinder rooms are to be fitted with thermometers for checking the room temperature.

3.3 Cylinder rooms are to be provided with adequate ventilation. Spaces where access from the open deck is not provided or which are located below deck are to be fitted with mechanical ventilation at not less than 6 air changes per hour. The exhaust duct should be led to the bottom of the space. Other spaces may not be connected to this ventilation

system.

3.4 Cylinder rooms are to be adequately heated if during the ship's service the nominal room temperature of 20°C cannot be maintained at the ambient conditions.

3.5 Where it is necessary for the crew to pass CO₂ protected cargo hold(s) to reach the cylinder room, e.g. if the cylinder room is located forward of CO₂ protected cargo hold(s) and the accommodation block is arranged in the aft area of the ship, remote release controls are to be placed in the accommodation area in order to facilitate their ready accessibility by the crew. The remote release controls and release lines are to be of robust construction or so protected as to remain operable in case of fire in the protected spaces. The capability to release different quantities of CO₂ into different cargo holds has to be included in the remote release arrangement.

4. Piping

4.1 Piping is to be made of weldable materials in accordance with Chapter 2 - Material.

4.2 The manifolds from the cylinder up to and including the distribution valves are to be designed for a nominal working pressure of PN 100.

Material certificates are to be provided acc. to the requirements for pipe class I (see Section 16). Manufacturers' inspection certificates may be accepted as equivalent provided that by means of the pipe marking (name of pipe manufacturers, heat number, test mark) unambiguous reference to the certificate can be established. The Rules regarding remarking are to be observed when processing the pipes.

4.3 Pipe work between distribution valves and nozzles is to be designed for a nominal working pressure of PN 40. However, for the purpose of material certification this piping may be considered in pipe class III.

4.4 All pipes are to be protected against external corrosion.

Distribution lines serving spaces other than machinery spaces are to be galvanized internally.

4.5 Wherever possible, welded pipe connections are to be used for CO₂ systems. For detachable connections which cannot be avoided and for valves and fittings, flanged joints are to be used. For pipes with a nominal bore of less than 50 mm., welded compression type couplings may be used.

Threaded joints may be used only inside CO₂ protected spaces and in CO₂ cylinder rooms.

4.6 Bends or suitable compensators are to be provided to accommodate the thermal expansion of the pipelines. Hoses for connecting the CO₂ cylinders to the manifold are to be type-approved, see Section 16, U.

4.7 Distribution piping for quick-flooding is to be designed such that icing due to expansion of the extinguishing gas cannot occur. Reference values shown in Table 18.6. System flow calculations shall be performed using a recognized calculation technique (e.g. NFPA calculation program).

4.8 The minimum nominal bore of flooding lines and of their branches to nozzles in cargo holds is 20 mm.; that of the nozzle connections 15 mm.

The pipe thicknesses are shown in Table 18.7.

For threaded pipes, where allowed, the minimum wall thickness is to be measured at the bottom of the thread.

In general the minimum thickness is the nominal wall thickness and no allowance need be made for negative tolerance or reduction in thickness due to bending.

4.9 A compressed air connection with a non-return valve and a shutoff valve is to be fitted at a suitable point. The compressed air connection must be of sufficient size to ensure that, when air is blown through the system at a pressure of 5 to 7 bar, it is possible to check the outflow of air from all nozzles.

4.10 CO₂ pipes may pass through accommodation spaces providing that they are thick walled acc. to Section 16, Table 16.7, Group D (for pipes with an outer diameter of less than 38 mm. the minimum wall thickness shall be 5,0 mm.) joined only by welding and not fitted with drains or other openings within such spaces.

CO₂ pipes may not be led through refrigerated spaces.

4.11 In piping sections where valve arrangements introduce sections of closed piping (e.g. manifolds with distribution valves), such sections shall be fitted with a pressure relief valve and the outlet of the valve shall be led to the open deck.

4.12 CO₂ pipes also used as smoke sampling pipes shall be self-draining.

4.13 CO₂ pipes passing through ballast water tanks are to be joined only by welding and be thick-walled acc. to Section 16, Table 16.7, Group D (for pipes with an outer diameter of less than 38 mm, the minimum wall thickness is to be 5,0 mm).

5. Release Devices

5.1 Release of flooding is to be performed manually. Automatic actuation is not acceptable

5.2 Release of the CO₂ cylinders, whether individually or in groups, and opening of the distribution valve must occur be actuated independently of each other. For spaces, for which CO₂ cylinders with quick-opening valves for group release are required (refer to G.2.1.3), two separate controls shall be provided for releasing CO₂ into protected space. One control shall be used for opening the distribution valve of the piping which conveys CO₂ into the protected space and a second control shall be used to discharge CO₂ from its storage cylinders. Positive means shall be provided so that these controls can only be operated in that order. The positive means shall be an interlock of mechanical and/or electrical type. **(16)**

5.3 Remotely operated cylinder actuating devices and distribution valves must be capable of local manual operation.

5.4 The controls for flooding of machinery spaces, closed ro/ro spaces, paint lockers and the like and of cargo pump and compressor spaces shall be readily accessible, simple to operate and be located

(16) Reference is made to BCS- I SC 252.

close to one of the entrances outside the space to be protected in a lockable case (release box). A separate release box is to be provided for each space which can be flooded separately, the space to which it relates being clearly indicated.

The emergency release from the CO₂ room must ensure the group release of the CO₂ cylinders for spaces requiring quick-flooding release (see G.2.1.3).

Small spaces located in close vicinity of the CO₂ room, e.g. paint store, may be flooded from the CO₂ room, in which case a separate release box may be dispensed with.

5.5 The key for the release station is to be kept in a clearly visible position next to the release station in a locked case with a glass panel.

5.6 A distribution valve (normally closed) is to be located in every flooding line outside the space to be protected in a readily accessible position. If the protection of a small space (e.g. galley range exhaust duct) requires only one cylinder with a maximum content of 6 kg CO₂, an additional shutoff downstream of the cylinder valve may be omitted.

5.7 Distribution valves are to be protected against unauthorised and unintentional actuation and fitted with signs indicating the space to which the associated CO₂ lines lead.

5.8 Distribution valves are to be made of a seawater-resistant material. It must be possible to see clearly whether the valves are open or closed.

5.9 Two separate controls (as defined in 5.2) are also to be provided in ro-ro spaces, container holds equipped with integral reefer containers, spaces accessible by doors or hatches, and other spaces in which personnel normally work or to which they have access.

In conventional cargo spaces and small spaces (such as compressor rooms, paint lockers etc.) with only a local release, two separate controls are not required.

Note: Conventional cargo spaces means cargo spaces other than ro-ro spaces or container holds equipped with integral

reefer containers, and they need not be provided with means for automatically giving audible and visual warning of the release.

The two controls shall be located inside a release box clearly identified for the particular space. If the box containing the controls is to be locked, a key to the box shall be in a break-glass-type enclosure conspicuously located adjacent to the box.

Table 18.6 Design of quick-flooding lines

Nominal diameter DN		Weight of CO ₂ for machinery and boiler spaces [kg]	Weight of CO ₂ for cargo holds for motor vehicles [kg]
[mm]	[inches]		
15	1/2	45	400
20	3/4	100	800
25	1	135	1200
32	1 1/4	275	2500
40	1 1/2	450	3700
50	2	1100	7200
65	2 1/2	1500	11500
80	3	2000	20000
90	3 1/2	3250	
100	4	4750	
110	4 1/2	6810	
125	5	9500	
150	6	15250	

Table 18.7 Minimum steel pipe thicknesses for CO₂

d _a [mm]	From cylinders to distribution valves s [mm]	From distribution valves to nozzles s [mm]
21.3 -26.9	3.2	2.6
30.0 -48.3	4.0	3.2
51.0 -60.3	4.5	3.6
63.5 -76.1	5.0	3.6
82.5 -88.9	5.6	4.0
101.6	6.3	4.0
108.0-114.3	7.1	4.5
127.0	8.0	4.5
133.0-139.7	8.0	5.0
152.4-168.3	8.8	5.6

5.10 Pilot bottles

When the simultaneous operation of the bottles is actuated by means of carbon dioxide pressure from a driver bottle, at least two pilot bottles are to be provided, with valves capable of being locally manoeuvred at all times.

The pipes connecting the pilot bottles to the valves of the other bottles are to be of steel and their arrangement is to allow piping distortion due to thermal variations or, failing this, the connection is to be made by means of a flexible pipe recognised as suitable by **BCS**.

6. CO₂ Discharge Nozzles

6.1 The number and arrangement of the nozzles provided must ensure even distribution of the CO₂.

6.2 Boiler rooms and machinery spaces

The nozzles are to be arranged preferably in the lower part of the machinery space, taking into account the room configuration, and in the bilges. At least eight nozzles are to be provided, not less than two of which shall be located in the bilges.

Nozzles shall be provided in the engine- or funnel casing, in case of equipment of fire risk being arranged there, e.g. oil fired equipment or components of the thermal oil plant.

The number of nozzles may be reduced for small machinery spaces.

6.3 Cargo spaces

Nozzles are to be sited in the upper part of the space.

When the CO₂ system is connected with a sample extraction smoke detection system, not more than four nozzles may be connected to a flooding line and the nozzles are to be so arranged that no part of the overhead deck area is more than 12 m horizontally away from a nozzle.

In cargo holds where non-gastight tween deck panels (movable stowage platforms) are provided, the nozzles shall be located in both the upper and lower parts of the cargo holds.

Demands on sample extraction smoke detection systems are detailed in C.6.2 of this Section and in the **BCS** Rules Chapter 5 - Electrical Installations, Section 9, D.3.7.2.

7. Alarm Systems

7.1 For machinery spaces, boiler, cargo pump rooms and similar spaces, acoustic alarms of horn or siren sound and visual alarms are to be provided which shall be independent of the discharge of CO₂. The audible warning shall be located so as to be audible throughout the protected space with all machinery operating and is to be clearly distinguishable from all other alarm signals by adjustment of sound pressure or sound patterns.

When audible alarms are fitted to warn of the release of fire extinguishing medium into pump rooms see D.2.3.

The pre-discharge alarms must be automatically actuated a suitable time before flooding occurs. As adequate shall be considered the period of time necessary to evacuate the space to be flooded but not less than 20 s. The system is to be designed such that flooding is not possible before this period of time has elapsed by means of a mechanical timer.

The automatic actuation of the CO₂ alarm in the protected space may be realized by e.g., opening the door of the release station.

The alarm must continue to sound as long as the flooding valves are open.

7.2 Where adjoining and interconnecting spaces (e.g. machinery space, purifier room, machinery control room) have separate flooding system, any danger to persons must be excluded by suitable alarms in the adjoining spaces.

7.3 Audible and visual warnings (pre-discharge alarms as defined in 7.1) are also to be provided in any ro-ro spaces, container holds equipped with integral reefer containers, spaces accessible by doors or hatches, and other spaces in which personnel normally work or to which they have access.

In conventional cargo spaces audible/visual alarms are not required.

Note: Conventional cargo spaces means cargo spaces other than ro-ro spaces or container holds equipped with integral reefer containers, and they need not be provided with means for automatically giving audible and visual warning of the release.

In small spaces (such as compressor rooms, paint lockers etc.) with only a local release, the alarms may be dispensed with if the CO₂ system can be released either from a place next to the access door outside of this space or from the CO₂ room provided this room is located in close vicinity to the protected space.

7.4 The power supply to electrical alarm systems must be guaranteed in the event of failure of the ships main power supply.

7.5 If the alarm is operated pneumatically, a permanent supply of compressed air for the alarm system is to be ensured.

7.6 Alarm systems for the cargo area of tankers: Chapter 5 - Electrical Installations, Section 15.

8. General Arrangement Plan

On the bridge and in the CO₂ rooms arrangement plans are to be displayed showing the disposition of the entire CO₂ systems. The plan must also indicate how many cylinders are to be released to extinguish fires in individual spaces.

Clear operating instructions are to be posted at all release stations.

9. Warning Signs

9.1 For CO₂ systems the following signs are to be displayed:

9.1.1 At the release stations:

"Do not operate release until personnel have left the space, the ventilation has been shutoff and the space has been sealed."

9.1.2 At the distribution stations and in the CO₂ room:

"Before flooding with CO₂ shutoff ventilation and close air intakes. Open distribution valves first, then the cylinder valves!"

9.1.3 In the CO₂ room and at entrances to spaces which can be flooded:

"WARNING!"

"In case of alarm or release of CO₂ leave the space immediately (danger of suffocation)."

The space may be re-entered only after thorough ventilating and checking of the atmosphere."

9.1.4 In the CO₂ cylinder room:

"This space may be used only for the storage of CO₂ cylinders for the fire extinguishing system. The temperature of the space is to be monitored."

9.1.5 At the release station for the CO₂ system for the cargo pump and gas compressor rooms of tank ships carrying flammable materials, the warning sign is to bear the additional instruction:

"Release device to be operated only after outbreak of fire in.....space".

10. Testing

10.1 After installation, the piping is to be subject to hydraulic pressure tests in the presence of a BCSSurveyor by using following test pressures:

- Piping between cylinders and distribution valves to be tested at 150 bar.
- Piping passing through accommodation spaces to be tested at 50 bar
- All other piping to be tested at 10 bar.

The hydrostatic test may also be carried out prior to installation on board in the case of piping which is manufactured complete and equipped with all fittings.

Joints welded on board must undergo a hydrostatic test at the appropriate pressure.

Where water cannot be used as the test medium and the piping cannot be dried prior to putting the system into service, proposals for alternative test media or test procedures are to be submitted to **BCS** for approval.

10.2 After assembly on board, a tightness test is to be performed using air or other suitable media.

The selected pressure depends on the method of leak detection used.

10.3 All piping is to be checked for free passage and tightness.

10.4 A test of the free air flow in all pipes and nozzles is to be carried out.

10.5 A functional test of the alarm equipment is to be carried out.

H. Low-Pressure CO₂ Fire Extinguishing Systems

1. Calculation of the Necessary Quantity of CO₂

Calculation of the necessary quantity of CO₂ is subject to the provisions set out in G.1.

2. CO₂ Containers

2.1 Design and construction

2.1.1 The system control devices and the refrigerating plants shall be located within the same room where the pressure vessels are stored.

2.1.2 The rated CO₂ supply is to be stored in pressure vessels at a pressure of 18 to 22 bar.

2.1.3 With regard to their material, manufacture, construction, equipment and testing, the containers must comply with the requirements contained in Section 14.

2.1.4 The containers may be filled with liquid CO₂ up to a maximum of 95 % of their volumetric capacity calculated at 18 bar.

2.1.5 Provision is to be made for:

- Pressure gauge
- High pressure alarm: not more than setting of the relief valve;
- Low pressure alarm: not less than 18 bar;
- Branch pipes with stop valves for filling the vessel;
- Discharge pipes;
- Liquid CO₂ level indicator, fitted on the Vessel(s);
- Two safety valves.

The vapour space must be sufficient to allow for the increase in volume of the liquid phase due to a temperature rise corresponding to the setting pressure of the relief valves.

2.2 Equipment

2.2.1 Pressure monitoring

The container pressure is to be monitored and an independent visual/audible alarm signaling both high pressure prior to the attainment of the setting pressure of the relief valves and low pressure at not less than 18 bar is to be provided.

2.2.2 Monitoring of liquid level

Each container is to be equipped with two level gauges mutually independent, one of which must provide permanent monitoring of the liquid level.

A liquid level of 10 % or more below the set level shall trip a visual/audible alarm.

Where more than one space is protected by the CO₂ system, a remote indicator is to be provided at all

release stations outside the room in which the container is located. A remote indicator may be dispensed with if, after release, the discharge of the rated quantity of CO₂ is regulated automatically, e.g. by an automatic timer.

2.2.3 Safety relief valves

Each container is to be fitted with two safety relief valves with shutoff valves on the inlet side. The shut-off valves shall be interlocked in such a way that the cross-sectional area of one relief valve is available at all times.

The setting pressure of the relief valves must be at least 10 % above the cut-in pressure of the refrigerating units.

The capacity line of each relief valve must be so dimensioned that the quantity of gas produced by the action of fire on the container can be discharged without the pressure in the container exceeding the setting pressure of the relief valves by more than 20 %. For the calculation see Chapter 10 - Liquefied Gas Tankers.

The blow-off line is to discharge into the open.

2.2.4 Insulation

Containers and piping which are normally filled with CO₂ are to be insulated in such that after failure of the refrigeration, assuming a container pressure equal to the cut-in pressure of the refrigerating units and an ambient temperature of 45°C, the setting pressure of the relief valves is not reached before a period of 24 h.

3. Refrigerating Plant

3.1 At least two complete, mutually independent, automatically refrigerating sets are to be provided. The capacity of the refrigerating sets shall be such that the required CO₂ temperature can be maintained under conditions of continuous operating during 24 hours with an ambient temperature of 45°C and a seawater temperature of 32°C.

3.2 The failure of a refrigerating set must cause the standby set to start up automatically. Manual switchover must be possible.

3.3 Separate electrical supply must be provided from the main switchboard busbars by a separate feeder.

3.4 At least two circulating pumps must be available for the cooling water supply. One of these pumps can be used as standby pump for other purposes provided that it can be put into operation immediately without endangering other essential system.

3.5 The supply of cooling water must be available from two sea chests, wherever possible from either side of the ship, preferably one port and one starboard.

4. Location and Disposition

CO₂ containers and the corresponding refrigerating equipment are to be located in special rooms.

The disposition and equipping of the rooms are to comply with the applicable provisions of G.3.

The system control devices and the refrigerating plants shall be located in the same room where the pressure vessels are stored.

5. Piping, Valves and Fittings

Unless otherwise specified below, G.4, G.5 and G.6 apply analogously together with Section 16, B. wherever relevant.

5.1 Safety relief devices are to be provided in each section of pipe that may be isolated by block valves and in which there could be a build-up of pressure in excess of the design pressure of any of the components.

5.2 The flooding lines are to be so designed that, when flooding occurs, the vaporization of CO₂ does not occur until it leaves the nozzles. The pressure at the nozzles must be at least 10 bar.

5.3 A filling connection with the necessary means of pressure equalization is to be provided on either side of the ship.

6. Monitoring

Audible and visual alarms are to be given in a central

control station for the following variations from the reference condition:

- Pressure above maximum or below minimum in accordance with 2.2.1,
- Liquid level too low in accordance with 2.2.2,
- Failure of a refrigerating set.

This alarm may function as group alarm "Fault in the CO₂ fire extinguishing system"

7. Release

7.1 The automatic release of CO₂ flooding is not permitted.

7.2 If a device is provided which automatically regulates the discharge of the rated quantity of carbon dioxide into the protected spaces, it shall be also possible to regulate the discharge manually.

7.3 If devices are fitted for automatically gauging the rated quantity of CO₂ provision must also be made for manual control. G.5.2 also applies.

7.4 If the system serves more than one space, means for control of discharge quantities of CO₂, shall be provided, e.g. automatic timer or accurate level indicators located at the control positions.

8. Alarm Systems General Arrangement Plans and Warning Signs

Signs giving the following information are to be permanently fixed in the CO₂ cylinder room and to the valve groups for the flooding of individual spaces with CO₂:

- Name of space and gross volume in m³,
- Necessary volume of CO₂,
- Number of nozzles for the space,
- Flooding time in minutes (i.e. the time the flooding valves must remain open).

G.7, G.8 and G.9 also apply as appropriate.

9. Tests

9.1 After installation, lines between tanks and distribution valves are to be pressure-tested at least 1,5 times the pressure setting of the relief valves.

Lines which pass through accommodation spaces are to be tested after installation at a pressure of 50 bar gauge. A test pressure of 10 bar is required for all other lines.

The performance of the test is to conform to G.10.1.

9.2 G.10.2 to G.10.5 apply wherever relevant.

I. Gas Fire-Extinguishing Systems Using Gases Other than CO₂ for Machinery Spaces and Cargo Pump-Rooms

1. General

1.1 Suppliers for the design and installation of fire extinguishing systems using extinguishing gases other than CO₂ are subject to special approval by **BCS**.

1.2 Systems using extinguishing gases other than CO₂ shall be approved in accordance with a standard acceptable to **BCS**. (17)

1.3 The system shall be designed to allow evacuation of the protected space prior to discharge. Means shall be provided for automatically giving audible and visual warning of the release of the fire extinguishing medium into the protected space.

The alarm shall operate for the period of time necessary to evacuate the space, but not less than 20 sec before the medium is released. Unnecessary exposure, even at concentrations below an adverse effect level, shall be avoided.

(17) Refer to IMO MSC/Circ. 848, "Revised Guidelines for the Approval of Equivalent Fixed Gas Fire Extinguishing Systems, as Referred to in SOLAS 74, for Machinery Spaces and Cargo Pump Rooms", as amended by MSC.I/Circ.1267.

1.3.1 Even at concentrations below an adverse effect level, exposure to gaseous fire extinguishing agents shall not exceed 5 min. Halocarbon clean agents may be used up to the NOAEL (No Observed Adverse Effect Level) calculated on the net volume of the protected space at the maximum expected ambient temperature without additional safety measures.

If a halocarbon clean agent shall be used above its NOAEL, means shall be provided to limit exposure to no longer than the time specified according to a scientifically accepted physiologically based pharmacokinetic (PBPK) model **(18)** or its equivalent which clearly establishes safe exposure limits both in terms of extinguishing media concentration and human exposure time.

1.3.2 For inert gas systems, means shall be provided to limit exposure to no longer than 5 min for systems designed to concentrations below 43 % (corresponding to an oxygen concentration of 12 %) or to limit exposure to no longer than 3 min for systems designed to concentrations between 43 % and 52 % (corresponding to between 12 % and 10 % oxygen) calculated on the net volume of the protected space at the maximum expected ambient temperature.

1.3.3 In no case shall a halocarbon clean agent be used at concentrations above the LOAEL (Lowest Observed Adverse Effect Level) nor the ALC (Approximate Lethal Concentration) nor shall an inert gas be used at gas concentrations above 52 % calculated on the net volume of the protected space at the maximum expected ambient temperature.

1.4 For systems using halocarbon agents the system shall be designed for a discharge of 95 % of the design concentration in not more than 10 s.

For systems using inert gases, the discharge time shall not exceed 120 s for 85 % of the design concentration.

(18) Refer to documented IMO FP 44/INF.2 – “Physiologically based pharmacokinetic model to establish safe exposure criteria for halocarbon fire extinguishing agents.”

1.5 For cargo pump rooms handling flammable liquids other than oil or petroleum products, the system may be used only if the design concentration for the individual cargo has been established in accordance with the approval standard **(18)** and is documented in the approval certificate.

2. Calculation of the Supply of Extinguishing Gas

2.1 The supply of extinguishing gas shall be calculated based on the net volume of the protected space, at the minimum expected ambient temperature using the design concentration specified in the system's type approval certificate.

2.2 The net volume is that part of the gross volume of the space which is accessible to the free extinguishing gas including the volumes of the bilge and of the casing. Objects that occupy volume in the protected space should be subtracted from the gross volume. This includes, but is not necessarily limited to:

- Internal combustion engines,
- Reduction gear,
- Boilers,
- Heat exchangers,
- Tanks and trunks,
- Exhaust gas pipes, -boilers and –silencers.

2.3 The volume of free air contained in air receivers located in a protected space shall be added to the net volume unless the discharge from the safety valves is led to the open air.

2.4 In systems with centralized gas storage for the protection of more than one space the quantity of extinguishing gas available need not be more than the largest quantity required for any one space so protected.

3. Gas Containers

3.1 Containers for the extinguishing gas or a propellant needed for the discharge shall comply in respect of their material, construction, manufacture and testing with the relevant **BCS** Rules on pressure vessels.

3.2 The filling ratio shall not exceed that specified in the system's type approval documentation.

3.3 Means are to be provided for the ship's personnel to safely check the quantity of medium in the containers. These means shall be so arranged that it is not necessary to move the cylinders completely from their fixing position. This is achieved, for instance, by providing hanging bars above each bottle row for a weighting device or by using suitable surface indicators.

4. Storage of Containers

4.1 Centralised systems

Gas containers in centralised systems are to be stored in a storage space complying with the requirements for CO₂ storage spaces (See Section 18, G.3), with the exception that storage temperatures up to 55 °C are permitted, unless otherwise specified in the type approval certificate.

4.2 Modular systems

4.2.1 All systems covered by these Regulations may be executed as modular systems with the gas containers, and containers with the propellant if any, permitted to be stored within the protected space providing the conditions of I.4.2.2 through I.4.2.9 below are complied with.

4.2.2 Inside a protected space, the gas containers shall be distributed throughout the space with bottles or groups of bottles located in at least six separate locations. Duplicate power release lines have to be arranged to release all bottles simultaneously. The release lines shall be so arranged that in the event of damage to any power release line, five sixth of the fire extinguishing gas can still be discharged. The bottle

valves are considered to be part of the release lines and a single failure shall include also failure of the bottle valve.

For systems that need less than six containers (using the smallest bottles available), the total amount of extinguishing gas in the bottles shall be such that in the event of a single failure to one of the release lines (including bottle valve), five sixth of the fire extinguishing gas can still be discharged. This may be achieved by for instance using more extinguishing gas than required so that if one bottle is not discharging due to a single fault, the remaining bottles will discharge the minimum five sixth of the required amount of extinguishing gas. This can be achieved with minimum two bottles. However, the NOAEL value calculated at the highest expected engine room temperature may not be exceeded when discharging the total amount of extinguishing gas simultaneously.

Systems that cannot comply with the above (for instance where it is intended to locate only one bottle inside the protected space) are not permitted. Such systems must be designed with bottle(s) located outside the protected space, in a dedicated room complying with the requirements for CO₂ storage spaces (see G.3).

4.2.3 Duplicate sources of power located outside the protected space shall be provided for the release of the system and be immediately available, except that for machinery spaces, one of the sources of power may be located inside the protected space.

4.2.4 Electric power circuits connecting the containers shall be monitored for fault conditions and loss of power. Visual and audible alarms shall be provided to indicate this.

4.2.5 Pneumatic or hydraulic power circuits connecting the containers shall be duplicated. The sources of pneumatic or hydraulic pressure shall be monitored for loss of pressure. Visual and audible alarms shall be provided to indicate this.

4.2.6 Within the protected space, electrical circuits essential for the release of the system shall

be heat-resistant, e.g. mineral-insulated cable or equivalent.

Piping systems essential for the release of systems designed to be operated hydraulically or pneumatically shall be of steel or other equivalent heat resistant material.

4.2.7 The containers shall be monitored for decrease in pressure due to leakage or discharge. Visual and audible alarms in the protected space and on the navigating bridge or in the space where the fire control equipment is centralized shall be provided to indicate this.

4.2.8 Each container is to be fitted with an overpressure release device which under the action of fire causes the contents of the container to be automatically discharged into the protected space.

5. Piping and Nozzles

5.1 Piping is to be made of weldable steel materials and to be designed according to the working pressure of the system.

5.2 Wherever possible, pipe connections are to be welded. For detachable pipe joints, flange connections are to be used. For pipes with a nominal I.D of less than 50 mm. threaded welding sockets may be employed. Threaded joints may be used only inside protected spaces.

5.3 Piping terminating in cargo pump rooms shall be made of stainless steel or be galvanized.

5.4 Flexible hoses may be used for the connection of containers to a manifold in centralized systems or to a rigid discharge pipe in modular systems.

Hoses shall not be longer than necessary for this purpose and be type approved for the use in the intended installation. Hoses for modular systems are to be flame resistant.

5.5 Only nozzles approved for use with the system shall be installed. The arrangement of nozzles shall comply with the parameters specified in the

system's type approval certificate, giving due consideration to obstructions. In the vicinity of passages and stairways nozzles shall be arranged such as to avoid personnel being endangered by the discharging gas.

5.6 The piping system shall be designed to meet the requirements stipulated in item 1.4 above. System flow calculations shall be performed using a recognized calculation technique (e.g. NFPA calculation program).

5.7 In piping sections where valve arrangements introduce sections of closed piping (manifolds with distribution valves), such sections shall be fitted with a pressure relief valve and the outlet of the valve shall be led to the open deck.

6. Release Arrangements and Alarms

6.1 The system is to be designed for manual release only.

The controls for the release are to be arranged in lockable cabinets (release stations), the key being kept conspicuously next to the release station in a locked case with a glass panel. Separate release stations are to be provided for each space which can be flooded separately. The release stations shall be arranged near to the entrance of the protected space and shall be readily accessible also in case of a fire in the related space. Release stations shall be marked with the name of the space they are serving.

6.2 Centralized systems shall be provided with additional means of releasing the system from the storage space.

6.3 Audible and visual alarms shall be provided in the protected space and additional visual alarms at each access to the space.

6.4 The automatic actuation of the alarm in the protected space may be realized by e.g., opening of the release station door. Means are to be provided to safeguard that the discharge of extinguishing gas is not possible before the alarm has been actuated for a

period of time necessary to evacuate the space but not less than 20 s.

6.5 Audible alarms shall be of horn or siren sound. They shall be located so as to be audible throughout the protected space with all machinery operating and be clearly distinguishable from other audible signals by adjustment of sound pressure or sound patterns.

6.6 Electrical alarm systems shall have power supply from the main and emergency source of power.

6.7 For the use of electrical alarm systems in gas dangerous zones refer to the relevant section of the Rules, Chapter 5 - Electrical Installations.

6.8 Where pneumatically operated alarms are used the permanent supply of compressed air is to be safeguarded by suitable arrangements.

7. Tightness of the Protected Space

7.1 Apart from being provided with means of closing all ventilation openings and other openings in the boundaries of the protected space, special consideration shall be given to items 7.2 through 7.4. below.

7.2 A minimum agent holding time of 15 min should be provided.

7.3 The release of the system may produce significant over- or under pressurization in the protected space which may necessitate the provision of suitable pressure equalizing arrangements.

7.4 Escape routes which may be exposed to leakage from the protected space should not be rendered hazardous for the crew during or after the discharge of the extinguishing gas. In particular, hydrogen fluoride (HF) vapour can be generated in fires as a breakdown product of the fluorocarbon fire extinguishing agents and cause health effects such as upper respiratory tract and eye irritation to the point of impairing escape.

Control stations and other locations that require

manning during a fire situation are to have provisions to keep HF and HCl below 5 ppm at that location. The concentrations of other products are to be kept below values considered hazardous for the required duration of exposure.

8. Warning Signs and Operating Instructions

8.1 Warning signs are to be provided at each access to and within a protected space as appropriate:

- "WARNING! This space is protected by a fixed gas fire extinguishing system using . Do not enter when the alarm is actuated!"
- "WARNING! Evacuate immediately upon sounding of the alarm of the gas fire extinguishing system."

The release stations for cargo pump rooms are to be provided with an additional warnings as follows:

- "Release to be operated only in the event of fire in the pump room. Do not use for inerting purposes!"

8.2 Brief operating instructions are to be posted at the release stations.

8.3 A comprehensive manual with the description of the system and maintenance instructions is to be provided on the ship. The manual shall contain an advice that any modifications to the protected space that alter the net volume of the space will render the approval for the individual installation invalid. In this case amended drawings and calculations have to be submitted to **BCS** for approval.

The manual shall also address recommended procedures for the control of products of agent decomposition, including HF vapour generated from fluorocarbon extinguishing agents which could impair escape. Clearly, longer exposure of the agent to high temperatures would produce greater concentrations of these types of gases. The type and sensitivity of detection, coupled with the rate of discharge, shall be selected to minimize the exposure time of the agent to the elevated temperature. The performance of fire

extinguishing arrangements on passenger ships shall not present health hazards from decomposed extinguishing agents; for example on passenger ships, the decomposition products shall not be discharged in the vicinity of muster (assembly) stations. Further precautions include evacuation and donning masks.

9. Documents for Approval

9.1 Prior to commencing of the installation the following documents are to be submitted in triplicate to **BCS** H.O. for approval:

- Arrangement drawing of the protected space showing machinery etc. in the space, and the location of nozzles, containers (modular system only) and release lines as applicable;
- List of volumes deducted from the gross volume;
- Calculation of the net volume of the space and required supply of extinguishing gas;
- Isometrics and discharge calculations;
- Release schematic;
- Drawing of the release station and of the arrangement in the ship;
- Release instructions for display at the release station;
- Drawing of storage space (centralised systems only);
- Alarm system schematic;
- Part list;
- Shipboard manual.

10. Testing

10.1 Piping up to a shut-off valve if available is subject to hydrostatic testing at 1,5 times the max. allowable working pressure of the gas container.

10.2 Piping between the shut-off valve or the container valve and the nozzles is subject to hydrostatic testing at 1,5 times the max. pressure assessed by the discharge calculations.

10.3 Piping passing through spaces other than the protected space is subject to tightness testing after installation at 10 bar, and at 50 bar if passing through accommodation spaces.

J. Other Fire Extinguishing Systems

1. Steam Fire Extinguishing Systems

Steam may be used as extinguishant in limited local applications (e.g. scavenge trunks) if agreed upon with **BCS (19)**.

2. Aerosol Fire Extinguishing Systems

Systems using an aerosol as fire extinguishing medium shall be type approved by **BCS** in accordance with an international Standard **(20)**.

3. Dry Chemical Powder Fire-Extinguishing Systems

Dry chemical powder fire-extinguishing systems for the protection of ships carrying liquefied gases in bulk shall be approved by **BCS** in accordance with an international standard **(21)**.

(19) See FSS Code, Chapter 5.2.3.

(20) Refer to IMO MSC/Circ. 1270 , “Revised Guidelines for the Approval of Fixed Aerosol Fire-Extinguishing Systems Equivalent to Fixed Gas Fire-Extinguishing Systems, as Referred to in SOLAS 74, for Machinery Spaces.”, with Corr.1.

(21) Refer to IMO MSC.1/Circ.1315, “Guidelines for the Approval of Fixed Dry Chemical Powder Fire-Extinguishing Systems for the Protection of Ships carrying Liquefied Gases in Bulk”.

K. Foam Fire Extinguishing Systems**1. Foam Concentrates**

1.1 Only approved **(22)** foam concentrates may be used; see also D.1.3.

1.2 Distinction is made between low- and high-expansion foam.

In the case of low-expansion foam, produced by adding 3-6 % foam concentrate, the foam expansion ratio (i.e. the ratio of the volume of foam produced to the mixture of water and foam concentrate supplied) shall not exceed 12:1.

For high-expansion foam, produced by adding 1 - 3 % foam concentrate, the expansion ratio may be 100 : 1 up to 1000 : 1. Foam concentrate for the production of multi-purpose foam may be used.

Deviations from these expansion ratios require the approval of **BCS**.

Foam concentrates intended for use in the cargo area of chemical tankers must be alcohol-resistant if this is necessitated by the List of Products, Chapter 8 - Chemical Tankers.

Tankers for the carriage of alcohols and other flammable polar liquids shall be provided with alcohol resistant foam concentrate.

2. Low-Expansion Foam Systems for Tankers (Deck Foam Systems)

2.1 Deck foam systems on tankers carrying chemicals in bulk listed in Chapter 17 of the IBC Code having a flashpoint not exceeding 60 °C are to be designed according to the Rules of Chapter 8 - Chemical Tankers, Section 11, 11.3.

2.2 Deck foam systems on tankers carrying (see note below):

- crude oil or petroleum products having a flashpoint not exceeding 60 °C; or
- IBC Code chapter 18 products having a flashpoint not exceeding 60 °C; or
- petroleum products with a flashpoint exceeding 60 °C; or
- IBC Code chapter 17 products with a flashpoint exceeding 60 °C

shall be designed according to the revised Chapter 14 of the FSS Code as implemented with Res.MSC.339(91).

Note: For details, refer to paragraph 2.2.1.1 of the revised Chapter 14 of the FSS Code adopted with Res. MSC.339(91).

2.3 The foam fire extinguishing system is to be so designed that foam is available for the entire cargo deck area as well as for any cargo tank, the deck of which has ruptured.

2.4 The deck foam system shall be capable of simple and rapid operation. The main control station for the system shall be suitably located outside the cargo area, adjacent to the accommodation spaces and readily accessible and operable in the event of fire in the areas protected.

The major equipment such as the foam concentrate tank and the pumps may be located in the engine room. The controls of the system are to be located in accordance with requirements above.

At each condition, it is to be obtained that the temperature inside space must not exceed the minimum and maximum storage temperatures of the foam concentrate as referred by the manufacturer according to MSC.1/Circ.1312, Annex, 3.13.11.

2.5 Capacity of the foam fire extinguishing system pump and supply of foam solution:

The rate of supply of foam solution (mixture of water and foam concentrate) is to be calculated in accordance

(22) See IMO MSC.1/Circ.1312 and MSC/Circ.670.

with the following formulae. The rate is to be based on the largest calculated value.

- a) 0,6 litres per minute per square metre of the cargo deck area, where cargo deck area means the maximum breadth of the ship multiplied by the total longitudinal extent of the cargo tank spaces.

$$V = 0,6 \cdot \ell_c \cdot B \text{ [ℓ/min]} \text{ or}$$

- b) 6 litres per minute per square metre of the horizontal sectional area of the single tank having the largest such area.

$$V = 6 \cdot \ell \cdot b \text{ [ℓ/min]} \text{ or}$$

- c) 3 litres per minute per square metre of the area to be protected by the largest monitor and lying entirely forward of the monitor, subject to a minimum of 1250 litres/minute.

$$V = 3 \cdot B \cdot 0,75 \ell_1 \text{ [ℓ/min]}$$

The minimum supply of foam concentrate shall be such that, based on the largest value calculated by applying a), b) and c), the production of foam is guaranteed for at least 30 minutes on tankers without an inert gas system and for at least 20 minutes on tankers with an inert gas system.

$$S_{\min} = V \cdot s \cdot t \text{ [ℓ]}$$

V = Rate of supply of foam solution, [ℓ/min]

ℓ_c = Length of cargo area, [m]

B = Breadth of ship, [m]

ℓ = Length of largest cargo tank, [m]

b = Breadth of largest cargo tank, [m]

S_{\min} = Minimum supply of foam concentrate, [ℓ]

s = Dosing rate (for synthetic foam concentrate normally 0,03),

ℓ_1 = Throw of monitor, [m]

t = Duration of foam application, [min]

2.5.1 The foam concentrate supplied on board shall be approved by **BCS** (see note below) for the cargoes intended to be carried. Type B foam concentrates shall be supplied for the protection of crude oil, petroleum products and non-polar solvent cargoes. Type A foam concentrates shall be supplied for polar solvent cargoes, as listed in the table of Chapter 17 of the IBC Code. Only one type of foam concentrate shall be supplied, and it shall be effective for the maximum possible number of cargoes intended to be carried. For cargoes for which foam is not effective or is incompatible, additional arrangements to the satisfaction of **BCS** shall be provided.

Note: Refer to the Guidelines for performance and testing criteria and surveys of foam concentrates for fixed fire-extinguishing systems (MSC.1/Circ.1312).

2.5.2 Liquid cargoes with a flashpoint not exceeding 60 °C for which a regular foam fire-fighting system is not effective shall comply with the provisions of Regulation II-2/1.6.2.1 of SOLAS.

2.6 Foam distribution and capacity of monitors

Foam from the fixed foam system shall be supplied by means of monitors and foam applicators. Prototype tests of the monitors and foam applicators shall be performed to ensure the foam expansion and drainage time of the foam produced does not differ more than ± 10 per cent of that determined in item 2.5.1. When medium expansion ratio foam (between 21 to 1 and 200 to 1 expansion ratio) is employed, the application rate of the foam and the capacity of a monitor installation shall be to the satisfaction of **BCS**.

2.6.1 The foam from the fixed foam system is to be discharged through monitors and foam applicators. Each monitor must be capable of supplying at least 50 % of the required foam solution. The delivery rate of a monitor may not be less than 1250 litres/minute.

On tankers of less than 4000 dwt, foam applicators may be provided instead of monitors.

2.6.2 The number and position of the monitors is to comply with the requirements specified in 2.3. The capacity of any monitor in litres per minute of foam solution must be at least three times the deck area in square metres protected by that monitor, such area being entirely forward of the monitor.

2.6.3 The distance from the monitor to the farthest extremity of the protected area forward of that monitor shall not be more than 75 % of the monitor throw in still air conditions.

$$M = 3 B 0,75 l_1 [l/min]$$

M = Delivery rate of one monitor $\geq 0,5 V$, but not less than 1250 l/min, [l/min]

2.6.4 A monitor and a hose connection for a foam applicator shall be situated to both port and starboard at the poop front or the accommodation spaces facing the cargo deck. The port and starboard monitors may be located in the cargo areas provided they are aft of cargo tanks and that they protect below and aft of each other. In addition, connections for foam applicator are to be sited between the monitors to give greater flexibility in the fighting of fires. The capacity of each foam applicator may not be less than 400 litres per minute and the applicator throw may not be less than 15 m. still air conditions.

At least four foam applicators must be available. The number and disposition of foam hydrants are to be such that foam from at least two applicators can be directed on to any area of the cargo deck. Applicators shall be provided to ensure flexibility of action during fire-fighting operations and to cover areas screened from the monitors.

2.6.5 On tankers of less than 4000 dwt, one hose connection each for a foam applicator is to be provided to port and starboard at the poop front or the accommodation spaces facing the cargo deck. The capacity of each foam applicator must be equivalent to at least 25 % of the quantity of foam solution calculated

in accordance with 2.5 a) or 2.5 b). The capacity and throw of the foam applicators may not be less than those specified in 2.6.4.

2.6.6 Valves shall be provided in the foam main, and in the fire main when this is an integral part of the deck foam system, immediately forward of any monitor position to isolate damaged sections of those mains.

2.7 Operation of a deck foam system at its required output shall permit the simultaneous use of the minimum required number of jets of water at the required pressure from the fire main (see item E). Where the deck foam system is supplied by a common line from the fire main, additional foam concentrate shall be provided for operation of two nozzles for the same period of time required for the foam system. The simultaneous use of the minimum required jets of water shall be possible on deck over the full length of the ship, in accommodation, control stations, service spaces and machinery spaces (23).

2.8 The supply of foam concentrate and the necessary pumps are to be located outside the area to be protected. The means of control of any such systems shall be readily accessible and simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by a fire in the protected space.

3. High-Expansion Foam Systems

3.1 General

High-expansion foam systems for protection of machinery spaces, cargo pump rooms, vehicle and ro-ro spaces as well as cargo spaces shall be **BCS** type approved.(24)

(23) Refer to IMO MSC/Circ.1120, as amended

(24) Reference is made to IMO circular MSC.1/Circ.1384, "Guidelines for the Testing and Approval of Fixed High-Expansion Foam Systems".

3.2 Inside air foam systems, outside air foam systems, and foam systems using outside air with foam generators installed inside the protected space

The type of system used and the scope of system design requirements to be applied depend on the location of the foam generators (inside or outside the protected space) and the kind of space protected (machinery space or vehicle space, etc.). The details of the system used (dimensioning and capacity provisions, arrangement of foam generators, power supply, etc.) and the scope of testing after installation shall satisfy the requirements of the revised Chapter 6 of the FSS Code (Refer to Res. MSC.327(90)).

Note:

Refer to BCS- I SC262 for largest protected space required for defining of sufficient foam generating capacity provided for machinery space of category A protected by a fixed high - expansion foam fire -extinguishing system complying with the provisions of the FSS Code.

4. Low-Expansion Foam Systems for Boiler Rooms and Machinery Spaces

Low-expansion foam systems do not substitute for the fire extinguishing systems prescribed in Table 18.1.

4.1 Capacity of the system

The system must be so designed that the largest area over which fuel can spread can be covered within five minutes with a 150 mm. thick blanked of foam.

4.2 Foam distribution

4.2.1 The foam solution must be conveyed through fixed pipe lines and foam distributors to the points at which oil fires are liable to occur.

4.2.2 Foam distributors and controls are to be arranged in suitable groups and positioned in such a way that they cannot be cut-off by a fire in the protected space.

L. Pressure Water Spraying Systems

1. Automatic Pressure Water Spraying Systems (Sprinkler Systems) (25)

1.1 General

1.1.1 Any parts of the system which may be subjected to freezing temperatures in service shall be suitably protected against freezing.

1.1.2 Special attention shall be paid to the specification of water quality provided by the system manufacturer to prevent internal corrosion of sprinklers and clogging or blockage arising from products of corrosion or scale-forming minerals.

1.2 Pressure water tanks

1.2.1 Pressure water tanks are to be fitted with a safety valve, connected to the water space of the tank without means of isolating, with a water level indicator that can be shutoff and is protected against damage, and with a pressure gauge. The requirements specified in Section 14, Pressure Vessels, are also applicable.

1.2.2 The volume of the pressure water tank shall be equivalent to at least twice the specified pump capacity per minute.

The tank shall contain a standing charge of fresh water equivalent to at least the specified pump capacity per one minute.

The tank is to be fitted with a connection to enable the entire system to be refilled with fresh water.

1.2.3 Means are to be provided for replenishing the air cushion in the pressure water tank.

Note :

Instead of a pressure tank, approved water mist systems (26) may be provided with an equivalent bottle battery consisting of water and gas cylinders.

(25) *Pressure water spraying systems deviating from these Rules may be used if approved as equivalent by BCS. See also IMO-Resolution A.800(19), “Revised Guidelines for Approval of Sprinkler Systems Equivalent to that Referred to in Regulation II 2/12 of SOLAS 74” as amended by Res.MSC.265(84) and Res.MSC.284(86).*

1.3 Pressure water spraying pump

1.3.1 The pressure water spraying pump may only be used for supplying water to the pressure water spraying system.

In the event of a pressure drop in the system, the pump shall start up automatically before the fresh water charge in the pressure water tank has been exhausted. Suitable means of testing are to be provided.

1.3.2 The capacity of the pump shall be sufficient to cover an area of at least 280 m² at the pressure required for the spray nozzles. At a rate of application of at least 5 l/m² · min, this is equivalent to a minimum delivery rate of 1400 l/min.

Note :

The minimum flow rate of 5 litre/m²/min is not applicable to approved water mist systems (26).

1.3.3 The pump is to be equipped with a direct sea suction. The shutoff device is to be secured in the open position. On the discharge side, the pump is to be fitted with a test valve and pipe connection whose cross-section corresponds to the capacity of the pump at the prescribed pressure.

1.4 Location

Pressure water tanks and pumps are to be located outside and a sufficient distance away from the spaces to be protected, from boiler rooms and from spaces containing oil treatment plant or internal combustion engines.

The pressure water tank is to be installed in a frost proof space.

1.5 Water supply

1.5.1 The system shall be completely charged with fresh water when not in operation.

In addition to the water supply as per 1.3 the system is also to be connected to the fire main via a screw-down non-return valve.

1.5.2 The system must be kept permanently under pressure and must be ready at all times for immediate, automatic operation. With the test valve at the alarm valve in the fully open position, the pressure at the level of the highest spray nozzles shall still be at least 1,75 bar.

1.5.3 Control stations, where water may cause damage to essential equipment, may be fitted with a dry pipe system or a pre-action system as permitted by SOLAS Regulation II-2/10.6.1.1.

Note:

See also FSS Code Chapter 8 and see IMO Res. A.800(19) as amended by Res.MSC.265(84) and Res.MSC.284(86) for definitions for “dry pipe system” and “preaction system”.

1.6 Power supply

At least two mutually independent power sources shall be provided for supplying the pump and the automatic indicating and alarm systems. Each source shall be sufficient to power the system (Chapter 5 - Rules for Electrical Installation, Section 7).

1.7 Piping, valves and fittings

1.7.1 Lines between sea chest, pump, water tank, shore connection and alarm valve are to comply with the dimensional requirements set out in Section 16, Table 16.6. Lines shall be effectively protected against corrosion.

1.7.2 Check valves are to be fitted to ensure that sea-water cannot penetrate into the pressure water tank nor fresh water be discharged into the sea through pump suction lines.

1.7.3 Each sprinkler section shall be capable of being isolated by one section valve only. The section valves shall be arranged readily accessible outside of the associated section or in cabinets within stairway enclosures, the location being clearly and permanently indicated. Suitable means are to be provided to prevent the operation of the section valves by unauthorised persons.

Any stop valves in the system from the sea water inlet up to the section valves shall be secured in operating position.

1.7.4 A test valve is to be arranged downstream of each section valve. The flow of the test valve shall correspond to the smallest sprinkler in the pertinent section.

1.7.5 Small sections where the possibility of freezing exists during operation of the ship in cold climates may be of the dry type **(26)**.

Saunas shall be fitted with a dry pipe system.

1.8 Sprinklers

1.8.1 The sprinklers are to be grouped into sections. Each section may not comprise more than 200 sprinklers.

1.8.2 On passengers ships, a sprinkler section may extend only over one main fire extinguishing section or more one watertight compartment and may not include more than two vertically adjacent decks.

1.8.3 The sprinklers are to be so arranged in the upper deck area that a water volume of not less than $5\text{l/m}^2 \cdot \text{min}$ is sprayed over the area to be protected.

Note :

*The minimum flow rate of 5 litre/m²/min is not applicable to approved water mist systems **(25)**.*

Inside accommodation and service spaces the sprinklers shall be activated within a temperature range from 68 °C to 79 °C. This does not apply to spaces with higher temperatures such as drying rooms, galleys or alike. Here the triggering temperature may be up to 30 °C above the maximum temperature in the deck head area.

In saunas a release temperature of up to 140 °C is accepted.

1.8.4 The sprinklers are to be made of corrosion resistant material. Sprinklers of galvanized steel are not allowed.

1.8.5 Spare sprinklers of all types and ratings installed in the ship are to be provided as follows. The

number of spare sprinklers of any type need not exceed the number of sprinklers actually installed.

< 300 sprinklers – 6 spare

300 – 1000 sprinklers – 12 spare

> 1000 sprinklers – 24 spare

1.9 Indicating and alarm systems

1.9.1 Each sprinkler section shall be provided with means for the activation of a visual and audible alarm signal at one or more indicating panels. At the panels the sprinkler section in which a sprinkler has come into operation shall be indicated. The indicating panels shall be centralised on the navigation bridge. In addition to this visible and audible alarms from the indicating panels shall be located in a position other than on the navigation bridge, so as to ensure that an alarm is immediately received by the crew.

Design of alarm systems see Seagoing Ships, Chapter 5 - Electrical Installations, Section 9.

1.9.2 A gauge indicating the pressure in the system shall be provided at each section valve according to 1.7.3 as well as at the centralized indication panel(s) on the navigating bridge.

1.10 Stipulating charts and instructions

A list or plan is to be displayed at each indicating panel showing the spaces covered and the location of the zone in respect of each section.

Suitable instructions for testing and maintenance must be available.

2. Manually Operated Pressure Water Spraying Systems

2.1 Pressure water spraying systems for machinery spaces and cargo pump rooms

2.1.1 Conventional pressure water-spraying systems

Conventional pressure water-spraying systems for machinery spaces and cargo pump-rooms are to be

(26) Definition of “dry pipe system”, see IMO Res. A.800(19) as amended by Resolution MSC.265(84) and Resolution MSC.284(86), Annex, Item 2.3

approved by **BCS** on the basis of an internationally recognized standard **(28)**.

2.1.2 Equivalent pressure water-spraying (water-mist) systems

Water-mist systems for machinery spaces and cargo pump-rooms are to be approved by **BCS** on the basis of an internationally recognized standard **(27)**.

2.2 Pressure water spraying systems for exhaust gas fired thermal oil heaters

2.2.1 The flow rate of the water spraying system is to be at least 5 l/min per m² of heating surface.

The use of fresh water is preferred. An adequate water supply for at least 20 minutes is to be ensured.

2.2.2 The required volume of water is to be distributed over the heated surfaces by means of suitable nozzles. A pipe and nozzle system intended for cleaning purpose may be incorporated into the water spraying system.

2.2.3 The nozzles may be installed below the heated surface instead. A prerequisite for this arrangement is that in the event of a fire in the exhaust gas fired thermal oil heater, the engine is kept running at reduced load and the exhaust gas continues to flow over the heating surfaces.

2.2.4 The piping system for water supply and distribution must be a fixed installation.

To protect against uncontrolled water leaks in the exhaust gas fired heater, the supply line is to be fitted with two shutoff valves with a drain valve between them.

2.2.5 An effective water trap which may drain into the engine room bilge or a suitable tank is to be installed in the exhaust gas line beneath the exhaust

gas fired heater. Suitable measures are to be taken to prevent leakage of exhaust gases.

2.2.6 All valves and pump starters required for operation of the water spraying system are to be installed for easy access in one place if possible at a safe distance from the exhaust gas fired heater.

Concise operating instructions are to be permanently displayed at the operating position.

2.3 Pressure water spraying systems for special category and ro/ro cargo spaces

2.3.1 Fixed water-based fire fighting systems for protection of vehicle, special category and ro-ro spaces shall be designed in accordance with the guidelines of MSC.1/Circ.1430/Rev.2 **(28)**.

2.3.2 Water spray systems shall be designed according to sections 3 and 4 of MSC.1/Circ.1430/Rev.2. The water spray nozzles shall be approved as per item 3.11 of the guidelines.

(27) Refer to IMO MSC/Circ. 1165 "Revised Guidelines for the Approval of Equivalent Water-Based Fire Extinguishing Systems for Machinery Spaces and Cargo Pump Rooms", as amended by circulars MSC.1/Circ.1237, MSC.1/Circ.1269 and MSC.1/Circ.1386. Extrapolation from the maximum tested volume to a larger volume in actual installations is permitted based on the conditions given in IMO MSC.1/Circ.1385, "Scientific Methods on Scaling of Test Volume for Fire Test on Water-Mist Fire-Extinguishing Systems" See also BCS- I SC 218 and BCS- I SC 219.

(28) Refer to IMO MSC.1/Circ.1430/Rev.2, "Revised Guidelines for the Approval of Fixed Water-Based Fire-Fighting Systems for Ro-Ro Spaces and Special Category Spaces"

2.3.3 Water mist systems shall be type approved and be designed acc. to sections 3 and 5 of MSC.1/Circ.1430/Rev.2.

2.3.4 A pressure gauge is to be provided on the valve manifold.

Each distribution valve must be clearly marked as to the section served.

Instructions for maintenance and operation are to be displayed in the valve (drencher) room.

2.3.5 In case of manually activated systems, the water spraying pump must be capable of being started from the distribution valve group. All the shutoff valves located between the seawater inlet and the distribution valves must be capable of being opened from the distribution valve group, unless they are secured in the open position.

2.3.6 Drainage and pumping arrangements are to be designed in compliance with Section 16, N.4.3.5 and N.4.4 of this Chapter, as applicable.

The system has to be fitted with sufficient number of drainage valves.

2.4 Pressure water spraying systems for the cargo area of tankers

These are subject to the Rules for Liquefied Gas Tankers, Section 11.3.

3. Fixed Local Application Fire-Fighting Systems (29)

3.1 This item is to be applied to category A machinery spaces above 500 m³ in gross volume of passenger ships of 500 GT and above and cargo ships of 2000 GT and above.

3.2 In addition to the main fire extinguishing system, fire hazard areas as listed in L.3.3 below are to be protected by fixed local application fire-fighting systems, which must be type approved by **BCS** in accordance with international regulations. **(30)**.

On ships with class notation AUT or AUT-C these systems must have both automatic and manual release capabilities.

In case of continuously manned machinery spaces, these systems are only required to have a manual release capability.

3.3 The fixed local application fire-fighting systems are to protect areas such as the following without the necessity of engine shutdown, personnel evacuation, or sealing of the spaces:

- For ships constructed before 1 July 2014, the fire hazard portions of internal combustion machinery used for the ship's main propulsion power generation and other purposes. For ships constructed after 1 July 2014, the fire hazard portions of internal combustion machinery. In multi-engine installations, at least two sections should be arranged.
- Oil fired equipment, such as incinerators, boilers, inert gas generators and thermal oil heaters;

(29) *This item applies to ships with keel laying date on or after 1st July, 2002.*

(30) *Refer to IMO circular MSC.1/Circ.1387, "Revised Guidelines for the Approval of Fixed Water-Based Local Application Fire Fighting Systems for Use in Category A Machinery Spaces (MSC/Circ.913)". See BCS- I SC176 for details of fixed local application fire extinguishing systems.*

- Purifiers for heated fuel oil.

The fixed local application fire-fighting systems are to protect such fire risk areas of above plants where fuel oil spray of a damaged fuel oil line is likely to be ignited on hot surfaces, i.e. normally only the engine top including the cylinder station, fuel oil injection pumps, turbocharger and exhaust gas manifold as well as the oil burners need to be protected. Where the fuel oil injection pumps are located in sheltered position such as under a steel platform, the pumps need not be protected by the system.

For the fire extinguishing medium, a water-based extinguishing agent is to be used. The pump supplying the extinguishing medium shall be located outside the protected areas. The system must be available for immediate use and capable of continuously supplying the extinguishing medium for at least 20 minutes. The capacity of the pump shall be based on the protected area demanding the greatest volume of extinguishing medium.

The water supply for local application systems may be fed from the supply to a total flooding water mist system (main fire-extinguishing system), on condition that adequate water quantity and pressure are available to operate both systems for the required period of time.

3.4 Systems for which automatic activation is required are to be released by means of a suitably designed fire detection and alarm system. This system must ensure a selective fire detection of each area to be protected as well as a fast and reliable activation of the local fire-fighting system. For details of the design of the fire detection and alarm system, see Seagoing Ships, Chapter 5 - Electrical Installations, Section 9, D.4.

3.5 Grouped visual and audible alarms as well as indication of the activated zone are to be provided in each protected space, in the engine control room and in the wheelhouse.

3.6 Any installation of nozzles on board shall reflect the arrangement successfully tested in accordance with MSC.1/Circ.1387.

If a specific arrangement of the nozzles is foreseen, deviating from the one tested, it can be accepted provided such arrangement additionally passes fire tests based on the scenarios defined in MSC.1/Circ.1387.

3.7 For each internal combustion engine used for the ship's main propulsion or power generation, a separate nozzle section as well as separate means for detecting a fire and release of the system are to be provided.

In case four (or more) main engines or main diesel generators are installed in the engine room, an arrangement in pairs of the nozzle sectioning as well as of the means for fire detection and release of the system are acceptable, provided the unrestricted maneuverability of the ship can be ensured by the pair of main engines or main diesel generators not involved.

The nozzle sections of the local application systems may form nozzle sections of a total flooding water mist system (main fire-extinguishing system) provided that the additional nozzle sections of the main fire extinguishing system are capable of being isolated.

3.8 The operation (release) controls shall be located at easily accessible positions inside and outside the protected space. The controls inside the space shall not be liable to be cut off by a fire in the protected areas.

3.9 Means shall be provided for testing the operation of the system for assuring the required pressure and flow and for blowing air through the system during testing to check for any possible obstructions.

3.10 The piping system shall be sized in accordance with a recognized hydraulic calculation technique (e.g. Hazen-Williams method) to ensure availability of flows and pressures required for correct performance of the system.

3.11 Where automatically operated systems are installed, a warning notice is to be displayed outside each entry point stating the type of extinguishing medium used and the possibility of automatic release.

3.12 Operating and maintenance instructions as well as spare parts for the system shall be provided as recommended by the manufacturer. The operating instructions are to be displayed at each operating station.

3.13 Nozzles and piping shall not prevent access to engines or other machinery for routine maintenance. In machinery spaces fitted with overhead hoists or other moving equipment, nozzles and piping shall not be located to prevent operation of such equipment.

3.14 The objects to be protected are to be covered with a grid of nozzles subject to the nozzle arrangement parameters indicated in the type approval Certificate (maximum horizontal nozzle spacing, minimum and maximum vertical distance from the protected object, minimum lateral distance from the protected object).

Where the width of the protected area does not exceed $\frac{1}{2}$ the maximum horizontal nozzle spacing, a single line of nozzles may be provided on condition that the distance between the nozzles is not more than $\frac{1}{2}$ the maximum horizontal nozzle spacing and the end nozzles are either pointing at least at the edge of the protected area or are located with a lateral distance from the protected object if such a minimum required distance is indicated in the type approval Certificate.

Where the width and length of the protected area do not exceed $\frac{1}{2}$ the maximum horizontal nozzle spacing, a single nozzle may be provided which is to be located above the protected object at the centre.

Illustrative sketches of acceptable nozzle arrangements are shown for clarity in MSC.1/Circ.1276.

3.15 If the engine room is protected with a highexpansion foam or aerosol fire-extinguishing system, appropriate operational measures or interlocks shall be provided to prevent the local application systems from interfering with the effectiveness of these systems.

4. Pressure water-spraying system for cabin balconies of passenger ships

4.1 The cabin balconies of passenger ships are to be provided with an approved pressure water-spraying system **(31)**, if the furniture and furnishings on such balconies are not of restricted fire risk **(7)**.

5. Combined water mist systems for multiarea protection

A water mist system designed to serve different areas and spaces and supplied by one common pump unit is accepted provided that each sub-system is **BCS** type approved **(25), (27), (28), (30), (31), (32)**.

M. Fire Extinguishing Systems for Paint Lockers, Flammable Liquid Lockers, Galley Range Exhaust Ducts and Deep-Fat Cooking Equipment

1. Paint Lockers and Flammable Liquid Lockers

1.1 A fixed fire extinguishing system based on CO₂, dry powder, water or an equivalent extinguishing medium and capable of being operated from outside the room is to be provided.

(31) Reference is made to MSC.1/Circ.1268, "Guidelines for the Approval of Fixed Pressure Water-Spraying and Water-Based Fire-Extinguishing Systems for Cabin Balconies".

(32) ISO 15371 "Ships and marine technology – Fire-extinguishing systems for protection of galley cooking equipment".

1.1.1 If CO₂ is used, the extinguishing medium supply is to be calculated for a concentration of 40 % relative to the gross volume of the room concerned.

1.1.2 Dry-powder fire extinguishing systems are to be designed with a least 0,5 kg. per cubic metre of the gross volume of the room concerned. Steps are to be taken to ensure that the extinguishing medium is evenly distributed.

1.1.3 For pressure water spraying systems, a uniform distribution rate of 5 l/m² · min relative to the floor area is to be ensured. The water may be supplied from the fire main.

1.2 For lockers of a deck area of less than 4 m², which do not give access to accommodation spaces, CO₂ portable or dry powder fire extinguisher(s) sized in accordance with 1.1.1 or 1.1.2, which can be discharged through a port in the boundary of the locker may be used. The extinguishers are to be stowed adjacent to the port. Alternatively, a port or hose connection may be provided for this purpose to facilitate the use of fire main water.

1.3 In cargo sampling lockers onboard tankers a fixed fire extinguishing system may be dispensed with if such spaces are positioned within the cargo area.

2. Galley Range Exhaust Ducts

2.1 A fixed fire extinguishing system is to be provided for galley range exhaust ducts:

- On all passenger ships carrying more than 36 passengers
- On cargo ships and passenger ships carrying not more than 36 passengers, where the ducts pass through accommodation spaces or spaces containing combustible materials.

The fixed means for extinguishing a fire within the galley range exhaust duct shall be so designed that the extinguishant is effective over the entire length between the outer fire damper and the fire damper to be fitted in the lower end of the duct.

2.2 Manual actuation is to be provided. The controls are to be installed near the access to the galley, together with the emergency cut-off switches for the galley ventilation supply- and exhaust fans and the actuating equipment for the fire dampers.

Automatic actuation of the fire extinguishing system may additionally be provided on application.

3. Deep-Fat Cooking Equipment (30)

Deep-fat cooking equipment is to be fitted with following arrangements:

- An automatic or manual fire extinguishing system tested to an international standard and approved by **BCS (33)**;
- A primary and backup thermostat with an alarm to alert the operator in the event of failure of either thermostat;
- Arrangements for automatically shutting off the electrical power upon activation of the fire extinguishing system;
- An alarm for indicating operation of the fire extinguishing system in the galley where the equipment is installed; and
- Controls for manual operation of the fire extinguishing system which are clearly labelled for ready use by the crew.

N. Waste Incineration

1. Incinerator spaces, waste storage spaces or combined incinerator and waste storage spaces are to be equipped with fixed fire extinguishing and fire detection systems as per Table 18.8:

2. On passenger ships the sprinklers shall be supplied from the sprinkler system of the ship.

3. On cargo ships the sprinkler system may be connected to the fresh water hydrofore system,

provided the hydrofore pump is capable of meeting the demand of the required number of sprinklers.

Table 18.8 Required fire safety system

	Automatic pressure water spraying system (sprinkler), re 2. and 3.	Fixed fire extinguishing system (CO ₂ , high expansion foam, pres-sure water spraying system or equivalent)	Fixed fire detection system
Combined incinerator and waste storage space	1	x	x
Incinerator space	2	x	x
Waste storage space	x		

O. Fire Extinguishing Equipment for Helicopter Landing Decks

1. In close proximity to the helideck there shall be provided and stored near the means of access to that helideck:

1.1 At least two dry powder extinguishers having a total capacity of not less than 45 kg;

1.2 CO₂ extinguishers of a total capacity of not less than 18 kg. or equivalent;

1.3 Foam firefighting appliances

1.3.1 Application

This item details the specifications for foam firefighting appliances for the protection of helidecks and helicopter landing areas as required by chapter II-2 of the SOLAS.

1.3.2 Definitions

1.3.2.1 *D-value* means the largest dimension of the helicopter used for assessment of the helideck when its

rotors are turning. It establishes the required area of foam application.

1.3.2.2 *Deck integrated foam nozzles* are foam nozzles recessed into or edge mounted on the helideck.

1.3.2.3 *Foam-making branch pipes* are air-aspirating nozzles in tube shape for producing and discharging foam, usually in straight stream only.

1.3.2.4 *Helicopter landing area* is as defined in SOLAS regulation II-2/3.57.

1.3.2.5 *Helideck* is as defined in SOLAS II-2/3.26.

1.3.2.6 *Hose reel foam station* is a hose reel fitted with a foam-making branch pipe and non-collapsible hose, together with fixed foam proportioner and fixed foam concentrate tank, mounted on a common frame.

1.3.2.7 *Monitor foam station* is a foam monitor, either self-inducing or together with separate fixed foam proportioner, and fixed foam concentrate tank, mounted on a common frame.

1.3.2.8 *Obstacle free sector* is the take-off and approach sector which totally encompasses the safe landing area and extends over a sector of at least 210°, within which only specified obstacles are permitted.

1.3.2.9 *Limited obstacle sector* is a 150° sector outside the take-off and approach sector that extends outward from a helideck where objects of limited height are permitted.

1.3.3 Engineering specifications for helidecks and helicopter landing areas

1.3.3.1 The system shall be capable of manual release, and may be arranged for automatic release.

1.3.3.2 For helidecks the foam system shall contain at least two fixed foam monitors or deck integrated foam nozzles. In addition, at least two hose reels fitted with a foam-making branch pipe and non-collapsible hose sufficient to reach any part of the helideck shall be provided. The minimum foam system discharge rate shall be determined by multiplying the D-value area by 6 l/min/m². The minimum foam system discharge rate for

deck integrated foam nozzle systems shall be determined by multiplying the overall helideck area by 6 l/min/m². Each monitor shall be capable of supplying at least 50% of the minimum foam system discharge rate, but not less than 500 l/min. The minimum discharge rate of each hose reel shall be at least 400 l/min. The quantity of foam concentrate shall be adequate to allow operation of all connected discharge devices for at least 5 min.

1.3.3.3 Where foam monitors are installed, the distance from the monitor to the farthest extremity of the protected area shall be not more than 75% of the monitor throw in still air conditions.

1.3.3.4 For helicopter landing areas, at least two portable foam applicators or two hose reel foam stations shall be provided, each capable of discharging a minimum foam solution discharge rate, in accordance with the Table 18.9.

Table 18.9 Required foam quantity

Category	Helicopter overall length	Discharge rate foam solution (l/min)
H1	< 15 m.	250
H2	≥ 15 m... < 24 m.	500
H3	≥ 24 m... < 35 m.	800

The quantity of foam concentrate shall be adequate to allow operation of all connected discharge devices for at least 10 min. For tankers fitted with a deck foam system, BCS may consider an alternative arrangement, taking into account the type of foam concentrate to be used.

1.3.3.5 Manual release stations capable of starting necessary pumps and opening required valves, including the fire main system, if used for water supply, shall be located at each monitor and hose reel. In addition, a central manual release station shall be provided at a protected location. The foam system shall be designed to discharge foam with nominal flow and at design pressure from any connected discharge devices within 30 s of activation.

1.3.3.6 Activation of any manual release station shall initiate the flow of foam solution to all connected hose reels, monitors, and deck integrated foam nozzles.

1.3.3.7 The system and its components shall be designed to withstand ambient temperature changes, vibration, humidity, shock impact and corrosion normally encountered on the open deck, and shall be manufactured and tested to the satisfaction of the TL.

1.3.3.8 A minimum nozzle throw of at least 15 m shall be provided with all hose reels and monitors discharging foam simultaneously. The discharge pressure, flow rate and discharge pattern of deck integrated foam nozzles shall be to the satisfaction of BCS, based on tests that demonstrate the nozzle's capability to extinguish fires involving the largest size helicopter for which the helideck is designed.

1.3.3.9 Monitors, foam-making branch pipes, deck integrated foam nozzles and couplings shall be constructed of brass, bronze or stainless steel. Piping, fittings and related components, except gaskets, shall be designed to withstand exposure to temperatures up to 925°C.

1.3.3.10 The foam concentrate shall be demonstrated effective for extinguishing aviation fuel spill fires and shall conform to performance standards not inferior to those acceptable to **BCS (33)**. Where the foam storage tank is on the exposed deck, freeze protected foam concentrates shall be used, if appropriate, for the area of operation.

(33) Refer to the "International Civil Aviation Organization Airport Services Manual, part 1, Rescue and Fire Fighting, chapter 8, Extinguishing Agent Characteristics, paragraph 8.1.5, Foam specifications table 8-1, Performance Level B", or to the "Revised Guidelines for the performance and testing criteria, and surveys of foam concentrates for fixed fire-extinguishing systems (MSC.1/Circ.1312, as amended)".

1.3.3.11 Any foam system equipment installed within the take-off and approach obstacle-free sector shall not exceed a height of 0,25 m. Any foam system equipment installed in the limited obstacle sector shall not exceed the height permitted for objects in this area.

1.3.3.12 All manual release stations, monitor foam stations, hose reel foam stations, hose reels and monitors shall be provided with a means of access that does not require travel across the helideck or helicopter landing area.

1.3.3.13 Oscillating monitors, if used, shall be pre-set to discharge foam in a spray pattern and have a means of disengaging the oscillating mechanism to allow rapid conversion to manual operation.

1.3.3.14 If a foam monitor with flow rate up to 1,000 l/min is installed, it shall be equipped with an air-aspirating nozzle. If a deck integrated nozzle system is installed, then the additionally installed hose reel shall be equipped with an air-aspirating handline nozzle (foam branch pipes). Use of non-air-aspirating foam nozzles (on both monitors and the additional hose reel) is permitted only where foam monitors with a flow rate above 1,000 l/min are installed. If only portable foam applicators or hose reel stations are provided, these shall be equipped with an air-aspirating handline nozzle (foam branch pipes).

1.4 At least two nozzles of dual-purpose type and hoses sufficient to reach any part of the helideck;

1.5 Two fireman's outfits in addition to those required by SOLAS 74 or national regulations.

1.6 At least the following equipment, stored in a manner that provides for immediate use and protection from the elements:

- Adjustable wrench,
- Blanket, fire resistant,
- Cutters bolt 600 mm.,

- Hook, grab or salving,
- Hacksaw, heavy duty complete with 6 spare blades,
- Ladder,
- Life line 5 mm. diameter x 15 m. length,
- Pliers, side cutting,
- Set of assorted screwdrivers,
- Harness knife complete with sheath.

2. Drainage facilities in way of helidecks shall be constructed of steel and lead directly overboard independent of any other system and designed so that drainage does not fall on to any part of the vessel.

P. Carriage of Dangerous Goods in Packaged Form

1. General

1.1 Scope

1.1.1 The following requirements apply additionally to ships carrying dangerous goods in packaged form. The requirements are not applicable if such goods are transported only in limited or excepted quantities according to the IMDG Code, Volume 2, Chapter 3.4 and 3.5.

1.1.2 The requirements depend on the type of cargo space, the dangerous goods class and the special properties of the goods to be carried. The requirements for the different types of cargo spaces are shown in the following tables:

- Table 18.10a for conventional cargo spaces
- Table 18.10b for container cargo spaces

- Table 18.10c for closed ro-ro spaces
- Table 18.10d for open ro-ro spaces
- Table 18.10e for shipborne barges
- Table 18.10f for weather decks

1.1.3 The requirements of **SOLAS**, Chapter VI, Part A, **SOLAS**, Chapter VII, Part A and the IMDG Code are to be observed.

Note :

A purpose built container space is a cargo space fitted with cell guides for stowage securing of containers.

Ro-ro spaces include special category spaces (Reg. 20) and vehicle spaces.

For the purposes of a ro-ro space fully open above and with full openings in both ends may be treated as a weather deck.

1.1.4 The requirements for open top container cargo spaces are to be agreed upon with **BCS**, see 1.2.6 and 1.2.7.

1.2 Documents for Approval

Diagrammatic plans, drawings and documents covering the following are to be submitted for approval.

Form ST236 "Application Form Dangerous Goods" for application for certification according to 1.4

- "Water fire extinguishing system" according to 3.2, as applicable
- Water cooling system according to 3.3, as applicable
- Form ST184, "Details about the Construction of electrical Equipment in hazardous areas" including corresponding copies of certificates of conformity for electrical equipment according to 4., as applicable

- Fire detection and alarm system including arrangement of detectors according to 5., as applicable
- Ventilation system according to 6., as applicable
- Bilge system according to 7., as applicable
- Insulation according to 10., as applicable
- Arrangement for separation of ro-ro spaces according to 11., as applicable

1.3 References to other rules

1.3.1 **SOLAS**, Chapter II-2, Regulation 19, "Carriage of dangerous goods"

1.3.2 **SOLAS** Chapter II-2, Regulation 10.7.2. "Fixed gas fire-extinguishing systems for dangerous goods"

1.3.3 **SOLAS**, Chapter VI, Part A, "General provisions"

1.3.4 **SOLAS**, Chapter VII, Part A, "Carriage of dangerous goods in packaged form"

1.3.5 IMO International Maritime Dangerous Goods (IMDG) Code

1.3.6 Medical First Aid Guide for Use in Accidents Involving Dangerous Goods (MFAG)

1.3.7 IMO MSC/Circ.608/Rev.1, "Interim Guidelines for Open Top Containerships"

1.3.8 BCS - I SC 109, 110 and 111, "Open top container holds – Water supplies – Ventilation – Bilge pumping"

1.3.9 IEC 60079, "Electrical apparatus for explosive atmospheres"

1.4 Certification

The **DG** additional notation assigned to the ship will remain valid as long as the “Document of Compliance for the Carriage of Dangerous goods ” issued by **BCS** remains valid.

1.5 Classification of dangerous goods

The following classes are specified for goods in packaged form in the appendix of the Document of Compliance for the Carriage of Dangerous goods.

Class 1.1 to 1.6:

Explosives.

Division 1.1: Substances and articles which have a mass explosion hazard.

Division 1.2: Substances and articles which have a projection hazard but not a mass explosion hazard.

Division 1.3: Substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard.

Division 1.4: Substances and articles which present no significant hazard.

Division 1.5: Very insensitive substances and articles which have a mass explosion hazard. Division 1.6: Extremely insensitive articles which do not have a mass explosion hazard.

Class 1.4S:

Explosives.

Division 1.4, compatibility group S: Substances or articles so packaged or designed that any hazardous effects arising from accidental functioning are confined within the package unless the package has been

degraded by fire, in which case all blast or projection effects are limited to the extent that they do not significantly hinder or prohibit fire fighting or other emergency response efforts in the immediate vicinity of the package.

Class 2.1 including hydrogen and hydrogen mixtures:

Flammable gases including hydrogen and hydrogen mixtures.

Class 2.1 except hydrogen and hydrogen mixtures:

Flammable gases with the exception of hydrogen and mixtures of hydrogen.

Class 2.2:

Non-flammable, non-toxic gases.

Class 2.3 flammable:

Toxic gases with a subsidiary risk class 2.1.

Class 2.3 non-flammable:

Toxic gases without a subsidiary risk class 2.1.

Class 3 FP < 23 °C:

Flammable liquids having a flashpoint below 23 °C according to the IMDG Code.

Class 3 23 °C ≤ FP ≤ 60 °C:

Flammable liquids having a flashpoint between 23 °C and 60 °C according to the IMDG Code.

Class 4.1:

Flammable solids, self-reactive substances and solid desensitized explosives.

Class 4.2:

Substances liable to spontaneous combustions.

Class 4.3 liquids:

Liquids which, in contact with water, emit flammable gases.

Class 4.3 solids:

Solids which, in contact with water, emit flammable gases.

Class 5.1:

Oxidizing substances.

Class 5.2:

Organic peroxides.

Class 6.1 liquids FP < 23 °C:

Toxic liquids having a flashpoint below 23 °C according to the IMDG Code.

Class 6.1 liquids 23 °C ≤ FP ≤ 60 °C:

Toxic liquids having a flashpoint between 23 °C and 60 °C according to the IMDG Code.

Class 6.1 liquids:

Toxic liquids having a flashpoint above 60 °C according to the IMDG Code.

Class 6.1 solids:

Toxic solids.

Class 8 liquids FP < 23 °C:

Corrosive liquids having a flashpoint below 23 °C according to the IMDG Code.

Class 8 liquids 23 °C ≤ FP ≤ 60 °C:

Corrosive liquids having a flashpoint between 23 °C and 60 °C according to the IMDG Code.

Class 8 liquids:

Corrosive liquids having a flashpoint above 60 °C according to the IMDG Code.

Class 8 solids:

Corrosive solids.

Class 9 including goods evolving flammable vapour:

Miscellaneous dangerous substances and articles and environmentally hazardous substances including goods evolving flammable vapour.

Class 9 except goods evolving flammable vapour:

Miscellaneous dangerous substances and articles and environmentally hazardous substances, which are not evolving flammable vapour.

Note:

The carriage of dangerous goods of classes 6.2 (infectious substances) and 7 (radioactive materials) is not covered by the Document of Compliance of Dangerous Goods. For the carriage of class 6.2 the IMDG Code and for the carriage of class 7 the IMDG Code and the INF Code are to be observed.

2. Fire-extinguishing system**2.1 Fixed gas fire-extinguishing system**

All cargo holds are to be equipped with a fixed CO₂ fire-extinguishing system complying with the requirements of G or H.

2.2 Fixed pressure water-spraying system

Open ro-ro spaces, ro-ro spaces not capable of being sealed and special category spaces are to be equipped with a pressure water-spraying system conforming to L.2.3 in lieu of a fixed CO₂ fire-extinguishing system. Drainage and pumping arrangements are to be designed in compliance with Section 16, N.4.3.5 and N.4.4, as applicable.

2.3 Stowage on weather deck

The requirements of 2.1 and 2.2 apply even if the dangerous goods are to be stowed exclusively on the weather deck.

Note:

For ships of less than 500 GT the requirement may be dispensed with subject to acceptance by the Administration.

Table 18.10a Requirements for the carriage of dangerous goods in packaged form in conventional cargo spaces

Class	Requirements									
	Fixed gas fire-extinguishing system	Water supplies	Water cooling	Sources of ignition	Detection system	Ventilation	Bilge pumping	Personnel protection	Portable fire-extinguishers	Machinery space boundaries
1.1 to 1.6	P.2.1	P.3.1 P.3.2	P.3.3	P.4 IIA T5, IP65	P.5.1 P.5.2					P.10.3
1.4S	P.2.1	P.3.1 P.3.2			P.5.1 P.5.2					
2.1 Including Hydrogen And Hydrogen Mixtures	P.2.1	P.3.1 P.3.2		P.4 IIC T4, IP55	P.5.1	P.6.1 P.6.2		P.8		P.10.1 P.10.2
2.1 Except Hydrogen And Hydrogen Mixtures	P.2.1	P.3.1 P.3.2		P.4 IIB T4, IP55	P.5.1	P.6.1 P.6.2		P.8		P.10.1 P.10.2
2.2	P.2.1	P.3.1 P.3.2			P.5.1			P.8		P.10.1 P.10.2
2.3 Flammable (1)										
2.3 Non-flammable (1)										
3 FP < 23°C	P.2.1	P.3.1 P.3.2		P.4 IIB T4, IP55	P.5.1	P.6.1 P.6.2	P.7	P.8	P.9	P.10.1 P.10.2
3 23°C ≤ FP ≤ 60°C	P.2.1	P.3.1 P.3.2			5.1			P.8	P.9	P.10.1 P.10.2
4.1	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2 (2)		P.8	P.9	P.10.1 P.10.2
4.2	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2 (2)		P.8	P.9	P.10.1 P.10.2
4.3 Liquids (1)	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2		P.8	P.9	P.10.1 P.10.2
4.3 Solids	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2		P.8	P.9	P.10.1 P.10.2
5.1	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2 (2)		P.8	P.9	P.10.1 P.10.2 (4)
5.2 (1)										
6.1 Liquids FP<23°C	P.2.1	P.3.1 P.3.2		P.4 IIB T4, IP55	P.5.1	P.6.1 P.6.2	P.7	P.8	P.9	P.10.1 P.10.2
6.1 Liquids 23°C ≤ FP ≤ 60°C	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2	P.7	P.8	P.9	P.10.1 P.10.2
6.1 Liquids	P.2.1	P.3.1			P.5.1		P.7	P.8		
6.1 Solids	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2 (2)		P.8		
8 Liquids FP < 23°C	P.2.1	P.3.1 P.3.2		P.4 IIB T4, IP55	P.5.1	P.6.1 P.6.2	P.7	P.8	P.9	P.10.1 P.10.2
8 Liquids 23°C ≤ FP ≤ 60°C	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2	P.7 (3)	P.8	P.9	P.10.1 P.10.2
8 Liquids	P.2.1	P.3.1 P.3.2			P.5.1		P.7 (3)	P.8		
8 Solids	P.2.1	P.3.1 P.3.2			P.5.1			P.8		
9 Including Goods Evolving Flammable Vapour	P.2.1	P.3.1 P.3.2		P.4 IIB T4, IP55		P.6.1 P.6.2		P.8		
9 Except Goods Evolving Flammable Vapour	P.2.1	P.3.1 P.3.2				P.6.1 P.6.2 (2)		P.8		
<p>(1) Under the provisions of the IMDG Code, as amended, stowage of class 2.3, class 4.3 liquids having a flashpoint less 23°C as lists in the IMDG Code and class 5.2 under deck is prohibited.</p> <p>(2) When “mechanically-ventilated spaces” are required by the IMDG Code, as amended.</p> <p>(3) Only applicable to dangerous goods having a subsidiary risk class 6.1.</p> <p>(4) When “away from sources of heat” is required by the IMDG Code, as amended.</p>										

Table 18.10b Requirements for the carriage of dangerous goods in packaged form in container cargo spaces

Class	Requirements								
	Fixed gas fire-extinguishing system	Water supplies	Water cooling	Sources of ignition	Detection system	Ventilation	Bilge pumping	Personnel protection	Machinery space boundaries
1.1 to 1.6	P.2.1	P.3.1 P.3.2	P.3.3	P.4 IIA T5, IP65	P.5.1 P.5.2				P.10.3
1.4S	P.2.1	P.3.1 P.3.2			P.5.1 P.5.2				
2.1 Including Hydrogen And Hydrogen Mixtures	P.2.1	P.3.1 P.3.2		P.4 IIC T4, IP55	P.5.1	P.6.1 P.6.3		P.8	P.10.2
2.1 Except Hydrogen And Hydrogen Mixtures	P.2.1	P.3.1 P.3.2		P.4 IIB T4, IP55	P.5.1	P.6.1 P.6.3		P.8	P.10.2
2.2	P.2.1	P.3.1 P.3.2			P.5.1			P.8	P.10.2
2.3 Flammable (1)									
2.3 Non-flammable (1)									
3 FP < 23°C	P.2.1	P.3.1 P.3.2		P.4 IIB T4, IP55	P.5.1	P.6.1 P.6.3	P.7	P.8	P.10.2
3 23°C ≤ FP ≤ 60°C	P.2.1	P.3.1 P.3.2			P.5.1			P.8	P.10.2
4.1	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.3 (2),(3)		P.8	P.10.2
4.2	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.3 (2),(3)		P.8	P.10.2
4.3 Liquids (1)	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.3		P.8	P.10.2
4.3 Solids	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.3 (3)		P.8	P.10.2
5.1	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2 (2),(3)		P.8	P.10.2 (5)
5.2 (1)									
6.1 Liquids FP<23°C	P.2.1	P.3.1 P.3.2		P.4 IIB T4, IP55	P.5.1	P.6.1 P.6.3	P.7	P.8	P.10.2
6.1 Liquids 23°C ≤ FP ≤ 60°C	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.3	P.7	P.8	P.10.2
6.1 Liquids	P.2.1	P.3.1 P.3.2			P.5.1		P.7	P.8	
6.1 Solids	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.3 (2)		P.8	
8 Liquids FP < 23°C	P.2.1	P.3.1 P.3.2		P.4 IIB T4, IP55	P.5.1	P.6.1 P.6.3	P.7	P.8	P.10.2
8 Liquids 23°C ≤ FP ≤ 60°C	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.3	P.7 (4)	P.8	P.10.2
8 Liquids	P.2.1	P.3.1 P.3.2			P.5.1		P.7 (4)	P.8	
8 Solids	P.2.1	P.3.1 P.3.2			P.5.1			P.8	
9 Including Goods Evolving Flammable Vapour	P.2.1	P.3.1 P.3.2		P.4 IIB T4, IP55		P.6.1 P.6.3		P.8	
9 Except Goods Evolving Flammable Vapour	P.2.1	P.3.1 P.3.2				P.6.1 P.6.3 (2)		P.8	

(1) Under the provisions of the IMDG Code, as amended, stowage of class 2.3, class 4.3 liquids having a flashpoint less 23°C as listed in the IMDG Code and class 5.2 under deck is prohibited.

(2) When “mechanically-ventilated spaces” are required by the IMDG Code, as amended.

(3) For solids not applicable to closed freight containers.

(4) Only applicable to dangerous goods having a subsidiary risk class 6.1.

(5) When “away from sources of heat” is required by the IMDG Code, as amended.

Table 18.10c Requirements for the carriage of dangerous goods in packaged form in closed ro-ro spaces

Class	Requirements										
	Fixed gas fire-extinguishing system	Water supplies	Water cooling	Sources of ignition	Detection system	Ventilation	Blige pumping	Personnel protection	Portable fire-extinguishers	Machinery space boundaries	Separation of ro-ro spaces (5)
1.1 to 1.6	P.2.1	P.3.1 P.3.2	P.3.3	P.4 IIA T5, IP65	P.5.1 P.5.2					P.10.3	P.11
1.4S	P.2.1	P.3.1 P.3.2			P.5.1 P.5.2						P.11
2.1 Including Hydrogen And Hydrogen Mixtures	P.2.1	P.3.1 P.3.2		P.4 IIC T4, IP55	P.5.1	P.6.1 P.6.2		P.8		P.10.1 P.10.2	P.11
2.1 Except Hydrogen And Hydrogen Mixtures	P.2.1	P.3.1 P.3.2		P.4 IIB T4, IP55	P.5.1	P.6.1 P.6.2		P.8		P.10.1 P.10.2	P.11
2.2	P.2.1	P.3.1 P.3.2			P.5.1			P.8		P.10.1 P.10.2	P.11
2.3 Flammable (1)											
2.3 Non-flammable (1)											
3 FP < 23°C	P.2.1	P.3.1 P.3.2		P.4 IIB T4, IP55	P.5.1	P.6.1 P.6.2	P.7	P.8	P.9	P.10.1 P.10.2	P.11
3 23°C ≤ FP ≤ 60°C	P.2.1	P.3.1 P.3.2			P.5.1			P.8	P.9	P.10.1 P.10.2	P.11
4.1	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2 (2)		P.8	P.9	P.10.1 P.10.2	P.11
4.2	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2 (2)		P.8	P.9	P.10.1 P.10.2	P.11
4.3 Liquids (1)	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2		P.8	P.9	P.10.1 P.10.2	P.11
4.3 Solids	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2		P.8	P.9	P.10.1 P.10.2	P.11
5.1	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2 (2)		P.8	P.9	P.10.1 P.10.2 (4)	P.11
5.2 (1)											
6.1 Liquids FP<23°C	P.2.1	P.3.1 P.3.2		P.4 IIB T4, IP55	P.5.1	P.6.1 P.6.2	P.7	P.8	P.9	P.10.1 P.10.2	P.11
6.1 Liquids 23°C ≤ FP ≤ 60°C	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2	P.7	P.8	P.9	P.10.1 P.10.2	P.11
6.1 Liquids	P.2.1	P.3.1 P.3.2			P.5.1		P.7	P.8			P.11
6.1 Solids	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2 (2)		P.8			P.11
8 Liquids FP < 23°C	P.2.1	P.3.1 P.3.2		P.4 IIB T4, IP55	P.5.1	P.6.1 P.6.2	P.7	P.8	P.9	P.10.1 P.10.2	P.11
8 Liquids 23°C ≤ FP ≤ 60°C	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2	P.7 (3)	P.8	P.9	P.10.1 P.10.2	P.11
8 Liquids	P.2.1	P.3.1 P.3.2			P.5.1		P.7 (3)	P.8			P.11
8 Solids	P.2.1	P.3.1 P.3.2			P.5.1			P.8			P.11
9 Including Goods Evolving Flammable Vapour	P.2.1	P.3.1 P.3.2		P.4 IIB T4, IP55		P.6.1 P.6.2		P.8			P.11
9 Except Goods Evolving Flammable Vapour	P.2.1	P.3.1 P.3.2				P.6.1 P.6.2 (2)		P.8			P.11

(1) Under the provisions of the IMDG Code, as amended, stowage of class 2.3, class 4.3 liquids having a flashpoint less 23°C as listed in the IMDG Code and class 5.2 under deck is prohibited.

(2) When “mechanically-ventilated spaces” are required by the IMDG Code, as amended.

(3) Only applicable to dangerous goods having a subsidiary risk class 6.1.

(4) When “away from sources of heat” is required by the IMDG Code, as amended.

(5) Only applicable for ships with keel-laying on or after 1 July 1998.

Table 18.10d Requirements for the carriage of dangerous goods in packaged form in open ro-ro spaces

Class	Requirements							
	Fixed gas fire-extinguishing system	Water supplies	Water cooling	Sources of ignition	Detection system	Personnel protection	Portable fire-extinguishers	Machinery space boundaries
1.1 to 1.6	P.2.2	P.3.1 P.3.2	P.3.3	P.4 IIA T5, IP65	P.5.2			P.10.3
1.4S	P.2.2	P.3.1 P.3.2			P.5.2	P.8		
2.1 Including Hydrogen And Hydrogen Mixtures	P.2.2	P.3.1 P.3.2		P.4 IIC T4, IP55		P.8		P.10.1 P.10.2
2.1 Except Hydrogen And Hydrogen Mixtures	P.2.2	P.3.1 P.3.2		P.4 IIB T4, IP55		P.8		P.10.1 P.10.2
2.2	P.2.2	P.3.1 P.3.2				P.8		P.10.1 P.10.2
2.3 Flammable	P.2.2	P.3.1 P.3.2		P.4 IIB T4, IP55		P.8		P.10.1 P.10.2
2.3 Non-flammable	P.2.2	P.3.1 P.3.2				P.8		P.10.1 P.10.2
3 FP < 23°C	P.2.2	P.3.1 P.3.2		P.4 IIB T4, IP55		P.8	P.9	P.10.1 P.10.2
3 23°C ≤ FP ≤ 60°C	P.2.2	P.3.1 P.3.2				P.8	P.9	P.10.1 P.10.2
4.1	P.2.2	P.3.1 P.3.2				P.8	P.9	P.10.1 P.10.2
4.2	P.2.2	P.3.1 P.3.2				P.8	P.9	P.10.1 P.10.2
4.3 Liquids	P.2.2	P.3.1 P.3.2		P.4 IIB T4, IP55 (2)		P.8	P.9	P.10.1 P.10.2
4.3 Solids	P.2.2	P.3.1 P.3.2				P.8	P.9	P.10.1 P.10.2
5.1	P.2.2	P.3.1 P.3.2				P.8	P.9	P.10.1 P.10.2(1)
5.2	P.2.2	P.3.1 P.3.2				P.8		P.10.1 P.10.2
6.1 Liquids FP<23°C	P.2.2	P.3.1 P.3.2		P.4 IIB T4, IP55		P.8	P.9	P.10.1 P.10.2
6.1 Liquids 23°C ≤ FP ≤ 60°C	P.2.2	P.3.1 P.3.2				P.8	P.9	P.10.1 P.10.2
6.1 Liquids	P.2.2	P.3.1 P.3.2				P.8		
6.1 Solids	P.2.2	P.3.1 P.3.2				P.8		
8 Liquids FP < 23°C	P.2.2	P.3.1 P.3.2		P.4 IIB T4, IP55		P.8	P.9	P.10.1 P.10.2
8 Liquids 23°C ≤ FP ≤ 60°C	P.2.2	P.3.1 P.3.2				P.8	P.9	P.10.1 P.10.2
8 Liquids	P.2.2	P.3.1 P.3.2				P.8		
8 Solids	P.2.2	P.3.1 P.3.2				P.8		
9 Including Goods Evolving Flammable Vapour	P.2.2	P.3.1 P.3.2		P.4 IIB T4, IP55		P.8		
9 Except Goods Evolving Flammable Vapour	P.2.2	P.3.1 P.3.2				P.8		

(1) When “away from sources of heat” is required by the IMDG Code, as amended.

(2) Applicable to goods having a flashpoint less than 23°C as listed in the IMDG Code, as amended.

Table 18.10e Requirements for the carriage of dangerous goods in packaged form in shipborne barges

Class	Requirements					
	Fixed gas fire-extinguishing system	Water supplies	Water cooling	Sources of ignition (2)	Detection system (2)	Ventilation
1.1 to 1.6	P.2.1	P.3.1 P.3.2	P.3.3	P.4 IIA T5, IP65	P.5.1	
1.4S	P.2.1	P.3.1 P.3.2			P.5.1	
2.1 Including Hydrogen And Hydrogen Mixtures	P.2.1	P.3.1 P.3.2		P.4 IIC T4, IP55	P.5.1	P.6.1 P.6.2
2.1 Except Hydrogen And Hydrogen Mixtures	P.2.1	P.3.1 P.3.2		P.4 IIB T4, IP55	P.5.1	P.6.1 P.6.2
2.2	P.2.1	P.3.1 P.3.2			P.5.1	
2.3 Flammable (1)						
2.3 Non-flammable (1)						
3 FP < 23°C	P.2.1	P.3.1 P.3.2		P.4 IIB T4, IP55	P.5.1	P.6.1 P.6.2
3 23°C ≤ FP ≤ 60°C	P.2.1	P.3.1 P.3.2			P.5.1	
4.1	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2 (3)
4.2	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2 (3)
4.3 Liquids (1)	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2
4.3 Solids	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2
5.1	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2 (3)
5.2 (1)						
6.1 Liquids FP<23°C	P.2.1	P.3.1 P.3.2		P.4 IIB T4, IP55	P.5.1	P.6.1 P.6.2
6.1 Liquids 23°C ≤ FP ≤ 60°C	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2
6.1 Liquids	P.2.1	P.3.1 P.3.2			P.5.1	
6.1 Solids	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2 (3)
8 Liquids FP < 23°C	P.2.1	P.3.1 P.3.2		P.4 IIB T4, IP55	P.5.1	P.6.1 P.6.2
8 Liquids 23°C ≤ FP ≤ 60°C	P.2.1	P.3.1 P.3.2			P.5.1	P.6.1 P.6.2
8 Liquids	P.2.1	P.3.1 P.3.2			P.5.1	
8 Solids	P.2.1	P.3.1 P.3.2			P.5.1	
9 Including Goods Evolving Flammable Vapour	P.2.1	P.3.1 P.3.2		P.4 IIB T4, IP55		P.6.1 P.6.2
9 Except Goods Evolving Flammable Vapour	P.2.1	P.3.1 P.3.2				P.6.1 P.6.2 (3)
<p>(1) Under the provisions of the IMDG Code, as amended, stowage of class 2.3, class 4.3 liquids having a flashpoint less than 23°C listed in the IMDG Code and class 5.2 under deck is prohibited.</p> <p>(2) In the special case where the barges are capable of containing flammable vapours or alternatively if they are capable of discharging flammable vapours to a safe outside the barge carrier compartment by means of ventilation ducts connected to the barges, these requirements may be reduced or waived to the satisfaction of the Administration.</p> <p>(3) When “mechanically-ventilated spaces” are required by the IMDG Code, as amended.</p>						

Table 18.10f Requirements for the carriage of dangerous goods in packaged form on the weather deck

Class	Requirements					
	Fixed gas fire-extinguishing system	Water supplies	Detection system	Personnel protection	Portable fire-extinguishers	Machinery space boundaries
1.1 to 1.6	P.2.3	P.3.1 P.3.2	P.5.2			P.10.3
1.4S	P.2.3	P.3.1 P.3.2	P.5.2			
2.1 Including Hydrogen And Hydrogen Mixtures	P.2.3	P.3.1 P.3.2		P.8		P.10.1 P.10.2
2.1 Except Hydrogen And Hydrogen Mixtures	P.2.3	P.3.1 P.3.2		P.8		P.10.1 P.10.2
2.2	P.2.3	P.3.1 P.3.2		P.8		P.10.1 P.10.2
2.3 Flammable	P.2.3	P.3.1 P.3.2		P.8		P.10.1 P.10.2
2.3 Non-flammable	P.2.3	P.3.1 P.3.2		P.8		P.10.1 P.10.2
3 FP < 23°C	P.2.3	P.3.1 P.3.2		P.8	P.9	P.10.1 P.10.2
3 23°C ≤ FP ≤ 60°C	P.2.3	P.3.1 P.3.2		P.8	P.9	P.10.1 P.10.2
4.1	P.2.3	P.3.1 P.3.2		P.8	P.9	P.10.1 P.10.2
4.2	P.2.3	P.3.1 P.3.2		P.8	P.9	P.10.1 P.10.2
4.3 Liquids	P.2.3	P.3.1 P.3.2		P.8	P.9	P.10.1 P.10.2
4.3 Solids	P.2.3	P.3.1 P.3.2		P.8	P.9	P.10.1 P.10.2
5.1	P.2.3	P.3.1 P.3.2		P.8	P.9	P.10.1 P.10.2 (1)
5.2	P.2.3	P.3.1 P.3.2		P.8		P.10.1 P.10.2
6.1 Liquids FP<23°C	P.2.3	P.3.1 P.3.2		P.8	P.9	P.10.1 P.10.2
6.1 Liquids 23°C ≤ FP ≤ 60°C	P.2.3	P.3.1 P.3.2		P.8	P.9	P.10.1 P.10.2
6.1 Liquids	P.2.3	P.3.1 P.3.2		P.8		
6.1 Solids	P.2.3	P.3.1 P.3.2		P.8		
8 Liquids FP < 23°C	P.2.3	P.3.1 P.3.2		P.8	P.9	P.10.1 P.10.2
8 Liquids 23°C ≤ FP ≤ 60°C	P.2.3	P.3.1 P.3.2		P.8	P.9	P.10.1 P.10.2
8 Liquids	P.2.3	P.3.1 P.3.2		P.8		
8 Solids	P.2.3	P.3.1 P.3.2		P.8		
9 Including Goods Evolving Flammable Vapour	P.2.3	P.3.1 P.3.2		P.8		
9 Except Goods Evolving Flammable Vapour	P.2.3	P.3.1 P.3.2		P.8		
(1) When “away from sources of heat” is required by the IMDG Code, as amended.						

3. Water supplies

3.1 Immediate supply of water

Immediate supply of water from the fire main shall be provided by remote starting arrangement for all main fire pumps from the navigation bridge or by permanent pressurization of the fire main and by automatic start-up of the main fire pumps.

3.2 Quantity of water and arrangement of hydrants

The capacity of the main fire pumps shall be sufficient for supplying four jets of water simultaneously at the prescribed pressure (see Table 18.3).

Hydrants are to be arranged on weather deck so that any part of the empty cargo spaces can be reached with four jets of water not emanating from the same hydrant.

Two of the jets shall be supplied by a single length of hose each, two may be supplied by two coupled hose lengths each.

Hydrants are to be arranged in ro-ro spaces so that any part of the empty cargo spaces can be reached with four jets of water not emanating from the same hydrant. The four jets shall be supplied by a single length of hose each. (34)

For additional hoses and nozzles see E.2.5.7.

3.3 Water cooling

3.3.1 Cargo spaces for transporting class 1, with the exception of class 1.4S are to be fitted with arrangements for the application of water-spray.

3.3.2 The flow rate of water required is to be determined on the basis of 5 litre/m² and per minute of the largest horizontal cross section of the cargo space or a dedicated section of it.

3.3.3 The water may be supplied by means of the main fire pumps if the flow rate of the water delivered in parallel flow ensures the simultaneous operation of the nozzles specified in 3.2.

3.3.4 The required water is to be distributed evenly over the cargo space area from above via a fixed piping system and full bore nozzles.

3.3.5 The piping and nozzle system may be divided into sections and be integrated into the hatch covers. Connection may be via hoses with quick-acting couplings. Additional hydrants are to be provided on deck for this purpose.

3.3.6 Drainage and pumping arrangements are to be such as to prevent the build-up of free surfaces:

- The drainage system shall have a capacity of not less than 1,25 times of the capacity discharged during the simultaneous operation of the water spraying system and four fire hose nozzles
- The valves of the drainage arrangement are to be operable from outside the protected space
- The bilge wells are to be of sufficient holding capacity and are to be arranged at both sides of the ship at a distance from each other of not more than 40 m in each watertight compartment.

If this is not possible, the additional weight of water and the influence of the free surfaces are to be taken into account in the ship's stability information.

4. Sources of ignition

The degree of explosion protection for the individual classes is specified in column "Sources of ignition" of Tables 18.10a to 18.10f. If explosion protection is required the following conditions are to be complied with

4.1 Electrical equipment

4.1.1 All electrical equipment coming into contact with the hold atmosphere and being essential for the ship's operation shall be of approved intrinsically safe type or certified safe type corresponding to the degree of explosion protection as shown in Tables 18.10a to 18.10f.

(34) Reference is made to BCS- I SC 168.

4.1.2 For the design of the electrical equipment and classification of the dangerous areas, see **BCS** Rules Chapter 5 - Electrical Installations.

4.1.3 Electrical equipment not being essential for ship's operation need not to be of certified safe type provided it can be electrically disconnected from the power source, by appropriate means other than fuses (e.g. by removal of links), at a point external to the space and to be secured against unintentional reconnection.

4.2 Safety of fans

4.2.1 For fans being essential for the ship's operation the design is governed by Section 20, B.5.3.2 and B.5.3.3. Otherwise the fans shall be capable of being disconnected from the power source, see 4.1.3.

4.2.2 The fans shall be such as to avoid the possibility of ignition of flammable gas air mixtures. Suitable wire mesh guards shall be fitted over inlet and outlet ventilation openings. (See also BCS- I SC52)

4.2.3 The air outlets are to be placed at a safe distance from possible ignition sources. A spherical radius of 3 m around the air outlets, within which ignition sources are prohibited, is required.

4.3 Other sources of ignition

Other sources of ignition may not be installed in dangerous areas, e.g. steam or thermal oil lines.

5. Detection system

5.1 The cargo spaces are to be equipped with an approved fixed fire detection and alarm system, see C.

5.2 If a cargo space or the weather deck is intended for the carriage of class 1 goods it is recommended to monitor adjacent cargo spaces, with the exception of open ro-ro spaces, by a fixed fire detection and alarm system.

6. Ventilation

6.1 Ducting

The ducting is to be arranged for removal of gases and

vapours from the upper and lower part of the cargo hold. This requirement is considered to be met if the ducting is arranged such that approximately 1/3 of the air volume is removed from the upper part and 2/3 from the lower part. The position of air inlets and air outlets shall be such as to prevent short circuiting of the air. Interconnection of the hold atmosphere with other spaces is not permitted.

For the construction and design requirements see **BCS** Rules for Chapter 28 - Ventilation, Section 1.

6.2 Mechanical ventilation (six air changes/h)

A ventilation system which incorporates powered fans with a capacity of at least six air changes per hour based on the empty cargo hold is to be provided.

6.3 Mechanical ventilation (two air changes/h)

The ventilation rate according to 6.2 may be reduced to not less than two air changes per hour, provided the goods are carried in container cargo spaces in closed freight containers.

For interpretation on required air changes BCS-I SC 288 is to be applied.

7. Bilge pumping

7.1 Inadvertent pumping

The bilge system is to be designed so as to prevent inadvertent pumping of flammable and toxic liquids through pumps and pipelines in the machinery space.

7.2 Isolating valves

The cargo hold bilge lines are to be provided with isolating valves outside the machinery space or at the point of exit from the machinery space located close to the bulkhead. The valves shall be capable of being secured in closed position (e.g. safety locking device). Remote controlled valves shall be capable of being secured in closed position. In case an ICMS (Integrated control and monitoring system) system is provided, this system shall contain a corresponding safety query on the display.

7.3 Warning signs

Warning signs are to be displayed at the isolating valve

or control positions, e.g. “This valve to be kept secured in closed position during the carriage of dangerous goods in cargo hold nos. __ and may be operated with the permission of the master only”.

7.4 Additional bilge system

7.4.1 An additional fixed bilge system with a capacity of at least 10 m³/h per cargo hold is to be provided. If more than two cargo holds are connected to a common system, the capacity need not exceed 25 m³/h.

7.4.2 The additional bilge system has to enable any leaked dangerous liquids to be removed from all bilge wells in the cargo space.

7.4.3 Pumps and pipelines are not to be installed in machinery spaces.

7.4.4 Spaces containing additional bilge pumps are to be provided with independent mechanical ventilation giving at least six air changes per hour. If this space has access from another enclosed space, the door shall be of self-closing type. For the design of the electrical equipment, see **BCS** Rules Chapter 5 - Electrical Installations.

7.4.5 Section 16, N. applies analogously.

7.4.6 Water-driven ejectors are to be equipped on the suction side with a means of reverse-flow protection.

7.4.7 If the bilge drainage of the cargo space is arranged by gravity drainage, the drainage is to be either led directly overboard or to a closed drain tank located outside the machinery spaces. Drainage from a cargo space into bilge wells in a lower space is only permitted if that space fulfils the same requirements as the cargo space above.

Notes :

a) Cargo spaces intended for carriage of flammable liquids with flash point less than 23 degrees C or toxic liquids shall be fitted with a fixed bilge drainage system independent or separated from the bilge system in machinery space and located outside of the machinery space.

If a single bilge drainage system completely independent of

the machinery space is provided, the system is to comply with the Rule requirement to redundancy based on the size of the space or spaces which it services.

b) Electrical equipment in the space containing bilge pumps serving cargo spaces intended for carriage of flammable or toxic liquids is to be according to BCS- I SC79.

7.5 Collecting tank

Where tanks are provided for collecting and storage of dangerous goods spillage, their vent pipes shall be led to a safe position on open deck.

8. Personnel protection

8.1 Full protective clothing

Four sets of full protective clothing appropriate to the properties of the cargo are to be provided for emergency purposes.

The protective clothing is to satisfy the equipment requirements specified in emergency procedures (EmS) of the Supplement to IMDG Code for the individual substances.

8.2 Self-contained breathing apparatuses

Additional two sets of self-contained breathing apparatuses with spare air cylinders for at least two refills for each set are to be provided

Note: “A suitable number of spare cylinders” to be carried on board to replace those used for fire drills shall be at least one ‘set of cylinders’ for each mandatory breathing apparatus, unless additional spare cylinders are required by the shipboard safety management system (SMS).

‘Set of cylinders’ means the number of cylinders which are required to operate the breathing apparatus.

No additional cylinders are required for fire drills for breathing apparatus sets required by SOLAS Reg. II-2/19, IMSBC Code, the IBC Code or IGC Code.

9. Portable fire extinguishers

Additional portable dry powder fire extinguishers containing a total of at least 12 kg of dry powder or equivalent are to be provided.

10. Machinery space boundaries**10.1 Bulkheads**

Bulkheads between cargo spaces and machinery spaces of category A are to be provided with a fire insulation to A-60 standard. Otherwise the cargoes are to be stowed at least 3 m away from the machinery space bulkhead.

10.2 Decks

Decks between cargo and machinery spaces of category A are to be insulated to A-60 standard.

10.3 Insulation for goods of class 1

For goods of class 1, with the exception of class 1.4S, both, the fire insulation of A-60 standard for the bulkhead between cargo space and machinery space of category A and stowage at least 3 m away from this bulkhead, is required. Stowage above machinery space of category A is not permitted in any case.

11. Separation of ro-ro spaces

11.1 A separation, suitable to minimise the passage of dangerous vapours and liquids, is to be provided between a closed ro-ro space and an adjacent open ro-ro space. Where such separation is not provided the ro-ro space is considered to be a closed ro-ro space over its entire length and the special requirements for closed ro-ro spaces apply.

11.2 A separation, suitable to minimise the passage of dangerous vapours and liquids, is to be provided between a closed ro-ro space and an adjacent weather deck. Where such separation is not provided the arrangements of the closed ro-ro space are to be in accordance with those required for the dangerous goods carried on the adjacent weather deck.

Q. Carriage of Solid Bulk Cargoes**1. General****1.1 Scope**

1.1.1 The following requirements apply additionally to ships carrying solid bulk cargoes other than grain.

1.1.2 The requirements depend on the dangerous goods class and special properties of the cargoes to be carried. The cargoes of Group B and the applicable provisions are shown in Table 18.11. For cargoes of Group A and C the requirements of 1.5 are to be observed only.

1.1.3 The requirements of **SOLAS**, Chapter VI, Part A and B, **SOLAS**, Chapter VII, Part A-1 and the IMSBC Code are to be observed.

Note:

For the carriage of grain the requirements of the IMO International Code for the Safe Carriage of Grain in Bulk are to be observed.

1.2 Documents for approval

Diagrammatic plans, drawings and documents covering the following are to be submitted for approval.

- Form ST236, "Application Form Dangerous Goods" for application for certification according to 1.4
- "Water fire extinguishing system" according to 3.2, as applicable
- Form ST184, "Details about the Construction of electrical Equipment in hazardous areas" including corresponding copies of certificates of conformity for electrical equipment according to 4., as applicable
- Ventilation system according to 6., as applicable
- Bilge system according to 7., as applicable
- Insulation according to 10., as applicable

1.3 References to other rules

1.3.1 SOLAS, Chapter II-2, Regulation 19, “Carriage of dangerous goods”

1.3.2 SOLAS, Chapter VI, Part A, “General provisions” and Part B, “Special provisions of solid bulk cargoes”

1.3.3 SOLAS, Chapter VII, Part A-1, “Carriage of dangerous goods in solid form in bulk”

1.3.4 ICLL, Annex B, Annex I, Chapter II, Regulation 19, “Ventilators”

1.3.5 IMO International Maritime Dangerous Goods (IMDG) Code

1.3.6 IMO International Maritime Solid Bulk Cargoes (IMSBC) Code

1.3.7 Medical First Aid Guide for Use in Accidents Involving Dangerous Goods (MFAG)

1.3.8 IMO MSC.1/Circ.1395/Rev.4 “List of solid bulk cargoes for which a fixed gas fire-extinguishing system may be exempted or for which a fixed gas fire extinguishing system is ineffective”

1.3.9 IEC 60079, “Electrical apparatus for explosive atmospheres”

1.4 Certification

1.4.1 The **DBC** additional notation assigned to the ship will remain valid as long as the “Document of Compliance for the Carriage of Dangerous goods” and “Statement of Compliance for the Carriage of Solid Bulk Cargoes” issued by **BCS** remains valid.

1.4.2 Certification for carriage of solid dangerous bulk cargoes covers only those cargoes listed in Group B in the IMSBC Code except cargoes classified solely as MHB. Other solid dangerous bulk cargoes may only be permitted subject to acceptance by the Administrations involved. (MSC/Circ. 1120)

Note:

For requirements and certification of dangerous goods in packaged form see P.

1.5 Identification and classification

1.5.1 Identification of solid bulk cargoes

1.5.1.1 Bulk Cargo Shipping Name

The Bulk Cargo Shipping Name (BCSN) identifies a solid bulk cargo. The BCSN shall be supplemented with the United Nations (UN) number when the cargo is dangerous goods according to the IMDG Code.

1.5.1.2 Cargo group

Solid bulk cargoes are subdivided into the following three groups:

- Group A consists of cargoes which may liquefy if shipped at a moisture content in excess of their transportable moisture limit.
- Group B consists of cargoes which possess a chemical hazard which could give rise to a dangerous situation on a ship. For classification of these cargoes see Q.1.5.2.
- Group C consists of cargoes which are neither liable to liquefy (Group A) nor to possess chemical hazards (Group B).

1.5.2 Classification of solid dangerous goods in bulk

Class 4.1: Flammable solids

Readily combustible solids and solids which may cause fire through friction.

Class 4.2: Substances liable to spontaneous combustion

Materials, other than pyrophoric materials, which, in contact with air without energy supply, are liable to self-heating.

Table 18.11 Requirements of the carriage of solid dangerous goods in bulk

Bulk Cargo Shipping Name (BCSN)	Class	Requirements															
		Fire-extinguishing system	Water supplies	Sources of ignition	Temperature measurement	Gas detection	Acidity of bilge water	Ventilation	Additional provisions on ventilation	Bilge pumping	Personnel protection	No smoking signs	Machinery space boundaries	Other boundaries	Gas sampling points	Weathertightness	Fuel tanks
ALUMINA HYDRATE	MHB	Q.2.2.1									Q.8.1.1 Q.8.2.1						
ALUMINIUM FERROSILICON POWDER UN 1395	4.3	Q.2.2.1		Q.4 IIC T2		Q.5.2.3 Q.5.2.6		Q.6.1 Q.6.5	Q.6.7.2 Q.6.7.3		Q.8.1.2 Q.8.2.2	Q.9	Q.10				
ALUMINIUM NITRATE UN 1438	5.1	Q.2.2	Q.3								Q.8.1.2 Q.8.2.2						
ALUMINIUM SILICON POWDER, UNCOATED UN 1398	4.3	Q.2.2.1		Q.4 IIC T2		Q.5.2.3 Q.5.2.6		Q.6.1 Q.6.5	Q.6.7.2 Q.6.7.3		Q.8.1.2 Q.8.2.2	Q.9	Q.10				
ALUMINIUM SMELTING BY-PRODUCTS or ALUMINIUM REMELTING BY-PRODUCTS UN 3170	4.3	Q.2.2.1		Q.4 IIC T2		Q.5.2.1 Q.5.2.3 Q.5.2.9		Q.6.1 Q.6.5	Q.6.7.2 Q.6.7.3		Q.8.1.2 Q.8.2.2	Q.9	Q.10.1 Q.10.2				
ALUMINIUM SMELTING / REMELTING BY-PRODUCTS, PROCESSED	MHB	Q.2.1		Q.4 IIC T1		Q.5.2.1 Q.5.2.3 Q.5.2.9		Q.6.1 Q.6.5	Q.6.7.2 Q.6.7.3	Q.7.1 Q.7.2 Q.7.3	Q.8.1.1	Q.9	Q.10.2				
AMMONIUM NITRATE UN 1942	5.1	Q.2.2	Q.3	Q.4 T3	Q.5.1.2						Q.8.1.2 Q.8.2.2	Q.9	Q.10.1			Q.13	Q.14.1 Q.14.2.1
AMMONIUM NITRATE BASED FERTILIZER UN 2067	5.1	Q.2.2	Q.3	Q.4 T3	Q.5.1.2						Q.8.1.2 Q.8.2.2	Q.9	Q.10.1			Q.13	Q.14.1 Q.14.2.3
AMMONIUM NITRATE BASED FERTILIZER UN 2071	9	Q.2.2	Q.3	Q.4 T3	Q.5.1.2						Q.8.1.2 Q.8.2.2	Q.9	Q.10.1			Q.13	Q.14.1 Q.14.2.3
AMORPHOUS SODIUM SILICATE LUMPS	MHB (CR)	Q.2.2.1									Q.8.1.2 Q.8.2.2						
BARIUM NITRATE UN 1446	5.1	Q.2.2	Q.3					Q.6.1 Q.6.2			Q.8.1.2 Q.8.2.2						
BORIC ACID	MHB (TX)	Q.2.2.1									Q.8.1.2 Q.8.2.2						
BROWN COAL BRIQUETTES	MHB	Q.2.2.1		Q.4 IIA T4, IP55	Q.5.1.2	Q.5.2.2 Q.5.2.4, .5	Q.5.3				Q.8.1.1 Q.8.2.1	Q.9		Q.11	Q.12	Q.13	Q.14.2.2
CALCIUM NITRATE UN 1454	5.1	Q.2.2	Q.3								Q.8.1.2 Q.8.2.2						

Table 18.11 Requirements of the carriage of solid dangerous goods in bulk (cont.)

Bulk Cargo Shipping Name (BCSN)	Class	Requirements															
		Fire-extinguishing system	Water supplies	Sources of ignition	Temperature measurement	Gas detection	Acidity of bilge water	Ventilation	Additional provisions on ventilation	Bilge pumping	Personnel protection	No smoking signs	Machinery space boundaries	Other boundaries	Sampling points	Leak-tightness	Stowage
CASTOR BEANS or CASTOR MEAL or CASTOR POMACE or CASTOR FLAKE UN 2969	9	Q.2.1	Q.3					Q.6.1 Q.6.2			Q.8.1.2 Q.8.2.2						
CHARCOAL	MHB	Q.2.1									Q.8.1.1						
CLINKER ASH	MHB	Q.2.2.1									Q.8.1.1						
COAL	MHB	Q.2.2.1		Q.4 IIA T4, IP55	Q.5.1.2	Q.5.2.2 Q.5.2.4, .5	Q.5.3	Q.6.1 Q.6.2			Q.8.2.1	Q.9		Q.11	Q.12	Q.13	Q.14.2.2
COAL TAR PITCH	MHB	Q.2.2.1									Q.8.1.1						
COPRA (dry) UN 1363	MHB	Q.2.2.1				Q.5.2.2 Q.5.2.4, .5		Q.6.1 Q.6.2			Q.8.2.1	Q.9					Q.14.2.2
DIRECT REDUCED IRON (A) Briquettes, hot-moulded	MHB	Q.2.2.1		Q.4 IIC T2	Q.5.1.2	Q.5.2.3 Q.5.2.5		Q.6.1 Q.6.2 Q.6.3			Q.8.1.1	Q.9		Q.11		Q.13	
DIRECT REDUCED IRON (B) Lumps, pellets, cold-moulded briquettes (1)	MHB	Q.2.2.1		Q.4 IIC T2	Q.5.1.2	Q.5.2.3 Q.5.2.5					Q.8.1.1	Q.9		Q.11		Q.13	
DIRECT REDUCED IRON (C) (Byproduct fines) (1)	MHB	Q.2.2.1		Q.4 IIC T2	Q.5.1.2	Q.5.2.3 Q.5.2.5					Q.8.1.1	Q.9		Q.11		Q.13	
FERROPHOSPHORUS	MHB	Q.2.2.1		Q.4 IIC T1		Q.5.2.3 Q.5.2.6 Q.5.2.7		Q.6.1 Q.6.5	Q.6.7.2 Q.6.7.3		Q.8.2.1	Q.9					
FERROSILICON UN 1408	4.3	Q.2.2.1		Q.4 IIC T1		Q.5.2.3 Q.5.2.6		Q.6.1 Q.6.5	Q.6.7.2 Q.6.7.3	Q.7	Q.8.1.2 Q.8.2.2	Q.9	Q.10				
FERROSILICON	MHB	Q.2.2.1		Q.4 IIC T1		Q.5.2.3 Q.5.2.6		Q.6.1 Q.6.5	Q.6.7.2 Q.6.7.3	Q.7	Q.8.2.2	Q.9	Q.10.2 Q.10.3				
FERROUS METAL BORINGS, SHAVINGS, TURNINGS or CUTTINGS UN 2793	4.2	Q.2.1	Q.3	3	Q.5.1.1						Q.8.1.2 Q.8.2.2	Q.9	Q.10.1				

Table 18.11 Requirements of the carriage of solid dangerous goods in bulk (cont.)

Bulk Cargo Shipping Name (BCSN)	Class	Requirements															
		Fire-extinguishing system	Water supplies	Sources of ignition	Temperature measurement	Gas detection	Acidity of bilge water	Ventilation	Additional provisions on ventilation	Bilge pumping	Personnel protection	No smoking signs	Machinery space boundaries	Other boundaries	Gas sampling points	Weathertightness	Fuel tanks
FISHMEAL (FISHSCRAP), STABILIZED UN 2216	9	Q.2.1	Q.3		Q.5.1.2	Q.5.2.5		Q.6.1 Q.6.2 Q.6.3			Q.8.1.2 Q.8.2.2						
FLUE DUST, CONTAINING LEAD AND ZINC	MHB	Q.2.1.1									Q.8.1.1 Q.8.2.1						
FLUORSPAR	MHB	Q.2.2.1									Q.8.1.1						
GRANULATED NICKEL MATTE (LESS THAN 2% MOISTURE CONTENT)	MHB	Q.2.2.1									Q.8.1.1 Q.8.2.1						
IRON OXIDE, SPENT or IRON SPONGE, SPENT UN 1376	4.2	Q.2.1	Q.3	Q.4 IIA T2.IP55		Q.5.2.5 Q.5.2.8		Q.6.1 Q.6.2 Q.6.3			Q.8.1.2 Q.8.2.2	Q.9	Q.10.1				
LEAD NITRATE UN 1469	5.1	Q.2.2	Q.3					Q.6.1 Q.6.2			Q.8.1.2 Q.8.2.2						
LIME (UNSLAKED)	MHB	Q.2.2.1									Q.8.1.1						
LINTED COTTON SEED	MHB	Q.2.1				Q.5.2.5					Q.8.2.1					Q.13	
MAGNESIA (UNSLAKED)	MHB	Q.2.2.1									Q.8.1.1						
MAGNESIUM NITRATE UN 1474	5.1	Q.2.2	Q.3					Q.6.1 Q.6.2			Q.8.1.2 Q.8.2.2						
MATTE CONTAINING COPPER AND LEAD	MHB	Q.2.2.1									Q.8.1.1 Q.8.2.1						
METAL SULPHIDE CONCENTRATES	MHB	Q.2.1				Q.5.2.5 Q.5.2.7					Q.8.1.1 Q.8.2.1						
METAL SULPHIDE CONCENTRATES, CORROSIVE UN 1759	8	Q.2.1				Q.5.2.5 Q.5.2.7					Q.8.1.2 Q.8.2.1						
METAL SULPHIDE CONCENTRATES, SELF-HEATING UN 3190	4.2	Q.2.1	Q.3		Q.5.1.2	Q.5.2.5 Q.5.2.7					Q.8.1.2 Q.8.2.1	Q.9	Q.10.1				
MONOAMMONIUM PHOSPHATE (M.A.P.), MINERAL ENRICHED COATING	MHB	Q.2.2.1									Q.8.1.2 Q.8.2.1						
MONOCALCIUMPHOSPHATE (MCP)	MHB	Q.2.2.1									Q.8.1.2 Q.8.2.1						
PEAT MOSS	MHB	Q.2.2.1				Q.5.2.5		Q.6.1 Q.6.2			Q.8.1.1						
PETROLEUM COKE (calcined or uncalcined)	MHB	Q.2.2.1									Q.8.1.1 Q.8.2.1						
PITCH PRILL	MHB	Q.2.2.1						Q.6.1 Q.6.2			Q.8.1.1 Q.8.2.1						Q.14.2.1
POTASSIUM NITRATE UN 1486	5.1	Q.2.2	Q.3					Q.6.1 Q.6.2			Q.8.1.2 Q.8.2.2						
PYRITES, CALCINED	MHB	Q.2.2.1									Q.8.1.1						

Table 18.11 Requirements of the carriage of solid dangerous goods in bulk (cont.)

Bulk Cargo Shipping Name (BCSN)	Class	Requirements															
		Fire-extinguishing system	Water supplies	Sources of ignition	Temperature measurement	Gas detection	Acidity of bilge water	Ventilation	Additional provisions on ventilation	Bilge pumping	Personnel protection	No smoking signs	Machinery space boundaries	Other boundaries	Gas sampling points	Weather-tightness	Fuel tanks
RADIOACTIVE MATERIAL, LOW SPECIFIC ACTIVITY (LSA-I) UN 2912 (*)	7	Q.2.2.1									Q.8.1.1 Q.8.2.1						
RADIOACTIVE MATERIAL, SURFACE CONTAMINATED OBJECTS (SCO-I) UN 2913(*)	7	Q.2.2.1									Q.8.1.1 Q.8.2.1						
SAND, MINERAL CONCENTRATE, RADIOACTIVE MATERIAL, LOW SPECIFIC ACTIVITY (LSA-I) UN 2912	7	Q.2.2.1									Q.8.1.2 Q.8.2.1						
SAWDUST	MHB	Q.2.1						Q.6.1 Q.6.2									
SEED CAKES AND OTHER RESIDUES OF PROCESSED OILY VEGETABLES	MHB	Q.2.1		Q.4 IIC T3	Q.5.1.2	Q.5.2.5		Q.6.1 Q.6.2 Q.6.3	Q.6.7.1		Q.8.2.1		Q.10.1			Q.13	
SEED CAKE, containing vegetable oil un 1386 (a)	4.2	Q.2.1	Q.3		Q.5.1.2	Q.5.2.5		Q.6.1 Q.6.2			Q.8.1.2 Q.8.2.2	Q.9	Q.10.1			Q.13	
SEED CAKE, containing vegetable oil un 1386 (b) mechanically expelled seeds	4.2	Q.2.1	Q.3	Q.4 IC T3	Q.5.1.2			Q.6.1 Q.6.4	Q.6.7.1		Q.8.1.2 Q.8.2.2	Q.9	Q.10.1			Q.13	
SEED CAKE, containing vegetable oil un 1386 (b) solvent extracted seeds	4.2	Q.2.1	Q.3	Q.4 IIC T3	Q.5.1.2	Q.5.2.5		Q.6.1 Q.6.4	Q.6.7.1		Q.8.1.2 Q.8.2.2	Q.9	Q.10.1			Q.13	
SEED CAKE UN 2217	4.2	Q.2.1	Q.3	Q.4 IIA T3	Q.5.1.2	Q.5.2.5		Q.6.1 Q.6.4	Q.6.7.1		Q.8.1.2 Q.8.2.2	Q.9	Q.10.1				
SILICONMANGANESE	MHB	Q.2.2.1		Q.4 IIC T1		Q.5.2.3 Q.5.5, .6		Q.6.1 Q.6.3			Q.8.2.1	Q.9				Q.13	
SODIUM NITRETE UN 1498	5.1	Q.2.2	Q.3					Q.6.1 Q.6.2			Q.8.1.2 Q.8.2.2						
SODIUM NITRATE AND POTASium NITRATE MIXTURE UN 1499	5.1	Q.2.2	Q.3					Q.6.1 Q.6.2			Q.8.1.2 Q.8.2.2						
SOLIDIFIED FUELS RECYCLED FROM PAPER AND PLASTICS	MHB	Q.2.1		Q.4 T3, IP55		Q.5.2.5					Q.8.1.1	Q.9					
SUGARCANE BIOMASS PELLETS	MHB	Q.2.1									Q.8.2.1						
SULPHUR UN 1350	4.1	Q.2.2.1	Q.3	Q.4 T4, IP55				Q.6.1 Q.6.2	Q.6.7.1		Q.8.1.2 Q.8.2.2	Q.9	Q.10.1				
TANKAGE	MHB	Q.2.1			Q.5.1.2						Q.8.1.1 Q.8.2.1						
VANADIUM ORE	MHB	Q.2.2.1									Q.8.1.1 Q.8.2.1						
(*) The cargo spaces carrying this cargo shall not be ventilated during voyage.																	

Table 18.11 Requirements of the carriage of solid dangerous goods in bulk (cont.)

		Requirements															
		Fire-extinguishing system	Water supplies	Sources of ignition	Temperature measurement	Gas detection	Acidity of bilge water	Ventilation	Additional provisions on ventilation	Bilge pumping	Personnel protection	No smoking signs	Machinery space boundaries	Other boundaries	Gas sampling points	Weathertightness	Fuel tanks
WOODCHIPS having a moisture content of 15% or more	HB	2.1				Q.5.2.5 Q.5.2.10		Q.6.1 Q.6.2			Q.8.2.1						
WOODCHIPS having a moisture content of less than 15%	MHB	Q.2.1				Q.5.2.5 Q.5.2.10		Q.6.1 Q.6.2			Q.8.2.1						
WOOD PELLETS CONTAINING ADDITIVES AND/OR BINDERS	MHB (WF)	Q.2.1				Q.5.2.2 Q.5.2.5 Q.5.2.10 Q.5.2.11		Q.6.1 Q.6.2			Q.8.2.1						
WOOD PELLETS NOT CONTAINING ANY ADDITIVES AND/OR BINDERS	MHB (OH)	Q.2.2				Q.5.2.2 Q.5.2.5 Q.5.2.10 Q.5.2.11		Q.6.1 Q.6.2			Q.8.2.1						
WOOD PRODUCTS - General	MHB	Q.2.2.1				Q.5.2.5 Q.5.2.10		Q.6.1 Q.6.2			Q.8.2.1						
WOOD TORREFIED	MHB	Q.2.1		Q.4 T3, IP55		Q.5.2.2 Q.5.2.5 Q.5.2.10 Q.5.2.11					Q.8.1.1 Q.8.2.1						
ZINC ASHES UN 1435	4.3	Q.2.2.1		Q.4 IIC T2		Q.5.2.3		Q.6.1 Q.6.5	Q.6.7.2		Q.8.1.2 Q.8.2.2	Q.9	Q.10.1				
ZINC OXIDE ENRICHED FLUE DUST	MHB	Q.2.2.1									Q.8.1.1 Q.8.2.1						
(1) The additional requirements for DIRECT REDUCED IRON (B) and (C) are to be agreed upon with BCS.																	

Class 4.3: Substances which, in contact with water, emit flammable gases

Solids which, by interaction with water, are liable to become spontaneously flammable or to give off flammable gases in dangerous quantities.

Class 5.1: Oxidizing substances

Materials that, while in themselves not necessarily combustible, may, generally by yielding oxygen, cause, or contribute to, the combustion of other material.

Class 7: Radioactive material

Materials containing radionuclides where both the activity concentration and the total activity in the consignment exceed the values specified in 2.7.2.2.1 to 2.7.2.2.6 of the IMDG Code.

Class 8: Corrosive substances

Substances which, by chemical action, will cause severe damage when in contact with living tissue or, in the case of leakage, will materially damage, or even destroy, other goods or the means of transport.

Class 9: Miscellaneous dangerous substances

Materials which, during transport, present a danger not covered by other classes.

Class MHB: Materials hazardous only in bulk

Materials which may possess chemical hazards when transported in bulk other than materials classified as dangerous goods in the IMDG Code.

1.6 Documentation

All vessels intended for the carriage of solid bulk cargoes are to be provided with following documentation:

1.6.1 The IMSBC Code, as amended.

1.6.2 The MFAG. To be provided for cargoes of Group B only.

1.6.3 The approved Loading Manual (see **BCS** Rules Part A, Chapter 1 - Section 6, A.4.).

1.6.4 The approved Stability Information (see **BCS** Rules for Part A, Chapter 1 - Section 26, E.).

1.6.5 The Bulk cargo booklet according to **SOLAS**, Chapter VI, Regulation 7.2.

2. Fire-Extinguishing System

2.1 Fixed gas fire-extinguishing system

All cargo holds of the following ships are to be equipped with a fixed CO₂ fire-extinguishing system complying with the provisions of G. and H., respectively:

- Ships intended for the carriage of dangerous goods in solid form in compliance with **SOLAS**, Chapter II-2, Regulation 19,
- Ships of 2000 GT and above intended for the carriage of cargoes of class MHB and cargoes of Group A and C.

The self-heating phenomenon (for certain individual schedules of solid bulk cargoes in Appendix 1 of the IMSBC Code as amended, such as FISHMEAL (FISHSCRAP) STABILIZED UN 2216, SEED CAKE containing vegetable oil UN 1386, SEED CAKE UN 2217) shall be regarded as an emergency condition such that it is not necessary to provide a separate fixed carbon dioxide fire-extinguishing system or inert gas system dedicated to the control of the self-heating of the cargo within the cargo holds. Fixed gas fire extinguishing systems or inert gas systems installed on board dedicated to the protection of spaces other than cargo spaces cannot be used for this purpose.

Note:

For ships of less than 500 GT the requirement may be dispensed with subject to acceptance by the Administration.

2.2 Exemption certificate

2.2.1 A ship may be exempted from the requirement of a fixed gas fire-extinguishing system if constructed and solely intended for the carriage of cargoes as specified MSC.1/Circ.1395/Rev.4. Such exemption may be granted only if the ship is fitted with steel hatch covers and effective means of closing all ventilators and other openings leading to the cargo spaces.

2.2.2 For cargoes according to MSC.1/Circ.1395/Rev.4, Table 2 a fire-extinguishing system giving equivalent protection is to be provided.

For fire-extinguishing systems giving equivalent protection refer to 3.2.

3. Water Supplies

3.1 Immediate supply of water

Immediate supply of water from the fire main shall be provided by remote starting arrangement for all main fire pumps from the navigation bridge or by permanent pressurization of the fire main and by automatic start-up for the main fire pumps.

3.2 Quantity of water and arrangement of hydrants

The capacity of the main fire pumps shall be sufficient for supplying four jets of water simultaneously at the prescribed pressure (see Table 18.3).

Hydrants are to be arranged on weather deck that any part of the empty cargo spaces can be reached with four jets of water not emanating from the same hydrant. Two of the jets shall be supplied by a single length of hose each, two may be supplied by two coupled hose lengths each. **(35)**

For additional hoses and nozzles see E.2.5.7.

4. Sources of Ignition

The degree of explosion protection for the individual cargoes is specified in column "Sources of ignition" of Table 18.11. If explosion protection is required the following condition are to be complied with.

4.1 Electrical equipment

4.1.1 All electrical equipment coming into contact with the hold atmosphere and being essential for the ship's operation shall be of approved intrinsically safe type or certified safe type corresponding to the degree explosion protection as shown in Table 18.11.

4.1.2 For the design of the electrical equipment and classification of the dangerous areas, see **BCS** Rules for Chapter 5 - Electrical Installation.

4.1.3 Electrical equipment not being essential for ship's operation need not to be of certified safe type provided it can be electrically disconnected from the power source, by appropriate means other than a fuses (e.g. by removal of links), at a point external to the space and to be secured against unintentional reconnection.

4.2 Safety of fans

4.2.1 For fans being essential for the ship's operation the design is governed by Section 20, B.5.3.2 and B.5.3.3. Otherwise the fans shall be capable of being disconnected from the power source, see 4.1.3.

4.2.2 The fan openings on deck are to be fitted with fixed wire mesh guards with a mesh size not exceeding 13 mm.

4.2.3 The ventilation outlets are to be placed at a safe distance from possible ignition sources. A spherical radius of 3 m around the air outlets, within which ignition sources are prohibited, is required.

4.3 Other sources of ignition

Other sources of ignition may not be installed in dangerous areas, e.g. steam or thermal oil lines.

5. Measurement equipment

Portable equipment required for the carriage of individual cargoes shall be available on board prior to loading.

5.1 Temperature measurement

5.1.1 Surface temperature

Means shall be provided for measuring the surface temperature of the cargo. In case of portable

(35) *Reference is made to BCS- I SC 168.*

temperature sensors, the arrangement shall enable the measurement without entering the hold.

5.1.2 Cargo temperature

Means shall be provided for measuring the temperature inside the cargo. In case of portable temperature sensors, the arrangement shall enable the measurement without entering the hold.

5.2 Gas detection

Suitable instruments for measuring the concentration of the following gases are to be provided:

5.2.1 Ammonia

5.2.2 Carbon monoxide

5.2.3 Hydrogen

5.2.4 Methane

5.2.5 Oxygen (0 - 21 % by volume)

5.2.6 Phosphine and arsine

5.2.7 Toxic gases that may be given off from the particular cargo

5.2.8 Hydrogen cyanide

5.2.9 Acetylene

5.2.10 Oxygen meters for crew entering cargo and adjacent enclosed spaces

5.2.11 Carbon monoxide meters for crew entering cargo and adjacent enclosed spaces

5.3 Acidity of bilge water

Means shall be provided for testing the acidity of the water in the bilge wells.

6. Ventilation

6.1 Ducting

The ducting is to be arranged such that the space

above the cargo can be ventilated and that exchange of air from outside to inside the entire cargo space is provided. The position of air inlets and air outlets shall be such as to prevent short circuiting of the air. Interconnection of the hold atmosphere with other spaces is not permitted.

Suitable wire mesh guards shall be fitted over inlet and outlet ventilation openings.

If adjacent spaces are not separated from cargo spaces by gastight bulkheads or decks then they are considered as part of the enclosed cargo space and the ventilation requirements shall apply to the adjacent space as for the enclosed cargo space itself.

For the construction and design requirements see **BCS Rules for Chapter 28 - Ventilation, Section 1.**

6.2 Natural ventilation

Natural ventilation shall be provided in enclosed cargo spaces intended for the carriage of solid dangerous goods in bulk.

A ventilation system which does not incorporate mechanical fans is sufficient.

6.3 Mechanical ventilation

A ventilation system which incorporates powered fans with an unspecified capacity is to be provided.

6.4 Mechanical ventilation (six air changes/h)

A ventilation system which incorporates powered fans with a capacity of at least six air changes per hour based on the empty cargo hold is to be provided.

6.5 Continuous ventilation (six air changes/h)

A ventilation system which incorporates at least two powered fans with a capacity of at least three air changes per hour each based on the empty cargo hold is to be provided. A common ventilation system with 2 fans connected is acceptable.

6.6 Portable fans

If ventilation fans are required portable fans may be used instead of fixed ones. If so, suitable arrangements for securing the fans safely are to be provided. Electrical connections are to be fixed and expertly laid for the duration of the installation. Details are to be submitted for approval.

6.7 Additional provisions on ventilation

6.7.1 Spark arresting screens

All ventilation openings on deck are to be fitted with suitable spark arresting screens.

6.7.2 Openings for continuous ventilation

The ventilation openings shall comply with the requirements of the Load Line Convention, for openings not fitted with means of closure. According to **ICLL**, Regulation 19(3) the openings shall be arranged at least 4,50 m above deck in position 1 and at least 2,30 m above deck in position 2.

Continuous ventilation, this does not prohibit ventilators from being fitted with a means of closure as required for fire protection purposes under SOLAS II-2/5.2.1.1.

6.7.3 Escaping gases

The ventilation outlets shall be arranged at least 10 m away from living quarters on or under deck.

7. Bilge Pumping

7.1 Inadvertent pumping

The bilge system is to be designed so as to prevent inadvertent pumping of flammable and toxic liquids through pumps and pipelines in the machinery space.

7.2 Isolating valve

The cargo hold bilge lines are to be provided with isolating valves outside the machinery space or at the point of exit from the machinery space located close to the bulkhead. The valves have to be capable of being

secured in closed position (e.g. safety locking device). Remote controlled valves have to be capable of being secured in closed position. In case an ICMS system (Integrated control and monitoring system) is provided, this system shall contain a corresponding safety query on the display.

7.3 Warning signs

Warning signs are to be displayed at the isolating valve or control positions, e.g. "This valve to be kept secured in closed position during the carriage of dangerous goods in cargo hold nos.... and may be operated with the permission of the master only".

8. Personnel Protection

8.1 Full protective clothing

8.1.1 Two sets of full protective clothing appropriate to the properties of the cargo are to be provided.

8.1.2 Four sets of full protective clothing appropriate to the properties of the cargo are to be provided.

8.2 Self-contained breathing apparatuses

8.2.1 Two sets of self-contained breathing apparatuses with spare air cylinders for at least two refills for each set are to be provided.

8.2.2 Additional two sets of self-contained breathing apparatuses with spare air cylinders for at least two refills for each set are to be provided.

Note: "A suitable number of spare cylinders" to be carried on board to replace those used for fire drills shall be at least one 'set of cylinders' for each mandatory breathing apparatus, unless additional spare cylinders are required by the shipboard safety management system (SMS).

'Set of cylinders' means the number of cylinders which are required to operate the breathing apparatus.

No additional cylinders are required for fire drills for breathing apparatus sets required by SOLAS Reg. II-2/19, IMSBC Code, the IBC Code or IGC Code.

9. No Smoking Signs

“NO SMOKING” signs shall be posted in the vicinity of cargo holds and in areas adjacent to cargo holds.

10. Machinery Space Boundaries

10.1 A-60 insulation

Bulkheads between cargo spaces and machinery spaces of category A are to be provided with a fire insulation to A-60 standard. Otherwise the cargoes are to be stowed at least 3 m away from the machinery space bulkhead.

Note

The 3 m distance can be provided by a grain bulkhead, big bags filled with inert gas or by other means of separation.

Decks between cargo and machinery spaces of category A are to be insulated to A-60 standard.

10.2 Gas-tightness

All boundaries between the cargo hold and the machinery space are to be gastight. Cable penetrations are not permitted.

Prior to loading, the bulkheads to the engine room shall be inspected and approved by the competent Authority as gastight.

11. Other Boundaries

All boundaries of the cargo holds shall be resistant to fire and passage of water (at least A-0 standard).

12. Gas Sampling Points

Two sampling points per cargo hold shall be arranged in the hatch cover or hatch coaming, provided with threaded stubs and sealing caps according to Fig. 12.2. The sampling points shall be located as high as possible, e.g. upper part of hatch.

13. Weathertightness

Hatch covers, closures for all ventilators and other

closures for openings leading to the cargo holds shall be inspected and tested (hose testing or equivalent) to ensure weathertightness.

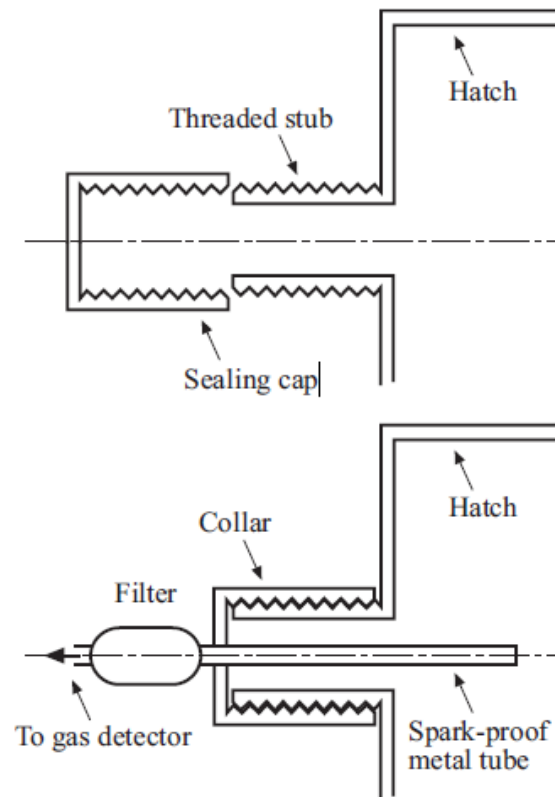


Fig. 18.2 Gas sampling points

14. Fuel Tanks

14.1 Tightness

Prior to loading, fuel tanks adjacent to the cargo holds shall be pressure-tested for tightness.

14.2 Sources of heat

14.2.1 Stowage adjacent to sources of heat, including fuel tanks which may require heating is not permitted

Note: For AMMONIUM NITRATE UN 1942, cargo shall not be loaded in cargo spaces adjacent to fuel oil tank(s), unless heating arrangements for the tank(s) are disconnected and remain disconnected during the entire voyage.

14.2.2 Stowage adjacent to sources of heat and to fuel tanks heated to more than 55 °C is not permitted.

*Note: For **BROWN COAL BRIQUETTES** and **COAL** this requirement is considered to be met if the fuel oil temperature is controlled at less than 55 °C. This temperature shall not exceed for periods greater than 12 hours in any 24-hour period and the maximum temperature reached shall not exceed 65 °C.*

14.2.3 Stowage adjacent to sources of heat and to fuel tanks heated to more than 50 °C is not permitted.

*Note: For **AMMONIUM NITRATE-BASED FERTILIZER UN 2067**, **AMMONIUM NITRATE-BASED FERTILIZER UN 2071** and **AMMONIUM NITRATE-BASED FERTILIZER** (non-hazardous) cargo shall not to be stowed immediately adjacent to any tank, double bottom or pipe containing heated fuel oil unless there are means to monitor and control the temperature so that it does not exceed 50°C.*

SECTION 19

MACHINERY FOR ICE CLASS NOTATION

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A. General

1. Application

The requirements in this section apply to vessels intended for navigation in waters with ice conditions.

2. Class Notation

2.1 Vessels built in accordance with the requirements of this section and the relevant structural requirements set out in Chapter 1 - Hull, Section 14 are to be assigned the class notation “**ICE-B4**”, “**ICE-B3**”, “**ICE-B2**”, “**ICE-B1**” or “**ICE-B**” after the character of classification + M.

2.2 The requirements in this section except those for ships with notation **ICE-B** are equivalent to those stated in the Finnish-Swedish Ice Class Rules for services in the northern Baltic in winter.

BCS ice classes are accepted as equivalent to the Finnish-Swedish ice classes as follows:

BCS ICE CLASS	FINNISH-SWEDISH ICE CLASS
ICE-B4	IA Super
ICE-B3	IA
ICE-B2	IB
ICE-B1	IC

2.3 Ships intended for navigation in Arctic waters may have the ice class notations **PC7 ÷ PC1** affixed to their character of classification if the guidelines given in Chapter 33 - Rules for the Construction of Polar Class Ships are complied with.

3. Assumptions

3.1 The method for determining the hull scantlings, engine output and other properties are based on certain assumptions concerning the nature of the ice load on the structure and operation of the ship as described in the Finnish-Swedish Ice Class Rules.

ICE-B4 Normally capable of navigating in difficult ice conditions without the assistance of icebreakers

ICE-B3 Capable of navigating in difficult ice conditions with the assistance of icebreakers when necessary

ICE-B2 Capable of navigating in moderate ice conditions with the assistance of icebreakers when necessary

ICE-B1 Capable of navigating in light ice conditions with the assistance of icebreakers when necessary

3.2 If the scantlings required by this Section are less than those required for ships without ice strengthening, the scantlings required by the other Sections of these Rules are to be maintained.

3.3 Assistance from icebreakers is normally assumed when navigating in ice bound waters.

B. Output of Propulsion Machinery

The necessary output of propulsion machinery is to be as stated in Chapter 1 - Hull, Section 14.

The rated output of the main engines in accordance with Section 2, must be such that they are able to supply in continuous service the propulsion power necessary for the ice class concerned.

C. Propulsion Machinery

1. Scope

These regulations apply to propulsion machinery covering open- and ducted-type propellers with controllable pitch or fixed pitch design for the ice classes **ICE-B4**, **ICE-B3**, **ICE-B2** and **ICE-B1**.

Note: Aspects not mentioned in this section are to be considered within the scope of requirements for ships without ice class.

The given propeller loads are the expected ice loads for the entire ship's service life under normal operational conditions, including loads resulting from the changing rotational direction of FP propellers. However, these loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice. However, the load models of the regulations do not include propeller/ice interaction loads when ice enters the propeller of a turned azimuthing thruster from the side (radially). The regulations also apply to azimuthing and fixed thrusters for main propulsion, taking consideration of loads resulting from propeller/ice interaction and loads on the thruster body/ice interaction. The given azimuthing thruster body loads are the expected ice loads for the ship's service life under normal operational conditions. The local strength of the thruster body shall be sufficient to withstand local ice pressure when the thruster body is designed for extreme loads.

The thruster global vibrations caused by blade order excitation on the propeller may cause significant vibratory loads.

2. Definitions

c	=	Chord length of blade section [m]
$c_{0,7}$	=	Chord length of blade section at 0.7R propeller radius [m]
CP	=	Controllable pitch [m]
D	=	Propeller diameter [m]
d	=	External diameter of propeller hub (at propeller plane) [m]
D_{limit}	=	Limit value for propeller diameter [m]
EAR	=	Expanded blade area ratio
F_b	=	Maximum backward blade force for the ship's service life [kN]
F_{ex}	=	Ultimate blade load resulting from blade loss through plastic bending [kN]

F_f	=	Maximum forward blade force during the ship's service life [kN]
F_{ice}	=	Ice load [kN]
$(F_{\text{ice}})_{\text{max}}$	=	Maximum ice load during the ship's service life [kN]
FP	=	Fixed pitch
h_0	=	Depth of the propeller centreline from lower ice waterline LIWL [m]
H_{ice}	=	Thickness of maximum design ice block entering the propeller [m]
I	=	Equivalent mass moment of inertia of all parts on the engine side of the component under consideration [kgm ²]
I_t	=	Equivalent mass moment of inertia of the whole propulsion system [kgm ²]
k	=	Shape parameter for Weibull distribution
LIWL	=	Lower ice waterline [m]
m	=	Slope for SN curve in log/log scale
M_{BL}	=	Blade bending moment [kNm]
MCR	=	Maximum continuous rating
n	=	Propeller rotational speed [rev./s]
n_n	=	Nominal propeller rotational speed at MCR in free running condition [rev./s]
N_{class}	=	Reference number of impacts per nominal propeller rotational speed per ice class
N_{ice}	=	Total number of ice loads on the propeller blade for the ship's service life
N_R	=	Reference number of load for the equivalent fatigue stress (10 ⁸ cycles)
N_Q	=	Number of propeller revolutions during a milling sequence

$P_{0,7}$	=	Propeller pitch at 0.7R radius [m]	T_f	=	Maximum forward propeller ice thrust during the ship's service life [kN]
$P_{0,7n}$	=	Propeller pitch at 0.7R radius at MCR in free running condition [m]	T_n	=	Propeller thrust at MCR in free running condition [kN]
$P_{0,7b}$	=	Propeller pitch at 0.7R radius at MCR in bollard condition [m]	T_r	=	Maximum response thrust along the shaft line [kN]
Q	=	Torque [kNm]	t	=	Maximum blade section thickness [m]
Q_{emax}	=	Maximum engine torque [kNm]	Z	=	Number of propeller blades
Q_{max}	=	Maximum torque on the propeller resulting from propeller/ice interaction [kNm]	α_i	=	Duration of propeller blade/ice interaction expressed in rotation angle [deg]
Q_{max}^n	=	Maximum torque on the propeller resulting from propeller/ice interaction reduced to the rotational speed in question [kNm]	α_1	=	Phase angle of propeller ice torque for blade order excitation component [deg]
Q_{motor}	=	Electric motor peak torque [kNm]	α_2	=	Phase angle of propeller ice torque for twice the blade order excitation component [deg]
Q_n	=	Nominal torque at MCR in free running condition [kNm]	$\gamma_{\epsilon 1}$	=	The reduction factor for fatigue; scatter effect
Q_r	=	Response torque along the propeller shaft line [kNm]	$\gamma_{\epsilon 2}$	=	The reduction factor for fatigue; test specimen size effect
Q_{peak}	=	Maximum of the response torque Q_r [kNm]	γ_v	=	The reduction factor for fatigue; variable amplitude loading effect
Q_{smax}	=	Maximum spindle torque of the blade for the ship's service life [kNm]	γ_m	=	The reduction factor for fatigue; mean stress effect
Q_{sex}	=	Maximum spindle torque due to blade failure caused by plastic bending [kNm]	ρ	=	A reduction factor for fatigue correlating the maximum stress amplitude to the equivalent fatigue stress for 10^8 stress cycles
Q_{vib}	=	Vibratory torque at considered component, taken from frequency domain open water torque vibration calculation (TVC) [kNm]	$\sigma_{0,2}$	=	Proof yield strength (at 0.2% offset) of blade material [MPa]
R	=	Propeller radius [m]	σ_{exp}	=	Mean fatigue strength of blade material at 10^8 cycles to failure in sea water [MPa]
r	=	Blade section radius [m]	σ_{fat}	=	Equivalent fatigue ice load stress amplitude for 10^8 stress cycles [MPa]
T	=	Propeller thrust [kN]			
T_b	=	Maximum backward propeller ice thrust during the ship's service life [kN]			

σ_{fi} = Characteristic fatigue strength for blade material [MPa]

$(\sigma_{ice})_{fmax}$ = Principal stress caused by the maximum forward propeller ice load [MPa]

σ_{ref1} = Reference stress $\sigma_{ref1} = 0,6 \cdot \sigma_{0,2} + 0,4 \cdot \sigma_u$ [MPa]

$(\sigma_{ice})_{max}$ = Maximum ice load stress amplitude [MPa]

σ_{ref2} = Reference stress $\sigma_{ref2} = 0,7 \cdot \sigma_u$ or $\sigma_{ref2} = 0,6 \cdot \sigma_{0,2} + 0,4 \cdot \sigma_u$ whichever is less [MPa]

σ_{st} = Maximum stress resulting from F_b or F_f [MPa]

σ_u = Ultimate tensile strength of blade material [MPa]

$(\sigma_{ice})_{bmax}$ = Principal stress caused by the maximum backward propeller ice load [MPa]

3. Design ice conditions

In estimating the ice loads of the propeller for various ice classes, account was taken of different types of operation as shown in Table 19.2. For the estimation of design ice loads, a maximum ice block size must be determined. The maximum design ice block entering the propeller is a rectangular ice block with the dimensions $H_{ice} \cdot 2H_{ice} \cdot 3H_{ice}$. The thickness of the ice block (H_{ice}) is given in Table 19.3.

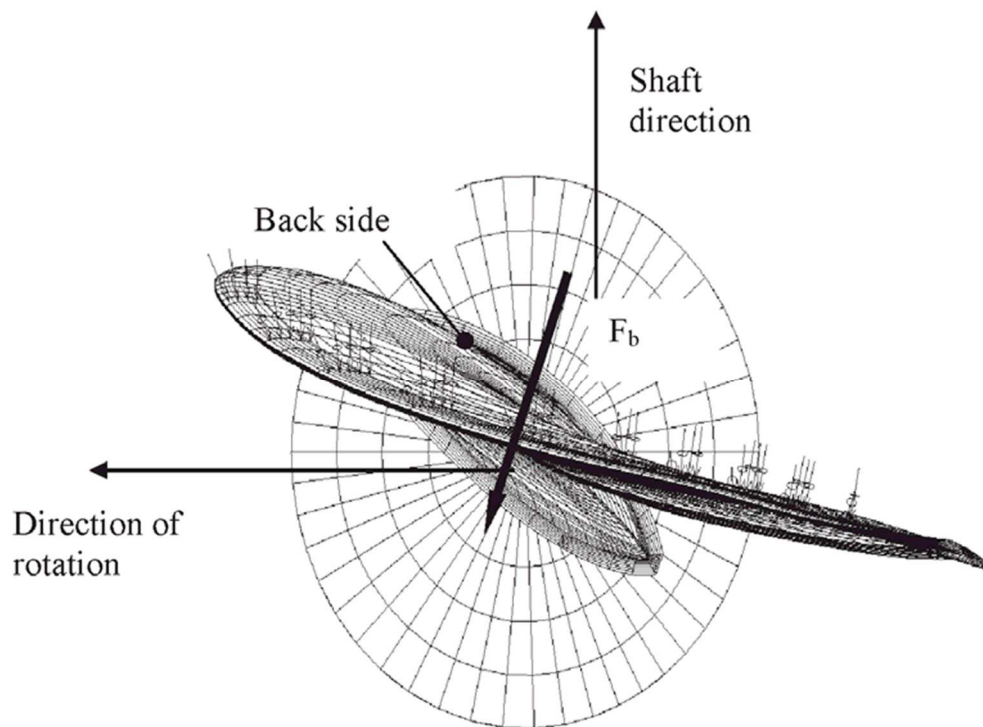


Figure 19.1 Direction of the resultant backward blade force taken perpendicular to the chord line at radius 0.7R. The ice contact pressure at the leading edge is indicated with small arrows.

Table 19.1 Definition of loads

	Definition	Use of the load in design process
F_b	The maximum lifetime backward force on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade. The direction of the force is perpendicular to the 0.7R chord line. See Figure 19.1.	Design force for strength calculation of the propeller blade.
F_f	The maximum lifetime forward force on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade. The direction of the force is perpendicular to the 0.7R chord line.	Design force for calculation of strength of the propeller blade.
Q_{smax}	The maximum lifetime spindle torque on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade.	When designing the propeller strength, the spindle torque is automatically taken into account because the propeller load is acting on the blade as distributed pressure on the leading edge or tip area.
T_b	The maximum lifetime thrust on propeller (all blades) resulting from propeller/ice interaction. The direction of the thrust is the propeller shaft direction and the force is opposite to the hydrodynamic thrust.	Is used for estimating the response thrust T_r . T_b can be used as an estimate of excitation for axial vibration calculations. However, axial vibration calculations are not required by the rules.
T_f	The maximum lifetime thrust on a propeller (all blades) resulting from propeller/ice interaction. The direction of the thrust is the propeller shaft direction acting in the direction of hydrodynamic thrust.	Is used for estimation of the response thrust T_r . T_f can be used as an estimate of excitation for axial vibration calculations. However, axial vibration calculations are not required by the rules.
Q_{max}	The maximum ice-induced torque resulting from propeller/ice interaction on one propeller blade, including hydrodynamic loads on that blade.	Is used for estimation of the response torque (Q_r) along the propulsion shaft line and as excitation for torsional vibration calculations.
F_{ex}	Ultimate blade load resulting from blade loss through plastic bending. The force that is needed to cause total failure of the blade so that a plastic hinge appears in the root area. The force is acting on 0.8 R. Spindle arm is to be taken as 2/3 of the distance between the axis of blade rotation and leading/trailing edge (whichever is the greater) at the 0.8R radius.	Blade failure load is used to dimension the blade bolts, pitch control mechanism, propeller shaft, propeller shaft bearing and trust bearing. The objective is to guarantee that total propeller blade failure should not lead to damage to other components.
Q_r	Maximum response torque along the propeller shaft line, taking into account of the dynamic behaviour of the shaft line for ice excitation (torsional vibration) and the hydrodynamic mean torque on the propeller.	Design torque for propeller shaft line components.
T_r	Maximum response thrust along the shaft line, taking into account of the dynamic behaviour of the shaft line for ice excitation (axial vibration) and the hydrodynamic mean thrust on the propeller.	Design thrust for propeller shaft line components.
F_{ti}	Maximum response force caused by ice block impacts on the thruster body or the propeller hub.	Design load for thruster body and slewing bearings.
F_{tr}	Maximum response force on the thruster body caused by ice ridge/thruster body interaction.	Design load for thruster body and slewing bearings.

Table 19.2 Types of operation for different ice classes

Ice class	Operation of the ship
ICE-B4	Operation in ice channels and in level ice The ship may proceed by ramming
ICE-B3, ICE-B2, ICE-B1	Operation in ice channels

4. Materials

4.1 Materials exposed to sea water

The materials of components exposed to sea water, such as propeller blades, propeller hubs, and thruster body, are to have an elongation of no less than 15% in a test specimen, the gauge length of which is five times the diameter. A Charpy V impact test is to be carried out for materials other than bronze and austenitic steel. An average impact energy value of 20 J based on three tests must be obtained at minus 10 °C. For nodular cast iron, average impact energy of 10 J at minus 10 °C is required accordingly.

4.2 Materials exposed to sea water temperature

Materials exposed to sea water temperature are to be made of steel or another ductile material and shall comply with Rules for Material. An average impact energy value of 20 J based on three tests must be obtained if no higher values are required in the Rules for Materials at minus 10 °C. This requirement applies to the propeller shaft, blade bolts, CP mechanisms, shaft bolts, strut-pod connecting bolts etc. It does not apply to surface hardened components, such as bearings and gear teeth. The nodular cast iron of a ferrite structure type may be used for relevant parts other than bolts. The average impact energy for nodular cast iron shall be a minimum of 10 J at minus 10 °C.

5. Design loads

The given loads are intended for component strength calculations only and are total loads including ice-

induced loads and hydrodynamic loads, during propeller/ice interaction. The presented maximum loads are based on a worst case scenario that occurs once during the service life of the ship. Thus, the load level for a higher number of loads is lower.

The values of the parameters in the formulae given in this section are provided in the units shown in the symbol list in item 2.

If the highest point of the propeller is not at a depth of at least h_i below the water surface when the ship is in ballast condition, the propulsion system is to be designed according to ICE-B3 for ice classes ICE-B2 and ICE-B1.

Note: In any case, where scantling dimensions prescribed in this section are less than those specified for ships without ice classes, the latter is to be used.

Table 19.3 Thickness of design ice block

	ICE-B4	ICE-B3	ICE-B2	ICE-B1
Thickness of the design maximum ice block entering the propeller (H_{ice})	1.75 m	1.5 m	1.2 m	1.0 m

5.1 Design loads on propeller blades

F_b is the maximum force experienced during the lifetime of a ship that bends a propeller blade backwards when the propeller mills an ice block while rotating ahead.

F_f is the maximum force experienced during the lifetime of a ship that bends a propeller blade forwards when the propeller mills an ice block while rotating ahead.

F_b and F_f originate from different propeller/ice interaction phenomena, and do not occur simultaneously. Hence, they are to be applied to one blade separately.

5.1.1 Maximum backward blade force F_b for open propellers

$$F_b = 27 \cdot [n \cdot D]^{0,7} \cdot \left[\frac{EAR}{Z} \right]^{0,3} \cdot D^2 \text{ [kN]}$$

when $D \leq D_{\text{limit}}$

$$F_b = 23 \cdot [n \cdot D]^{0,7} \cdot \left[\frac{EAR}{Z} \right]^{0,3} \cdot D \cdot H_{\text{ice}}^{1,4} \text{ [kN]}$$

when $D \geq D_{\text{limit}}$

where

$$D_{\text{limit}} = 0,85 \cdot H_{\text{ice}}^{1,4} \text{ [m]}$$

n is the nominal rotational speed (at MCR in free running condition) of a CP propeller and 85% of the nominal rotational speed (at MCR in free running condition) of an FP propeller.

5.1.2 Maximum forward blade force F_f for open propellers

$$F_f = 250 \cdot \left[\frac{EAR}{Z} \right] \cdot D^2 \text{ [kN]}$$

when $D \leq D_{\text{limit}}$

$$F_f = 500 \cdot \left[\frac{EAR}{Z} \right] \cdot D \cdot \frac{1}{\left(1 - \frac{d}{D}\right)} \cdot H_{\text{ice}} \text{ [kN]}$$

when $D \geq D_{\text{limit}}$

where

$$D_{\text{limit}} = \frac{2}{\left(1 - \frac{d}{D}\right)} \cdot H_{\text{ice}} \text{ [m]}$$

5.1.3 Loaded area on the blade for open propellers

Load cases 1-4 must be covered, as given in Table 19.4 below, for CP and FP propellers. To obtain blade ice loads for a reversing propeller, load case 5 must also be covered for FP propellers.

5.1.4 Maximum backward blade ice force F_b for ducted propellers

$$F_b = 9,5 \cdot [n \cdot D]^{0,7} \cdot \left[\frac{EAR}{Z} \right]^{0,3} \cdot D^2 \text{ [kN]}$$

when $D \leq D_{\text{limit}}$

$$F_b = 66 \cdot [n \cdot D]^{0,7} \cdot \left[\frac{EAR}{Z} \right]^{0,3} \cdot D^{0,6} \cdot H_{\text{ice}}^{1,4} \text{ [kN]}$$

when $D \geq D_{\text{limit}}$

where

$$D_{\text{limit}} = 4 \cdot H_{\text{ice}} \text{ [m]}$$

n is the nominal rotational speed (at MCR in free running condition) of a CP propeller and 85% of the nominal rotational speed (at MCR in free running condition) of an FP propeller.

5.1.5 Maximum forward blade ice force F_f for ducted propellers

$$F_f = 250 \cdot \left[\frac{EAR}{Z} \right] \cdot D^2 \text{ [kN]}$$

when $D \leq D_{\text{limit}}$

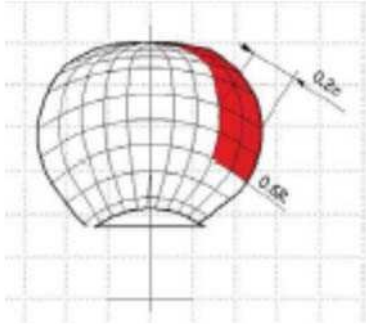
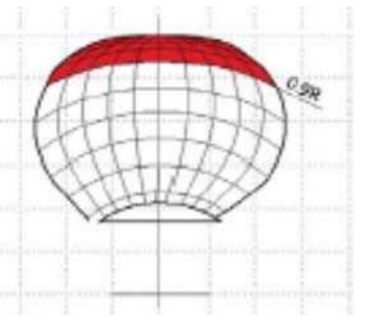
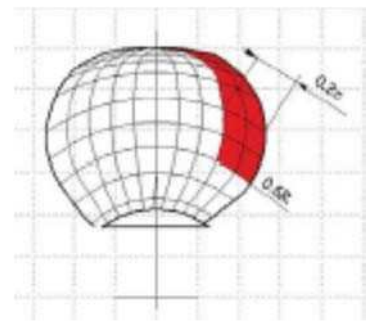
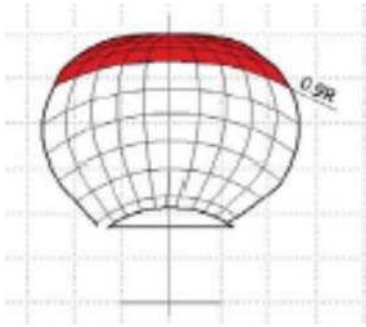
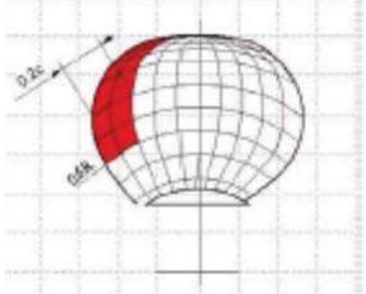
$$F_f = 500 \cdot \left[\frac{EAR}{Z} \right] \cdot D \cdot \frac{1}{\left(1 - \frac{d}{D}\right)} \cdot H_{\text{ice}} \text{ [kN]}$$

when $D \geq D_{\text{limit}}$

where

$$D_{\text{limit}} = \frac{2}{\left(1 - \frac{d}{D}\right)} \cdot H_{\text{ice}} \text{ [m]}$$

Table 19.4. Load cases for open propellers

	Force	Loaded area	Right-handed propeller blade seen from behind
Load case 1	F_b	Uniform pressure applied on the blade back (suction side) to an area from $0.6R$ to the tip and from the leading edge to 0.2 times the chord length.	
Load case 2	50% of F_b	Uniform pressure applied on the blade back (suction side) on the blade tip area outside $0.9R$ radius.	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from $0.6R$ to the tip and from the leading edge to 0.2 times the chord length.	
Load case 4	50% of F_f	Uniform pressure applied on the blade face (pressure side) of the blade tip area outside $0.9R$ radius.	
Load case 5	60% of F_f of F_b , whichever is greater	Uniform pressure applied on the blade face (pressure side) to an area from $0.6R$ to the tip and from the trailing edge to 0.2 times the chord length.	

5.1.6 Loaded area on the blade for ducted propellers

Load cases 1 and 3 have to be covered as given in Table 19.5 for all propellers, and an additional load case (load case 5) for an FP propeller, to cover ice loads when the propeller is reversed.

5.1.7 Maximum blade spindle torque Q_{smax} for open and ducted propellers

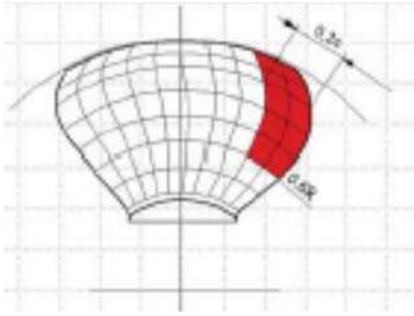
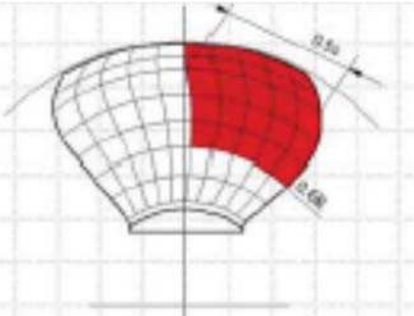
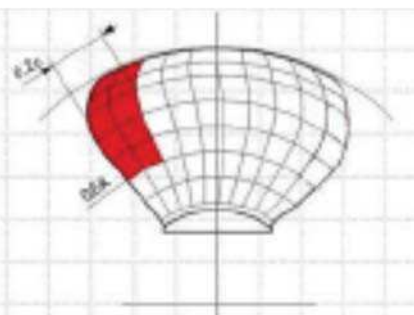
The spindle torque Q_{smax} around the axis of the blade fitting is to be determined both for the maximum

backward blade force F_b and forward blade force F_f , which are applied as in Table 19.4 and Table 19.5. The larger of the obtained torques is used as the dimensioning torque. If the above method gives a value which is less than the default value given by the formula below, the default value is to be used.

$$Q_{smax} = 0.25 \cdot F \cdot c_{0.7} \text{ [kNm]}$$

where $c_{0.7}$ is the length of the blade section at 0.7R radius and F is either F_b or F_f , whichever has the greater absolute value.

Table 19.5 Load cases for ducted propellers

	Force	Loaded area	Right-handed propeller blade seen from behind
Load case 1	F_b	Uniform pressure applied on the blade back (suction side) to an area from 0.6R to the tip and from the leading edge to 0.2 times the chord length.	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6R to the tip and from the leading edge to 0.5 times the chord length.	
Load case 5	60% of F_f or F_b , whichever is greater	Uniform pressure applied on the face (pressure side) to an area from 0.6R to the tip and from blade the trailing edge to 0.2 times the chord length.	

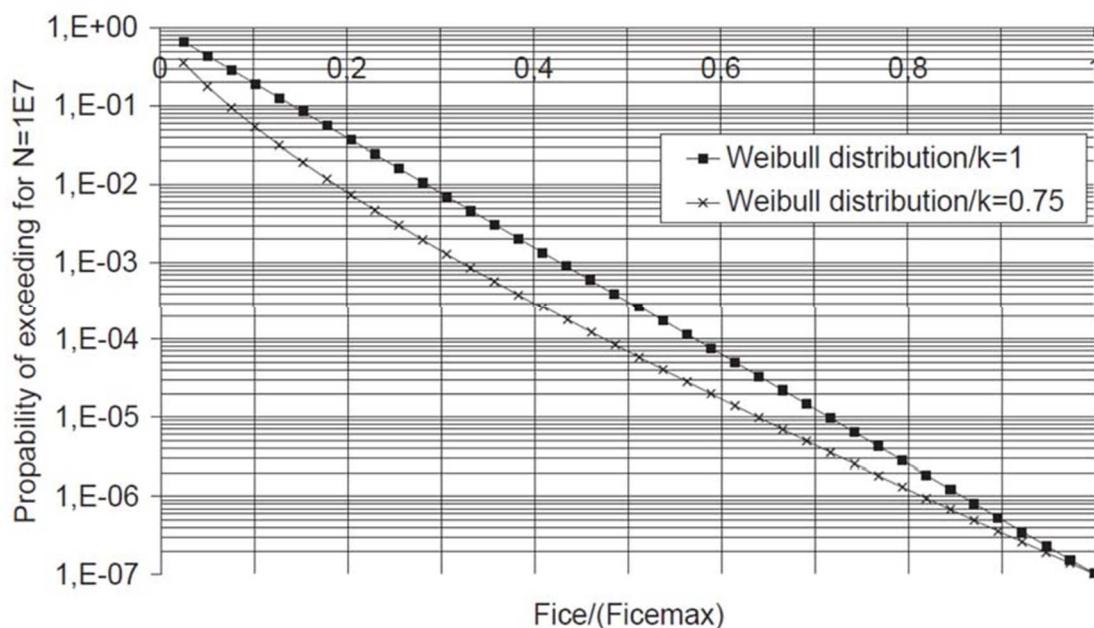


Figure 19.2 The Weibull-type distribution (probability that F_{ice} exceeds $(F_{ice})_{max}$) that is used for fatigue design.

5.1.8 Load distributions for blade loads

The Weibull-type distribution (probability that F_{ice} exceeds $(F_{ice})_{max}$), as given in Figure 19.2, is used for the fatigue design of the blade.

$$P\left(\frac{F_{ice}}{(F_{ice})_{max}} \leq \frac{F}{(F_{ice})_{max}}\right) = \exp\left(-\left(\frac{F}{(F_{ice})_{max}}\right)^k \ln(N_{ice})\right)$$

where k is the shape parameter of the spectrum, N_{ice} is the number of load cycles in the spectrum, and F_{ice} is the random variable for ice loads on the blade, $0 \leq F_{ice} \leq (F_{ice})_{max}$. The shape parameter $k=0.75$ is to be used for the ice force distribution of an open propeller and the shape parameter $k=1.0$ for that of a ducted propeller blade.

5.1.9 Number of ice loads

The number of load cycles per propeller blade in the load spectrum is to be determined according to the formula:

$$N_{ice} = k_1 \cdot k_2 \cdot k_3 \cdot N_{class} \cdot n_n$$

where the values for N_{class} are given in Table 19.6 and the propeller location factor k_1 in Table 19.7.

Table 19.6 Values of N_{class}

Ice Class	ICE-B4	ICE-B3	ICE-B2	ICE-B1
Impacts in life/ n_n	$9 \cdot 10^6$	$6 \cdot 10^6$	$3,4 \cdot 10^6$	$2,1 \cdot 10^6$

Table 19.7 Values of the propeller location factor k_1

	Center propeller Bow first operation	Wing Propeller Bow first operation	Pulling propeller (wing and centre) Bow propeller or Stern first operation
k_1	1	2	3

The submersion factor k_2 is determined from the equation

$$k_2 = \begin{cases} 0,8 - f & \text{when } f < 0 \\ 0,8 - 0,4 f & \text{when } 0 \leq f \leq 1 \\ 0,6 - 0,2 f & \text{when } 1 < f \leq 2,5 \\ 0,1 & \text{when } f > 2,5 \end{cases}$$

where the immersion function f is

$$f = \frac{h_0 - H_{ice}}{D/2} - 1$$

h_0 = Depth of the propeller centreline at the lower ice waterline (LIWL) of the ship.

The propulsion machinery type factor k_3 is 1 for fixed propulsors and 1,2 for azimuthing propulsors.

For components that are subject to loads resulting from propeller/ice interaction with all the propeller blades, the number of load cycles (N_{ice}) must be multiplied by the number of propeller blades (Z).

5.2 Axial design loads for open and ducted propellers

5.2.1 Maximum ice thrust on propeller T_f and T_b for open and ducted propellers

The maximum forward and backward ice thrusts are :

$$T_f = 1,1 F_f \text{ [kN]}$$

$$T_b = 1,1 F_b \text{ [kN]}$$

5.2.2 Design thrust along the propulsion shaft line for open and ducted propellers

The design thrust along the propeller shaft line must be calculated using the formulae below. The greater value of the forward and backward direction loads are to be taken as the design load for both directions. Factors 2,2 and 1,5 take account of the dynamic magnification resulting from axial vibration.

In a forward direction

$$T_r = T + 2,2 \cdot T_f \text{ [kN]}$$

In a backward direction

$$T_r = 1,5 \cdot T_b \text{ [kN]}$$

If the hydrodynamic bollard thrust, T , is not known, it must be taken as given in Table 19.8.

Table 19.8 Default values for hydrodynamic bollard thrust, T

Propeller type	T
CP propellers (open)	$1,25 T_n$
CP propellers (ducted)	$1,1 T_n$
FP propellers driven by turbine or electric motor	T_n
FP propellers driven by diesel engine (open)	$0,85 T_n$
FP propellers driven by diesel engine (ducted)	$0,75 T_n$

Here T_n is the nominal rotational thrust at MCR in the free running open water condition.

5.3 Torsional design loads

5.3.1 Design ice torque on propeller Q_{max} for open propellers

Note: Refer to item 5.3.6 for alternative determination of Q_{max} where detailed data is not available.

Q_{max} is the maximum torque on a propeller resulting from ice/propeller interaction during the service life of the ship.

$$Q_{max} = 10,9 \cdot \left[1 - \frac{d}{D} \right] \cdot \left[\frac{P_{0,7}}{D} \right]^{0,16} \cdot (nD)^{0,17} \cdot D^3 \text{ [kNm]}$$

when $D \leq D_{limit}$

$$Q_{max} = 20,7 \cdot \left[1 - \frac{d}{D} \right] \cdot \left[\frac{P_{0,7}}{D} \right]^{0,16} \cdot (nD)^{0,17} \cdot D^{1,9} \cdot H_{ice}^{1,1} \text{ [kNm]}$$

when $D > D_{limit}$

Where;

$$D_{limit} = 1,8 H_{ice} \text{ [m]}.$$

n is the rotational propeller speed at MCR in bollard condition. If unknown, n must be attributed a value in accordance with Table 19.9

Table 19.9 Default rotational propeller speed at MCR in bollard condition

Propeller type	n
CP propellers (open)	n_n
FP propellers driven by turbine or electric motor	n_n
FP propellers driven by diesel engine	$0,85 n_n$

Here n_n is the nominal rotational speed at MCR in the free running open water condition.

For CP propellers, the propeller pitch, $P_{0.7}$ is to correspond to MCR in bollard condition. If not known, $P_{0.7}$ is to have a value equal to $0.7P_{0.7n}$, where $P_{0.7n}$ is the propeller pitch at MCR in free running condition.

5.3.2 Design ice torque on propeller Q_{max} for ducted propellers

Note: Refer to item 5.3.6 for alternative determination of Q_{max} where detailed data is not available.

Q_{max} is the maximum torque on a propeller during the service life of the ship resulting from ice/propeller interaction.

$$Q_{max} = 7.7 \cdot \left[1 - \frac{d}{D} \right] \cdot \left[\frac{P_{0.7}}{D} \right]^{0.16} \cdot (nD)^{0.17} \cdot D^3 \quad [\text{kNm}]$$

when $D \leq D_{limit}$

$$Q_{max} = 14.6 \cdot \left[1 - \frac{d}{D} \right] \cdot \left[\frac{P_{0.7}}{D} \right]^{0.16} \cdot (nD)^{0.17} \cdot D^{1.9} \cdot H_{ice}^{1.1} \quad [\text{kNm}]$$

when $D > D_{limit}$

where

$$D_{limit} = 1.8 H_{ice} \quad [\text{m}].$$

n is the rotational propeller speed at MCR in bollard condition. If not known, n is to have a value according to Table 19.9.

For CP propellers, the propeller pitch, $P_{0.7}$ is to correspond to MCR in bollard condition. If not known, $P_{0.7}$ is to have a value equal to $0.7P_{0.7n}$, where $P_{0.7n}$ is the propeller pitch at MCR in free running condition.

5.3.3 Design torque for non-resonant shaft lines

If there is no relevant first blade order torsional resonance in the operational speed range or in the range 20% above and 20% below the maximum operating speed (bollard condition), the following estimation of the maximum torque can be used.

Directly coupled two stroke diesel engines without flexible coupling

$$Q_{peak} = Q_{emax} + Q_{vib} + Q_{max} I_e / I_t \quad [\text{kNm}]$$

and other plants

$$Q_{peak} = Q_{emax} + Q_{max} I_e / I_t \quad [\text{kNm}],$$

where

I_e is the equivalent mass moment of inertia of all parts on the engine side of the component under consideration and

I_t is the equivalent mass moment of inertia of the whole propulsion system.

All the torques and the inertia moments shall be reduced to the rotation speed of the component being examined.

If the maximum torque, Q_{emax} , is unknown, it shall be accorded the value given in Table 19.10.

Table 19.10 Default values for prime mover maximum torque Q_{emax}

Propeller type	Q_{emax}
Propellers driven by electric motor	$*Q_{motor}$
CP propellers not driven by electric motor	Q_n
FP propellers driven by turbine	Q_n
FP propellers driven by diesel engine	$0.75 Q_n$

Here $*Q_{motor}$ is the electric motor peak torque.

5.3.4 Design torque for shaft lines having resonances

If there is first blade order torsional resonance in the operational speed range or in the range 20% above and

20% below the maximum operating speed (bollard condition), the design torque (Q_{peak}) of the shaft component shall be determined by means of torsional vibration analysis of the propulsion line. There are two alternative ways of performing the dynamic analysis.

1. Time domain calculation for estimated milling sequence excitation
2. Frequency domain calculation for blade orders sinusoidal excitation.

The frequency domain analysis is generally considered conservative compared to the time domain simulation, provided that there is a first blade order resonance in the considered speed range.

5.3.4.1 Time domain calculation of torsional response

Time domain calculations shall be calculated for the MCR condition, MCR bollard conditions and for blade order resonant rotational speeds so that the resonant vibration responses can be obtained.

The load sequence given in this section, for a case where a propeller is milling an ice block, shall be used for the strength evaluation of the propulsion line. The given load sequence is not intended for propulsion system stalling analyses.

The following load cases are intended to reflect the operational loads on the propulsion system, when the propeller interacts with ice, and the respective reaction of the complete system. The ice impact and system response causes loads in the individual shaft line components. The ice torque Q_{max} may be taken as a constant value in the complete speed range. When considerations at specific shaft speeds are performed, a relevant Q_{max} may be calculated using the relevant speed according to item 5.3.

Diesel engine plants without an elastic coupling shall be calculated at the least favourable phase angle for ice versus engine excitation, when calculated in the time domain. The engine firing pulses shall be included in the calculations and their standard steady state harmonics can be used.

If there is a blade order resonance just above the MCR speed, calculations shall cover rotational speeds up to 105 % of the MCR speed.

The propeller ice torque excitation for shaft line transient dynamic analysis in the time domain is defined as a sequence of blade impacts which are of half sine shape. The excitation frequency shall follow the propeller rotational speed during the ice interaction sequence. The torque due to a single blade ice impact as a function of the propeller rotation angle is then defined using the formula:

$$Q(\phi) = C_q Q_{max} \sin(\phi(180/\alpha_i))$$

when ϕ rotates from 0 to α_i plus integer revolutions

$$Q(\phi) = 0,$$

when ϕ rotates from α_i to 360 plus integer revolutions,

where

ϕ is the rotation angle from when the first impact occurs and parameters C_q and α_i are given in Table 19.11.

α_i is the duration of propeller blade/ice interaction expressed in terms of the propeller rotation angle. See Figure 19.3.

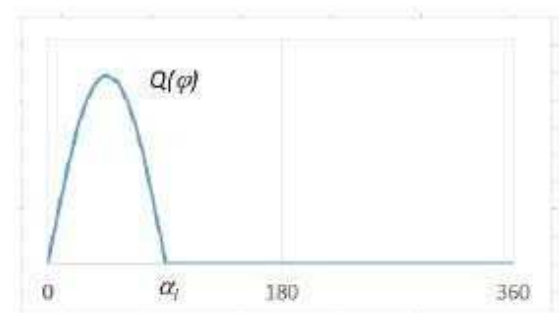


Figure 19.3 Schematic ice torque due to a single blade ice impact as a function of the propeller rotation angle

Table 19.11 Ice impact magnification and duration factors for different blade numbers

Torque excitation	Propeller / ice interaction	C _q	α _i [deg]			
			Z=3	Z=4	Z=5	Z=6
Excitation case 1	Single ice block	0,75	90	90	72	60
Excitation case 2	Single ice block	1,0	135	135	135	135
Excitation case 3	Two ice blocks (phase shift 360 / (2·Z) deg.	0,5	45	45	36	30
Excitation case 4	Single ice block	0,5	45	45	36	30

The total ice torque is obtained by summing the torque of single blades, while taking account of the phase shift 360 deg./Z, see Figure 19.4. At the beginning and end of the milling sequence (within the calculated duration) linear ramp functions shall be used to increase C_q to its maximum value within one propeller revolution and vice versa to decrease it to zero (see the examples of different Z numbers in Figure 19.4).

The number of propeller revolutions during a milling sequence shall be obtained from the formula:

$$N_Q = 2 H_{ice}$$

The number of impacts is Z·N_Q for blade order excitation. An illustration of all excitation cases for different numbers of blades is given in Figure 19.4.

A dynamic simulation must be performed for all excitation cases at the operational rotational speed range. For a fixed pitch propeller propulsion plant, a dynamic simulation must also cover the bollard pull condition with a corresponding rotational speed assuming the maximum possible output of the engine.

If a speed drop occurs until the main engine is at a standstill, this indicates that the engine may not be sufficiently powered for the intended service task. For the consideration of loads, the maximum occurring torque during the speed drop process must be used.

For the time domain calculation, the simulated response torque typically includes the engine mean torque and the propeller mean torque. If this is not the case, the

response torques must be obtained using the formula:

$$Q_{peak} = Q_{max} + Q_{rtd}$$

where Q_{rtd} is the maximum simulated torque obtained from the time domain analysis.

5.3.4.2 Frequency domain calculation of torsional response

For frequency domain calculations, blade order and twice-the-blade-order excitation may be used. The amplitudes for the blade order and twice-the-blade-order sinusoidal excitation have been derived based on the assumption that the time domain half sine impact sequences were continuous, and the Fourier series components for blade order and twice-the-blade-order components have been derived. The propeller ice torque is then:

$$Q_F(\varphi) = Q_{max} (C_{q0} + C_{q1} \sin(ZE_0\varphi + t_1) + C_{q2} \sin(2ZE_0\varphi + t_2)) \quad [\text{kNm}]$$

where

C_{q0} is mean torque parameter

C_{q1} is the first blade order excitation parameter

C_{q2} is the second blade order excitation parameter

α₁, α₂ are phase angles of the excitation component

φ is the angle of rotation

E₀ is the number of ice blocks in contact

The values of the parameters are given in Table 19.12

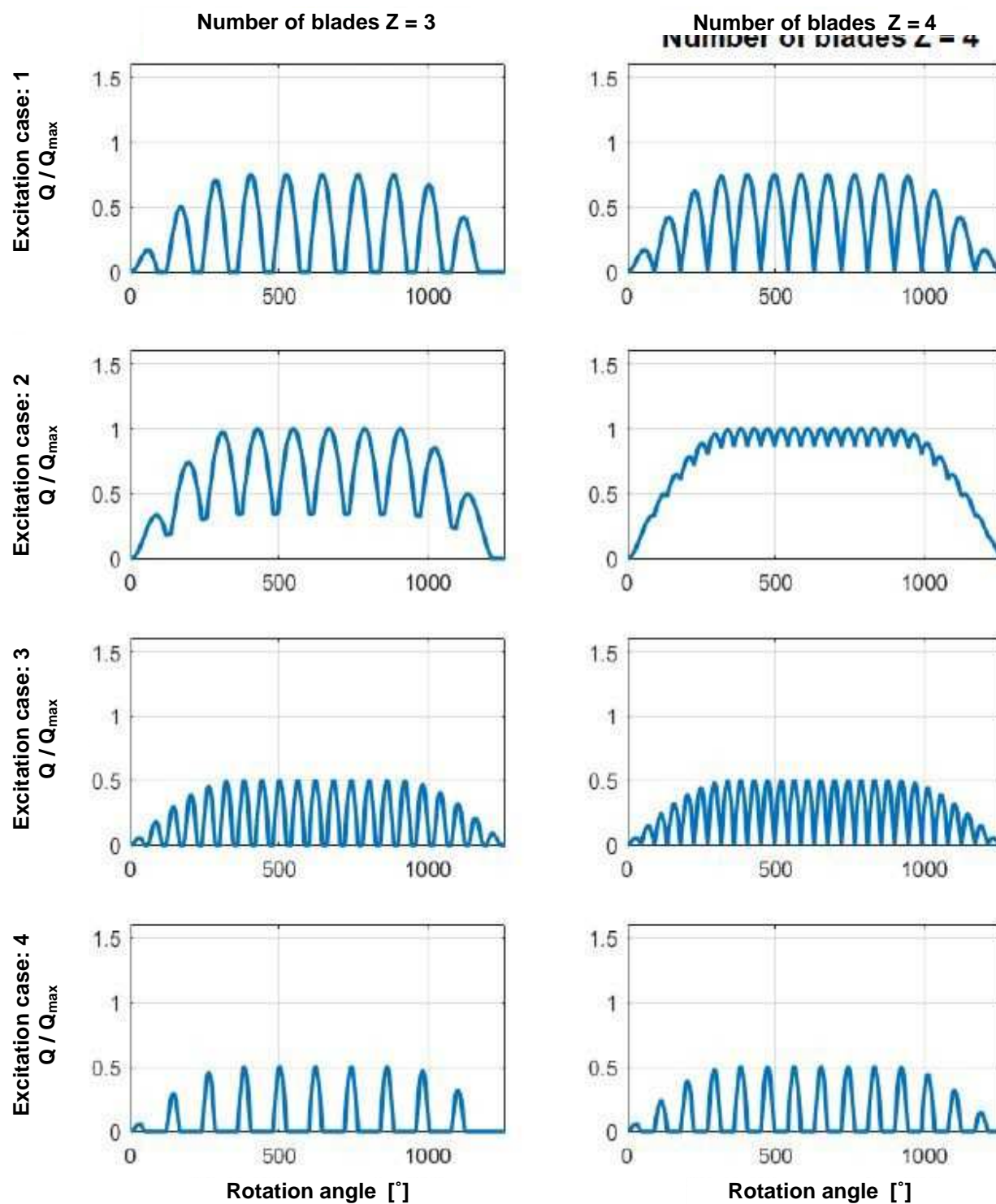


Figure 19.4 The shape of the propeller ice torque excitation sequences for propellers with 3, 4, 5 or 6 blades

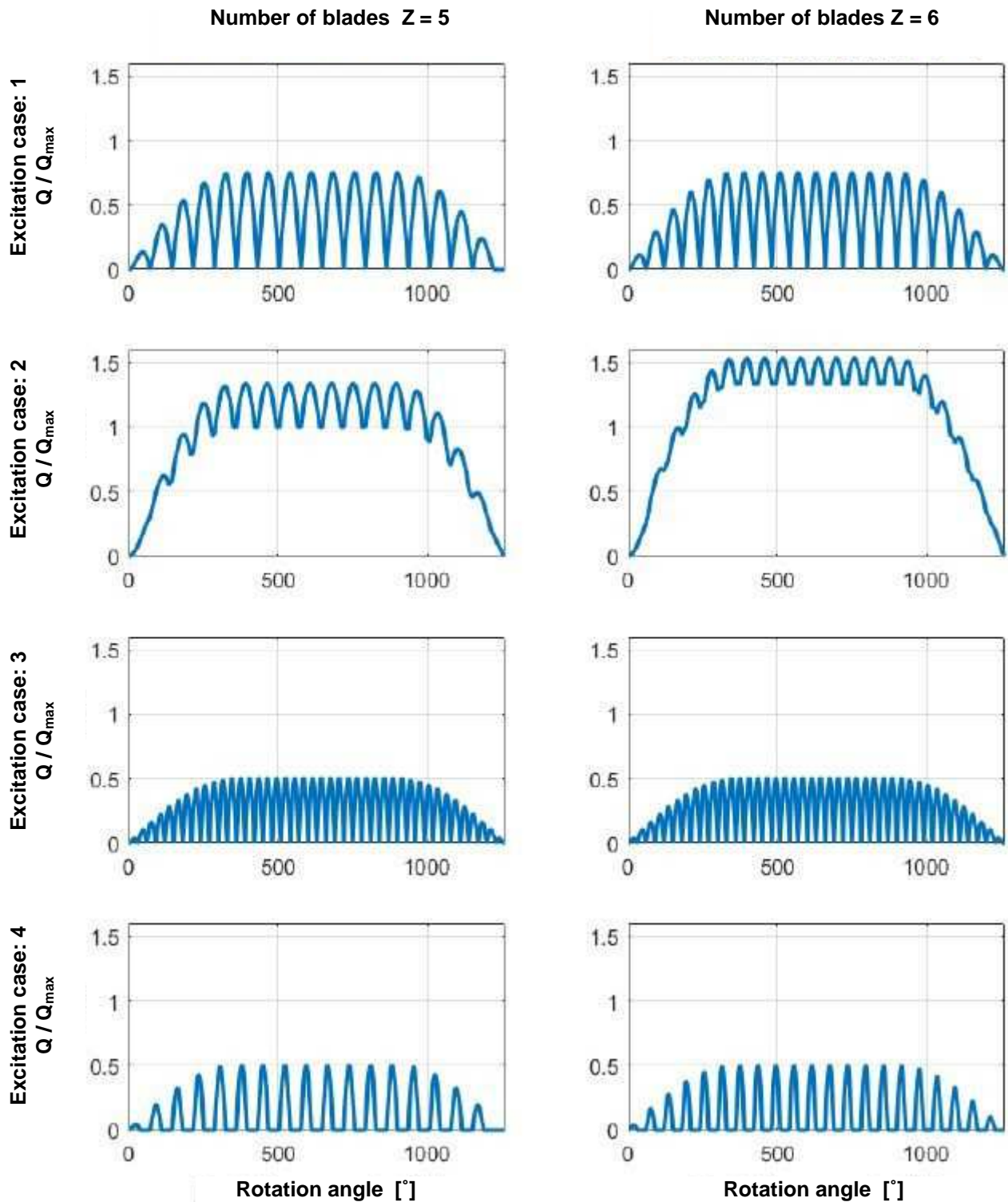


Figure 19.4 The shape of the propeller ice torque excitation sequences for propellers with 3, 4, 5 or 6 blades (cont.)

Table 19.12 Coefficient values for frequency domain excitation calculation

	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Torque excitation (Z=3)						
Excitation case 1	0,375	0,36	-90	0	0	1
Excitation case 2	0,7	0,33	-90	0,05	-45	1
Excitation case 3	0,25	0,25	-90	0	0	2
Excitation case 4	0,2	0,25	0	0,05	-90	1
Torque excitation (Z=4)						
Excitation case 1	0,45	0,36	-90	0,06	-90	1
Excitation case 2	0,9375	0	-90	0,0625	-90	1
Excitation case 3	0,25	0,25	-90	0	0	2
Excitation case 4	0,2	0,25	0	0,05	-90	1
Torque excitation (Z=5)						
Excitation case 1	0,45	0,36	-90	0,06	-90	1
Excitation case 2	1,19	0,17	-90	0,02	-90	1
Excitation case 3	0,3	0,25	-90	0,048	-90	2
Excitation case 4	0,2	0,25	0	0,05	-90	1
Torque excitation (Z=6)						
Excitation case 1	0,45	0,36	-90	0,05	-90	1
Excitation case 2	1,435	0,1	-90	0	0	1
Excitation case 3	0,3	0,25	-90	0,048	-90	2
Excitation case 4	0,2	0,25	0	0,05	-90	1

The design torque for the frequency domain excitation case must be obtained using the formula:

$$Q_{\text{peak}} = Q_{\text{emax}} + Q_{\text{vib}} + (Q_{\text{nmax}} C_{q0}) I_e / I_t + Q_{\text{rf1}} + Q_{\text{rf2}}$$

where

- Q_{nmax} is the maximum propeller ice torque at the operation speed in consideration
- C_{q0} is the mean static torque coefficient from Table 19.12
- Q_{rf1} is the blade order torsional response from the frequency domain analysis
- Q_{rf2} is the second order blade torsional response from the frequency domain analysis

If the prime mover maximum torque, Q_{emax} , is not known, it shall be taken as given in Table 19.10. All the torque values have to be scaled to the shaft revolutions for the component in question.

5.3.4.3 Guidance for torsional vibration calculation

The aim of time domain torsional vibration simulations is to estimate the extreme torsional load for the ship's lifespan. The simulation model can be taken from the normal lumped mass elastic torsional vibration model, including damping. For a time domain analysis, the model should include the ice excitation at the propeller, other relevant excitations and the mean torques provided by the prime mover and hydrodynamic mean torque in the propeller. The calculations should cover variation of phase between the ice excitation and prime mover excitation. This is extremely relevant to propulsion lines with directly driven combustion engines. Time domain calculations shall be calculated for the MCR condition, MCR bollard conditions and for resonant speed, so that the resonant vibration responses can be obtained.

For frequency domain calculations, the load should be estimated as a Fourier component analysis of the continuous sequence of half sine load sequences. First and second order blade components should be used for excitation.

The calculation should cover the entire relevant rpm range and the simulation of responses at torsional vibration resonances.

5.4 Blade failure load

5.4.1 Bending force, F_{ex}

The ultimate load resulting from blade failure as a result of plastic bending around the blade root shall be calculated using formula below, or alternatively by means of an appropriate stress analysis, reflecting the non-linear plastic material behaviour of the actual blade. In such a case, the blade failure area may be outside the root section. The ultimate load is assumed to be acting on the blade at the $0.8R$ radius in the weakest direction of the blade.

A blade is regarded as having failed if the tip is bent into an offset position by more than 10% of propeller diameter D .

$$F_{ex} = \frac{300ct^2\sigma_{ref1}}{0,8D - 2r} [kN]$$

where

$$a_{ref1} = 0,6a_{0,2} + 0,4 a_u [MPa]$$

a_u (minimum ultimate tensile strength to be specified on the drawing) and

$a_{0,2}$ (minimum yield or 0.2% proof strength to be specified on the drawing) are representative values for the blade material

c , t and r are, respectively, the actual chord length, maximum thickness and radius of the cylindrical root section of the blade, which is the weakest section outside the root fillet typically located at the point where the fillet terminates at the blade profile.

5.4.2 Spindle torque, Q_{sex}

The maximum spindle torque due to a blade failure load acting at $0.8R$ shall be determined. The force that causes blade failure typically reduces when moving

from the propeller centre towards the leading and trailing edges. At a certain distance from the blade centre of rotation, the maximum spindle torque will occur. This maximum spindle torque shall be defined by an appropriate stress analysis or using the equation given below.

$$Q_{sex} = \max (C_{LE0.8} ; 0,8C_{TE0.8}) C_{spex} F_{ex} [kNm]$$

Where

$$C_{spex} = C_{sp} C_{fex} = 0,7 \left(1 - \left(\frac{4EAR}{z} \right)^3 \right)$$

C_{sp} is a non-dimensional parameter taking account of the spindle arm

C_{fex} is a non-dimensional parameter taking account of the reduction of the blade failure force at the location of the maximum spindle torque.

If C_{spex} is below 0.3, a value of 0.3 shall be used for C_{spex} .

$C_{LE0.8}$ is the leading edge portion of the chord length at $0.8R$

$C_{TE0.8}$ is the trailing edge portion of the chord length at $0.8R$.

Figure 19.5 illustrates the spindle torque values due to blade failure loads across the entire chord length.

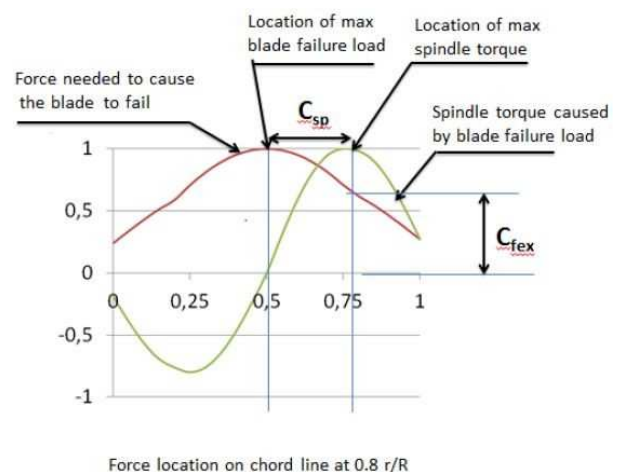


Figure 19.5 Schematic figure showing a blade failure load and the related spindle torque when the force acts at a different location on the chord line at radius $0.8R$

6. Design

6.1 Design principle

The strength of the propulsion line shall be designed according to the pyramid strength principle. This means that the loss of the propeller blade shall not cause any significant damage to other propeller shaft line components.

6.2 Propeller blade

6.2.1 Calculation of blade stresses

The blade stresses shall be calculated for the design loads given in item 5.1. Finite element analysis shall be used for stress analysis for the final approval of all propellers. The following simplified formulae can be used for estimating the blade stresses for all propellers at the root area ($r/R < 0.5$). Root area dimensions based on formula below can be accepted, even if the FEM analysis would show greater stresses at the root area.

$$\sigma_{st} = C_1 \frac{M_{BL}}{100ct^2} \quad [\text{MPa}]$$

where

constant C_1 is the actual stress/stress obtained from the beam equation. If the actual value is not available, C_1 should have a value of 1,6.

$M_{BL} = (0,75 - r/R) RF$, for relative radius $r/R < 0.5$

F is the force F_b or F_t , whichever has greater absolute value.

6.2.2 Acceptability criterion

The following criterion for calculated blade stresses has to be fulfilled:

$$\frac{\sigma_{ref2}}{\sigma_{st}} \geq 1.3$$

where;

σ_{st} is the calculated stress for the design loads. If FEM analysis is used for estimating the stresses, von Mises stresses are to be used

σ_{ref2} is the reference strength, defined as :

$$\sigma_{ref2} = 0,7 \cdot \sigma_u \text{ Or}$$

$$\sigma_{ref2} = 0,6 \cdot \sigma_{0.2} + 0,4 \cdot \sigma_u, \text{ whichever is less.}$$

6.2.3 Fatigue design of propeller blade

The fatigue design of the propeller blade is based on an estimated load distribution for the service life of the ship and the S-N curve for the blade material. An equivalent stress that produces the same fatigue damage as the expected load distribution is to be calculated and the acceptability criterion for fatigue should be fulfilled as given in item 6.2.4. The equivalent stress is normalised for 10^8 cycles.

For materials with a two-slope SN curve (Figure 19.6) fatigue calculations in accordance with this section are not required If the following criterion is fulfilled:

$$\sigma_{exp} \geq B_1 \cdot \sigma_{ref2}^{B_2} \cdot \log(N_{ice})^{B_3}$$

Where the B_1 , B_2 and B_3 coefficients for open and ducted propellers are given in the Table 19.13.

Table 19.13 Values of coefficient B_1 , B_2 and B_3

	Open propeller	Ducted propeller
B_1	0,00328	0,00223
B_2	1,0076	1,0071
B_3	2,101	2,471

For the calculation of equivalent stress, two types of S-N curves are available.

1. Two slope S-N curve (slopes 4.5 and 10), see Figure 19.6.

2. One slope S-N curve (the slope can be chosen), see Figure 19.7.

The type of the SN-curve is to be selected to correspond with the material properties of the blade. If the SN-curve is not known the two slope SN curve is to be used.

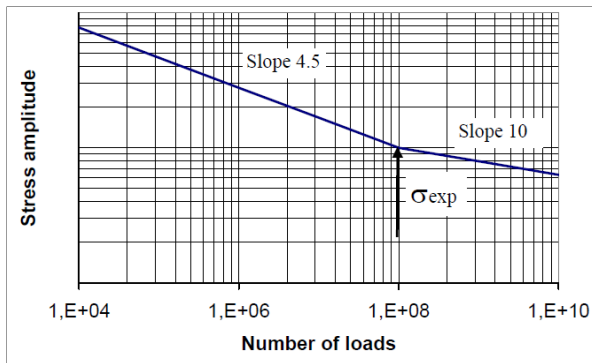


Figure 19.6 Two-slope S-N curve

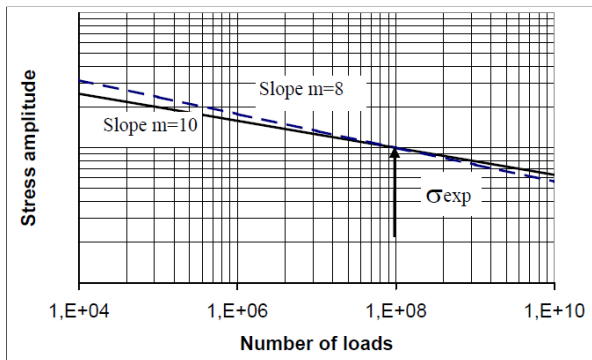


Figure 19.7 Constant-slope S-N curve

Equivalent fatigue stress

The equivalent fatigue stress for 10^8 stress cycles, which produces the same fatigue damage as the load distribution for the service life of the ship, is:

$$\sigma_{\text{fat}} = \rho \cdot (\sigma_{\text{ice}})_{\text{max}}$$

Where

$$(\sigma_{\text{ice}})_{\text{max}} = 0.5 \cdot ((\sigma_{\text{ice}})_{\text{fmax}} - (\sigma_{\text{ice}})_{\text{bmax}})$$

$(\sigma_{\text{ice}})_{\text{max}}$ = Mean value of the principal stress amplitudes resulting from design forward

and backward blade forces at the location being studied.

$(\sigma_{\text{ice}})_{\text{fmax}}$ = Principal stress resulting from forward load

$(\sigma_{\text{ice}})_{\text{bmax}}$ = Principal stress resulting from backward load

In the calculation of $(\sigma_{\text{ice}})_{\text{max}}$, case 1 and case 3 (or case 2 and case 4) are considered a pair for $(\sigma_{\text{ice}})_{\text{fmax}}$ and $(\sigma_{\text{ice}})_{\text{bmax}}$ calculations. Case 5 is excluded from the fatigue analysis.

Calculation of parameter ρ for two-slope S-N curve

The parameter ρ relates the maximum ice load to the distribution of ice loads according to the regression formulae:

$$\rho = C_1 \cdot (\sigma_{\text{e}})_{\text{max}}^{C_2} \cdot \sigma_{\text{fl}}^{C_3} \cdot \log(N_{\text{ice}})^{C_4}$$

where

$$\sigma_{\text{fl}} = \gamma_{\epsilon 1} \cdot \gamma_{\epsilon 2} \cdot \gamma_v \cdot \gamma_m \cdot \sigma_{\text{exp}}$$

where

$\gamma_{\epsilon 1}$ = Reduction factor due to scatter (equal to one standard deviation)

$\gamma_{\epsilon 2}$ = Reduction factor for test specimen size effect

γ_v = Reduction factor for variable amplitude loading

γ_m = Reduction factor for mean stress

σ_{exp} = Mean fatigue strength of the blade material at 10^8 cycles to failure in seawater.

The following values should be used for the reduction factors if actual values are not available: $\gamma_{\epsilon} = \gamma_{\epsilon 1} \gamma_{\epsilon 2} = 0,67$, $\gamma_v = 0,75$, and $\gamma_m = 0,75$.

The coefficients C_1 , C_2 , C_3 , and C_4 are given in Table 19.14.

Table 19.14 Parameters for ρ determination

	Open propeller	Ducted propeller
C_1	0,000747	0,000534
C_2	0,0645	0,0533
C_3	-0,0565	-0,0459
C_4	2,22	2,584

Calculation of parameter ρ for constant-slope S-N curve

For materials with a constant-slope S-N curve - see Figure 19.7 - the factor ρ is to be calculated from the following formula:

$$\rho = \left(G \cdot \frac{N_{ice}}{N_R} \right)^{(1/m)} \cdot (\ln(N_{ice}))^{-1/k}$$

where

k is the shape parameter of the Weibull distribution $k = 1,0$ for ducted propellers and $k=0,75$ for open propellers.

N_R is the reference number of load cycles ($=10^8$).

The applicable range of N_{ice} for calculating ρ is $5 \times 10^6 \leq N_{ice} \leq 10^8$.

Values for the parameter G are given in Table 19.15. Linear interpolation may be used to calculate the value for other m/k ratios other than those given in the Table 19.15.

6.2.4 Acceptability criterion for fatigue

The equivalent fatigue stress at all locations on the blade must fulfil the following acceptability criterion:

$$\frac{\sigma_{fl}}{\sigma_{fat}} \geq 1.5$$

$$\sigma_{fl} = \gamma_{e1} \cdot \gamma_{e2} \cdot \gamma_v \cdot \gamma_m \cdot \sigma_{exp}$$

Note: Refer to 6.2.3 for definition of symbols

6.3 Propeller bossing and CP mechanism

The blade bolts, the CP mechanism, the propeller boss, and the fitting of the propeller to the propeller shaft is to be designed to withstand the maximum and fatigue design loads, as defined in item 5. The safety factor against yielding is to be greater than 1,3 and that against fatigue greater than 1,5. In addition, the safety factor for loads resulting from loss of the propeller blade through plastic bending, as defined in item 5.4 is to be greater than 1,0 against yielding.

Table 19.15 Value of the parameter G for different m/k ratios

m/k	G	m/k	G	m/k	G
3	6	6,5	1871	10	$3,629 \cdot 10^6$
3,5	11,6	7	5040	10,5	$11,899 \cdot 10^6$
4	24	7,5	14034	11	$39,917 \cdot 10^6$
4,5	52,3	8	40320	11,5	$136,843 \cdot 10^6$
5	120	8,5	119292	12	$479,002 \cdot 10^6$
5,5	287,9	9	362880		
6	720	9,5	$1,133 \cdot 10^6$		

6.4 Propulsion shaft line

The shafts and shafting components, such as the thrust and stern tube bearings, couplings, flanges and sealings, are to be designed to withstand the propeller/ice interaction loads as given in item 5. The safety factor must be at least 1,3 against yielding for extreme operational loads, 1,5 for fatigue loads and 1,0 against yielding for the blade failure load.

6.4.1 Shafts and shafting components

The ultimate load resulting from total blade failure, as defined in item 5.4 should not cause yielding in shafts and shaft components. The loading is to consist of the combined axial, bending, and torsion loads, wherever this is significant. The minimum safety factor against yielding must be 1,0 for bending and torsional stresses.

6.5 Additional Requirements

These requirements are given in addition to those given by Finnish Swedish Ice Class Requirements.

6.5.1 Propeller mounting

Where the propeller is mounted on the propeller shaft by the oil injection method, the necessary contact pressure p_E [N/mm²] in the area of the mean taper diameter d_{mean} is to be determined by formula given below.

$$P_E = \frac{\sqrt{\theta^2 \cdot T_r^2 + f \cdot (K_r^2 + T_r^2)} - \theta \cdot T_r}{0.001 \cdot A \cdot f}$$

Where

K_r = tangential force in the contact area.

$$K_r = \frac{Q_{\text{peak}}}{\left(\frac{d_{\text{mean}}}{2}\right)^2}$$

A = Effective area of a shrink fit [mm²]

θ = Half-conicity

= $C/2$

C = Conicity of shaft ends

$$= \frac{\text{difference in taper diameter}}{\text{length of taper}}$$

d_{mean} = mean cone diameter [m]

The calculation has to be performed for T_r according to formulae given in 5.2.2 in forward and backward directions. T_r has to be introduced as positive value, if the response thrust increases the surface pressure at the taper and as negative value, if the response thrust decreases the surface pressure. The highest calculated surface pressure has to be realized as a minimum.

$$f = \left(\frac{\mu_o}{S}\right)^2 - \theta^2$$

μ_o = Coefficient of static friction

= 0,13 for hydraulic oil shrink joints

= 0,15 for dry fitted shrink joints bronze/steel

= 0,18 for dry fitted shrink joints steel/steel

The safety factor has to be at minimum $S = 2.0$, however $S \cdot Q_{\text{peak}} \geq 2,8 \cdot Q_{\text{cmax}}$ has to be ensured.

Other symbols are to be defined in accordance with item 5 and 8.

Keyed connections may be applied, provided that the peak torque Q_{peak} is transmitted via friction. Keyed connections are not permitted for ICE-B4.

6.5.2 Propulsion shafts

The plain shaft diameter [mm] at the aft end is to comply at minimum with the calculated diameter according to formula below.

$$d_{ps} = 140 \cdot \sqrt[6]{\left(F_{\text{ex}} \cdot S_{F_{\text{ex}}} \cdot \frac{D^2}{\sigma_Y}\right) + 5.6 \cdot \left(\frac{Q_r \cdot S_Q^2}{\sigma_Y}\right)} \cdot \sqrt[3]{\frac{1}{1 - \left(\frac{d_i}{d_{ps}}\right)^4}}$$

Where

d_i = inner shaft diameter [mm]

σ_y = yield strength of propeller shaft material
[MPa]

In front of the aft stern tube bearing the diameter may be reduced based on the assumption that the bending moment is linearly reduced to 20 % at the next bearing and in front of this linearly to zero at third bearing.

6.5.3 Shafts with torsional load

Where shafts are subject to torsional loads only, the plain shaft diameter can be calculated according to the equation given in 6.5.2, while $F_{ex} = 0$ and Q_r is replaced by Q_{peak} .

6.5.4 Shaft fatigue calculation

A load distribution as defined in item 5.1.8, based on Q_{max} and with at least 20 load steps Q_{max} i, has to be applied. Loads from torsional vibrations in open water conditions (refer to item 6) are to be considered.

Where bending and torsional amplitudes occur, both have to be taken into account.

The maximum bending amplitude has to be determined from F_b and F_t . A load distribution according to item 5.1.8 has to be applied.

A method for determination of an equivalent load amplitude, such as DIN 743-4, may be used.

All stress raisers have to be taken into account.

6.5.5 Shaft connections

The following safety factors have to be demonstrated:

S_{fat} = 1,5 for the range between main engine and (including) gear box,

S_Q = 1,3 for the remaining range and plants without gear box

6.5.5.1 Shrink fit

A shrink fit calculation may be performed according to formula given in item 6.5.1 including the safety factor S

= 2,0, however $S \cdot Q_{peak} \geq 2,5 \cdot Q_{e max}$ has to be ensured.

The respective axial (T_r) and torsional (Q_{peak}) loads, acting at the location of the fit, have to be applied. If no dynamic simulation has been performed, the estimation for the torque according to item 5.3.1 may be applied.

6.5.5.2 Keyed connections

Keyed connections may be applied, provided that the maximum local response torque Q_{peak} is transmitted via friction and in case of ICE-B4, an emergency repair can be performed without dry-docking.

6.5.5.3 Flange connections

Section 5, C.5 is to be applied accordingly.

- Any additional stress raisers such as recesses for bolt heads shall not interfere with the flange fillet.
- The flange fillet radius is to be at least 10 % of the shaft diameter.
- The diameter of ream fitted (light press fit) bolts shall be chosen so that the peak torque Q_{peak} (refer to item 5.3.5) does not cause shear stresses beyond the yield strength of the bolt material with a safety factor of $S_Q = 1.3$.
- The bolts are to be designed so that blade failure load F_{ex} (see C.5.4) in any direction (forward or backwards) does not cause yielding of bolts or flange opening.

Flanged propellers and the hubs of controllable pitch propellers are to be attached by means of fitted pins and retaining bolts (preferably necked down bolts).

The required diameter [mm] d_{pin} of the fitted pin is to be determined by applying formula below.

$$d_{pin} = \left(\frac{4489 \cdot Q_{peak} \cdot S_Q}{PCD_{pin} \cdot n_{pin} \cdot \sigma_Y} \right)^{0.5}$$

Where

d_{pin} = Root diameter of propeller shear pin [mm]

PCD_{pin} = Pitch circle diameter of propeller shear pins [m]

n_{pin} = Number of propeller shear pins

σ_Y = Yield strength of shear pin material [MPa]

The thread core diameter d_{bolt} (mm) of propeller flange bolts shall not be less than given below.

$$d^{bolt} = \left(\frac{1681 \cdot S_{Fe} \cdot F_{ex}}{n_{bolt} \cdot \sigma_y} \cdot \left(\frac{0.8 \cdot D}{PCD^{bolt}} + 1 \right) \cdot \alpha_A \right)^{0.5}$$

Where

PCD_{bolt} = Pitch circle diameter of bolts [m]

n_{bolt} = Number of bolts

α_A = Tightening factor for retaining bolts depending on the method of tightening used (see VDI 2230 or equivalent standards). Guidance values:

= 1.2 for angle control

= 1.3 for bolt elongation control

= 1.6 for torque control

σ_Y = yield strength of bolt material [MPa]

6.6 Azimuthing main propulsors

6.6.1 Design principle

In addition to the above requirements for propeller blade dimensioning, azimuthing thrusters must be designed for thruster body/ice interaction loads. Load formulae are given for estimating once in a lifetime extreme loads

on the thruster body, based on the estimated ice condition and ship operational parameters. Two main ice load scenarios have been selected for defining the extreme ice loads. Examples of loads are illustrated in Figure 19.8. In addition, blade order thruster body vibration responses may be estimated for propeller excitation. The following load scenario types are considered:

1. Ice block impact on the thruster body or propeller hub
2. Thruster penetration into an ice ridge that has a thick consolidated layer
3. Vibratory response of the thruster at blade order frequency

The steering mechanism, the fitting of the unit, and the

body of the thruster shall be designed to withstand the plastic bending of a blade without damage. The loss of a blade must be taken into account for the propeller blade orientation causing the maximum load on the component being studied. Top-down blade orientation typically places the maximum bending loads on the thruster body.

6.6.2 Extreme ice impact loads

When the ship is operated in ice conditions, ice blocks formed in channel side walls or from the ridge consolidated layer may impact on the thruster body and the propeller hub. Exposure to ice impact is very much dependent on the ship size and ship hull design, as well as the location of the thruster. The contact force will grow in terms of thruster/ice contact until the ice block reaches the ship speed.

The thruster must withstand the loads occurring when the design ice block defined in Table 19.3 impacts on the thruster body when the ship is sailing at a typical ice operating speed. Load cases for impact loads are given in Table 19.16. The contact geometry is estimated to be hemi-spherical in shape. If the actual contact geometry differs from the shape of the hemisphere, a sphere radius must be estimated so that the growth of the contact area as a function of penetration of ice corresponds as closely as possible to the actual geometrical shape penetration.

Table 19.16 Load cases for azimuthing thruster ice impact loads

	Force	Loaded are	
Load case T1a Symmetric longitudinal ice impact on thruster	F_{ti}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area.	
Load case T1b Non-symmetric longitudinal ice impact on thruster	50% of F_{ti}	Uniform distributed load or uniform pressure, which are applied on the other half of the impact area.	
Load case T1c Non-symmetric longitudinal ice impact on nozzle	F_{ti}	Uniform distributed load or uniform pressure, which are applied on the impact area. Contact area is equal to the nozzle thickness (H_{nz})*the contact height (H_{ice}).	
Load case T2a Symmetric longitudinal ice impact on propeller hub	F_{ti}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area.	
Load case T2b Non-symmetric longitudinal ice impact on propeller hub	50% of F_{ti}	Uniform distributed load or uniform pressure, which are applied on the other half of the impact area.	

Table 19.16 Load cases for azimuthing thruster ice impact loads (cont.)

	Force	Loaded area	
Load case T3a Symmetric lateral ice impact on thruster body	F_{ti}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area.	
Load case T3b Non-symmetric lateral ice impact on thruster body or nozzle	F_{ti}	Uniform distributed load or uniform pressure, which are applied on the impact area. Nozzle contact radius R to be taken from the nozzle length (L_{nz}).	

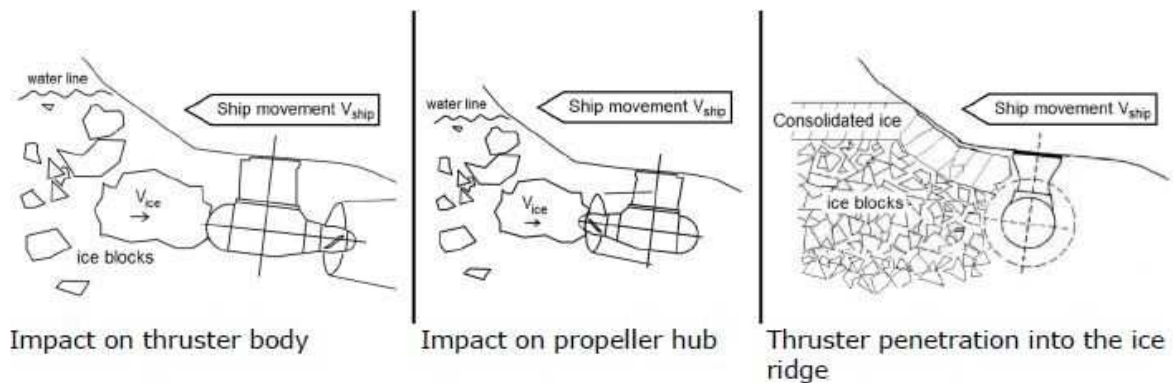


Figure 19.8 Examples of load scenario types

Table 19.17 Parameter values for ice dimensions and dynamic magnification

	ICE-B4	ICE-B3	ICE-B2	ICE-B1
Thickness of the design ice block impacting thruster (2/3 of H_{ice})	1,17 m	1,0 m	0,8 m	0,67 m
Extreme ice block mass (m_{ice})	8670 kg	5460 kg	2800 kg	1600 kg
C_{DMI} (if not known)	1,3	1,2	1,1	1,0

Table 19.18 Impact speeds for aft centerline thruster

Aft centerline thruster	ICE-B4	ICE-B3	ICE-B2	ICE-B1
Longitudinal impact in main operational direction	6 m/s	5 m/s	5 m/s	5 m/s
Longitudinal impact in reversing direction (pushing unit propeller hub or pulling unit cover end cap impact)	4 m/s	3 m/s	3 m/s	3 m/s
Transversal impact in bow first operation	3 m/s	2 m/s	2 m/s	2 m/s
Transversal impact in stern first operation (double acting ship)	4 m/s	3 m/s	3 m/s	3 m/s

Table 19.19 Impact speeds for aft wing, bow centerline and bow wing thrusters

Aft wing, bow centerline and bow wing thrusters	ICE-B4	ICE-B3	ICE-B2	ICE-B1
Longitudinal impact in main operational direction	6 m/s	5 m/s	5 m/s	5 m/s
Longitudinal impact in reversing direction (pushing unit propeller hub or pulling unit cover end cap impact)	4 m/s	3 m/s	3 m/s	3 m/s
Transversal impact	4 m/s	3 m/s	3 m/s	3 m/s

The ice impact contact load must be calculated using formula below. The related parameter values are given in Table 19.17. The design operation speed in ice can be derived from Tables 19.18 and 19.19, or the ship in question's actual design operation speed in ice can be used. The longitudinal impact speed in Tables 19.18 and 19.19 refers to the impact in the thruster's main operational direction. For the pulling propeller configuration, the longitudinal impact speed is used for load case T2, impact on hub; and for the pushing propeller unit, the longitudinal impact speed is used for load case T1, impact on thruster end cap. For the opposite direction, the impact speed for transversal impact is applied.

$$F_{ti} = C_{DMI} 3455 R_c^{0.5} (m_{ice} v_s^2)^{0.333} \quad [\text{kN}],$$

where

- R_c is the impacting part sphere radius, see Figure 19.9 [m]
 m_{ice} is the ice block mass [kg]
 v_s is the ship speed at the time of contact [m/s]
 C_{DMI} is the dynamic magnification factor for impact loads.

C_{DMI} shall be taken from Table 19.17 if unknown.

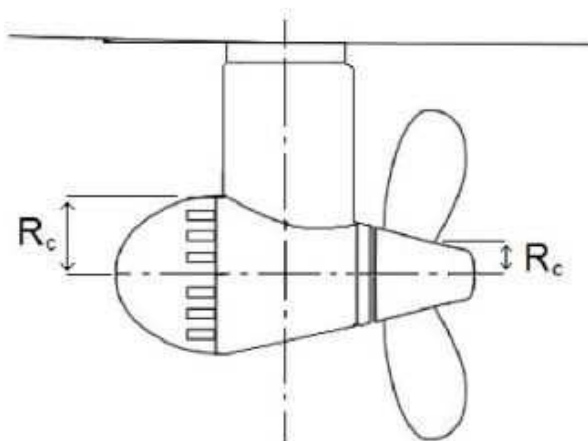


Figure 19.9 Dimensions used for R_c

For impacts on non-hemispherical areas, such as the impact on the nozzle, the equivalent impact sphere radius must be estimated using the equation below.

$$R_{ceq} = \sqrt{\frac{A}{\pi}} \quad [\text{m}]$$

If the $2 \cdot R_{ceq}$ is greater than the ice block thickness, the radius is set to half of the ice block thickness. For the impact on the thruster side, the pod body diameter can be used as a basis for determining the radius. For the impact on the propeller hub, the hub diameter can be used as a basis for the radius.

6.6.3 Extreme ice loads on thruster hull when penetrating an ice ridge

In icy conditions, ships typically operate in ice channels. When passing other ships, ships may be subject to loads caused by their thrusters penetrating ice channel walls. There is usually a consolidated layer at the ice surface, below which the ice blocks are loose. In addition, the thruster may penetrate ice ridges when backing. Such a situation is likely in the case of ICE-B4 ships in particular, because they may operate independently in difficult ice conditions. However, the thrusters in ships with lower ice classes may also have to withstand such a situation, but at a remarkably lower ship speed.

In this load scenario, the ship is penetrating a ridge in thruster first mode with an initial speed. This situation occurs when a ship with a thruster at the bow moves forward, or a ship with a thruster astern moves in backing mode. The maximum load during such an event is considered the extreme load. An event of this kind typically lasts several seconds, due to which the dynamic magnification is considered negligible and is not taken into account.

The load magnitude must be estimated for the load cases shown in Table 19.20, using equation below. The parameter values for calculations are given in Table 19.21 and Table 19.22. The loads must be applied as uniform distributed load or uniform pressure over the thruster surface. The design operation speed in ice can be derived from Table 19.21 or Table 19.22. Alternatively, the actual design operation speed in ice of the ship in question can be used.

$$F_{tr}=32 v_s^{0.66} H_r^{0.9} A_t^{0.74} \text{ [kN]},$$

where

v_s is ship speed [m/s]

H_r is design ridge thickness (the thickness of the consolidated layer is 18% of the total ridge thickness) [m]

A_t is the projected area of the thruster [m²].

When calculating the contact area for thruster-ridge interaction, the loaded area in the vertical direction is limited to the ice ridge thickness, as shown in Figure 19.10.

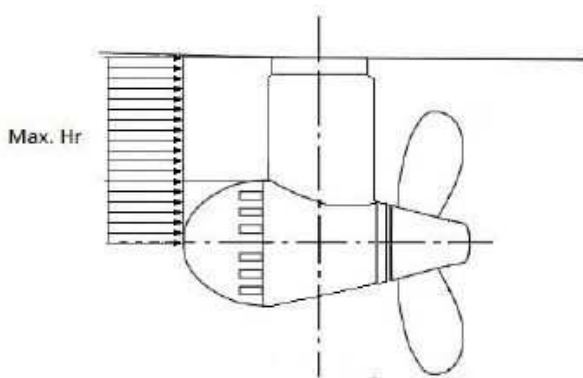


Figure 19.10 Schematic figure showing the reduction of the contact area by the maximum ridge thickness.

6.6.4 Acceptability criterion for static loads

The stresses on the thruster must be calculated for the extreme once-in-a-lifetime loads described in 6.6. The nominal von Mises stresses on the thruster body must have a safety margin of 1,3 against the yielding strength of the material. At areas of local stress concentrations, stresses must have a safety margin of 1,0 against yielding. The slewing bearing, bolt connections and other components must be able to maintain operability without incurring damage that requires repair when subject to the loads given in 6.6.2 and 6.6.3 multiplied by a safety factor of 1,3.

6.6.5 Thruster body global vibration

Evaluating the global vibratory behavior of the thruster body is important, if the first blade order excitations are in the same frequency range with the thruster global modes of vibration, which occur when the propeller

rotational speeds are in the high power range of the propulsion line. This evaluation is mandatory and it must be shown that there is either no global first blade order resonance at high operational propeller speeds (above 50% of maximum power) or that the structure is designed to withstand vibratory loads during resonance above 50% of maximum power.

When estimating thruster global natural frequencies in the longitudinal and transverse direction, the damping and added mass due to water must be taken into account. In addition to this, the effect of ship attachment stiffness must be modelled.

7. Alternative design procedure

7.1 Scope

As an alternative to items 5. and 6., a comprehensive design study may be carried out to the satisfaction of **BCS**. The study has to be based on ice conditions given

for different ice classes in item 3. It has to include both fatigue and maximum load design calculations and fulfil the pyramid strength principle, as given in item 6.1.

7.2 Loading

Loads on the propeller blade and propulsion system are to be based on an acceptable estimation of hydrodynamic and ice loads.

7.3 Design levels

The analysis is to indicate that all components transmitting random (occasional) forces, excluding propeller blade, are not subjected to stress levels in excess of the yield stress of the component material, with a reasonable safety margin.

Cumulative fatigue damage calculations are to indicate a reasonable safety factor. Due account is to be taken of material properties, stress raisers, and fatigue enhancements.

Vibration analysis is to be carried out and is to indicate that the complete dynamic system is free from harmful torsional resonances resulting from propeller/ice interaction.

Table 19.20 Load cases for ridge ice loads

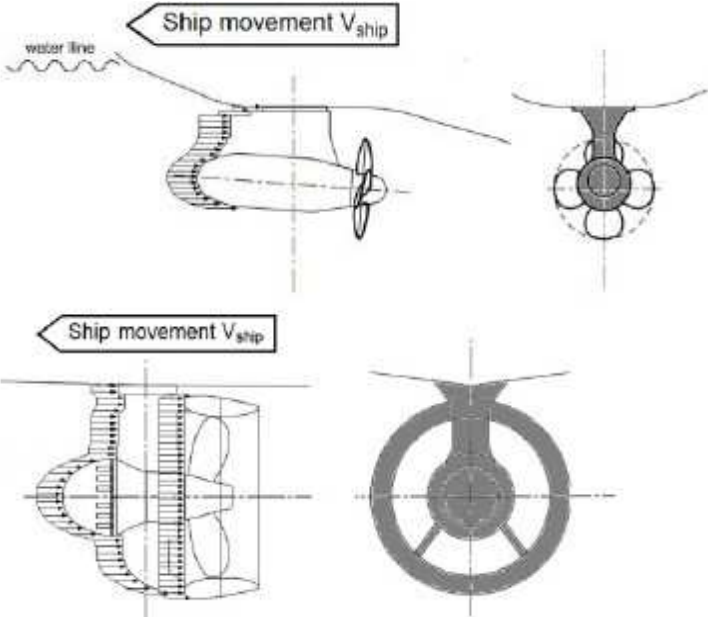
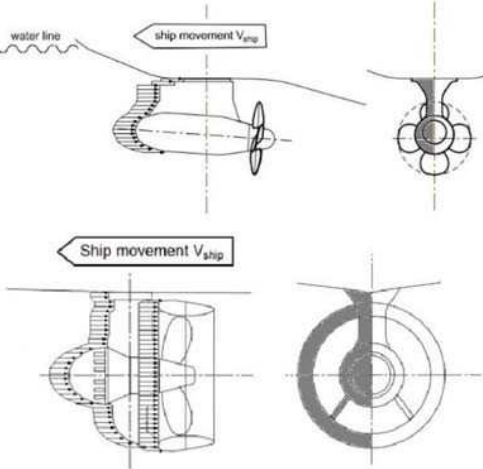
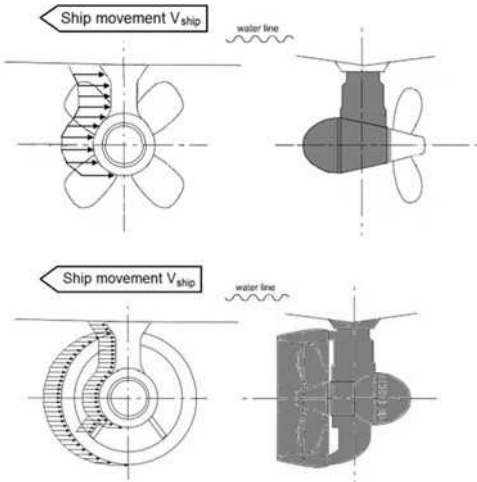
	Force	Load area	
Load case T4a Symmetric longi- tudinal ridge penetration loads	F_{tr}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area.	
Load case T4b Non-symmetric longitudinal ridge penetration loads	50% of F_{tr}	Uniform distributed load or uniform pressure, which are applied on the other half of the contact area.	
Load case T5a Symmetric lateral ridge penetration loads for ducted azimuthing unit and pushing open propeller unit	F_{tr}	Uniform distributed load or uniform pressure, which are applied symmetrically on the contact area.	

Table 19.20 Load cases for ridge ice loads (cont.)

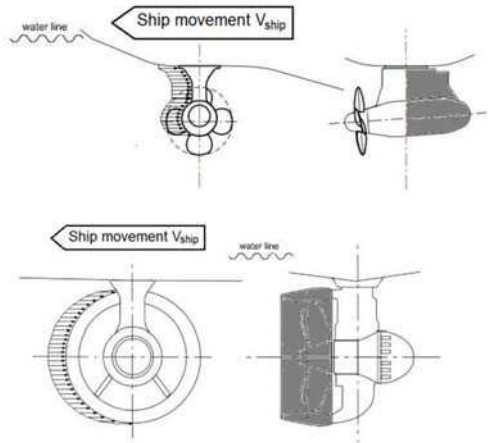
Load case T5b Non-symmetric lateral ridge penetration loads for all azimuthing units	50% of F_{tr}	Uniform distributed load or uniform pressure, which are applied on the other half of the contact area.	
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Table 19.21 Parameters for calculating maximum loads when the thruster penetrates an ice ridge. Aft thrusters. Bow first operation

	ICE-B4	ICE-B3	ICE-B2	ICE-B1
Thickness of the design ridge consolidated layer	1,5 m	1,5 m	1,2 m	1,0 m
Total thickness of the design ridge, H_r	8 m	8 m	6,5 m	5 m
Initial ridge penetration speed (longitudinal loads)	4 m/s	2 m/s	2 m/s	2 m/s
Initial ridge penetration speed (transversal loads)	2 m/s	1 m/s	1 m/s	1 m/s

Table 19.22 Parameters for calculating maximum loads when the thruster penetrates an ice ridge. Thruster first mode such as double acting ships

	ICE-B4	ICE-B3	ICE-B2	ICE-B1
Thickness of the design ridge consolidated layer	1,5 m	1,5 m	1,2 m	1,0 m
Total thickness of the design ridge, H_r	8 m	8 m	6,5 m	5 m
Initial ridge penetration speed (longitudinal loads)	6 m/s	4 m/s	4 m/s	4 m/s
Initial ridge penetration speed (transversal loads)	3 m/s	2 m/s	2 m/s	2 m/s

8. Gears

8.1 General

ICE-B2, ICE-B3, and ICE-B4 are to be of strengthened design. Besides the strengthening prescribed here for the design of toothing, gear shafts and of shrink fits, the other components of such gears, e.g. clutch couplings, bearings, casings and bolted joints, shall also be designed to withstand the increased loads encountered when navigating in ice.

8.2 Strengthening

Calculation of gear response torque Q_{rg} (kNm):

$$Q_{rg} = Q_{emax} + 0.75 \cdot Q_{max} \cdot \frac{I_H \cdot u^2}{I_L + I_H \cdot u^2} \leq K_A \cdot Q_n$$

Q_{rg} = Response torque at gear referring to propeller rpm [kNm]

Q_n = Nominal torque of propulsion engine at MCR condition referring to propeller rpm [kNm]

Q_{max} = Maximum ice torque [kNm], see 5.3.1, 5.3.2

I_H = Mass moment of inertia of all components rotating at input rpm [kgm²]

I_L = Mass moment of inertia of all components rotating at output rpm (including propeller with entrained water) [kgm²]

K_A = Application factor in accordance with Section 7, Table 7.3

u = Gear ratio (input rpm / output rpm)

- **Ice Class strengthening factor for tooth system**

The torque spectrum for the output gear wheel is defined as follows:

- Q_{rg} with N_{Zice} cycles

Gears in the main propulsion plant of ships with ICE-B1,

- $K_A \cdot Q_n$ with N^∞ - N_{Zice} cycles (if $N^\infty > N_{Zice}$)

N_{Zice} = Number of ice loads on output gear wheel, see 5.1.7

N^∞ = Number of cycles for unlimited operation (according ISO 6336 – Pt. 6)

For dimensioning of the tooth system, the following ice class strengthening factor has to be used.

$$K_E = \frac{Q_{eq,g}}{Q_{emax}}$$

K_E = Ice class strengthening factor for the tooth system

$Q_{eq,g}$ = Equivalent gear torque [kNm] (to be calculated from the gear torque spectrum ac ISO 6336 – Pt. 6)

For pinions and wheels with higher speed, the numbers of load cycles (and the torques) are found by multiplication (and division resp.) with the gear ratios.

- **Ice Class strengthening factor for shafts, clutches and couplings**

For dimensioning of shafts, clutches and couplings within the gear and between gear and engine the following ice class strengthening factor has to be used. However this ratio is not to be taken less than K_A .

$$K_E = \frac{Q_{rg}}{Q_n} \leq K_A$$

8.2.1 Tooth systems

The calculated safety factors for tooth root and flank stress are to satisfy the requirements stated in Section 7, Table 7.1 when the application factor K_A is substituted by the calculated ice class strengthening factor K_E in equation in items 5.1 and 5.3.

8.2.2 Gear shafts

$$d_{inc,gs} = q_e \cdot d$$

$d_{inc,gs}$ = Increased gear shaft diameter [mm]

d = Gear shaft diameter in accordance with Section 7, D.1 [mm]

$$q_E = 0.84 \cdot \sqrt[3]{K_E}$$

q_E is not to be taken less than 1

K_E = Ice class strengthening factor in accordance with formula given in item 8.2.

8.2.3 Shrink fits

Shrink fits within the gear may be calculated according to formula given in item 6.5.1 including the safety factor $S = 2.0$, however $S \cdot Q_{peak} \geq 3.0 \cdot Q_{e \max}$ has to be ensured. The respective axial (T_r) and torsional (Q_{peak}) loads, acting at the location of the fit, have to be applied.

Axial tooth forces have to be considered.

8.2.4 Clutches

For plants with a resulting ice class strengthening factor $K_E \geq 1.4$ the required static and dynamic friction torques according to Section 7, G.4.3.1 are to be increased by $K_E/1.4$.

9. Flexible couplings

Flexible couplings in the main propulsion installation shall be so designed that, given the load on the coupling due to torsional vibrations at T_{TOR} , they are able to withstand safely brief torque shocks T_E [Nm] of magnitude:

$$T_E = K_E \cdot T_{TOR}$$

Where

$$T_E \leq T_{Kmax1}$$

K_E = Ice class strengthening factor in accordance with formula given in item 8.2.

T_{TOR} = Driving torque [Nm]

T_{Kmax1} = Permissible torque of coupling for normal transient conditions [Nm]

10. Sea chests, discharge valves and cooling water system

For sea chests and discharge valves, Section 16, I.2.1 is to be observed. The cooling water system is to be designed such that sufficient cooling water is provided, while the ship is navigating in ice.

11. Steering gear

The dimensional design of steering gear components is to take account of the rudderstock diameter specified in Chapter 1 Hull Section 14 and 18.

12. Electric propeller drive

For ships with electrical propeller drive, refer to Chapter 5 Electrical Installations Section 13.

13. Lateral thrust units

Compliance of the machinery part of lateral thrust units with the requirements of this Section is not required as long as the lateral thrust unit is protected against ice contact by suitable means, such as grids at the tunnel inlets.

If such protection does not exist, the a.m. Rules for main propulsion plants with ducted propellers are to be applied.

Ice strengthening of the grid is to be considered according to hull requirements, Refer to Chapter 1 Hull Section 15 item D.10.

D. Reinforcements for ICE-B Notation

m_{ice} = Ice class factor to be taken as 8 for ICE-B

1. Propeller shafts, intermediate shafts, thrust shafts

S_t = 0.7 for shrink fits in gears

1.1 General

= 0.71 for the propeller shafts of fixed-pitch propellers

The necessary propeller shaft reinforcements in accordance with formula in 1.2, in conjunction with the formulae and factors specified in Section 5, C.2, apply to the area of the aft stern tube bearing or shaft bracket bearing as far as the forward load-bearing edge of the propeller or of the aft propeller shaft coupling flange subject to a minimum area of 2.5-d.

= 0.78 for the propeller shafts of controllable pitch propellers

In the case of ducted propellers, the values of S_t can be reduced by 10 %.

The diameter of the adjoining part of the propeller shaft to the point where it leaves the stern tube may be designed with an ice class reinforcement factor 15 % less than that calculated by $C_{isf,s}$ formula given in item 1.2.

2. Shrunk joints**2.1 Normal operation**

When designing shrink fits in the shafting system and in gearboxes, the necessary pressure per unit area P_E [N/mm²] is to be calculated in accordance with the formula below:

$$P_E = \frac{\sqrt{\theta^2 \cdot T^2 + f \cdot (c_A^2 \cdot c_e^6 \cdot Q^2 + T^2)} - \theta \cdot T}{A \cdot f}$$

The portion of the propeller shaft located forward of the stern tube can be regarded as an intermediate shaft. Intermediate and thrust shafts do not need to be strengthened.

c_A = Coefficient for shrink-fitted joints, depending on the kind of driving unit:

1.2 Reinforcements

$$d_{inc,s} = C_{isf,s} \cdot d$$

$d_{inc,s}$ = Increased diameter of propeller shaft [mm]

= 1.0 for geared oil engine and turbine drives,

d = Shaft diameter [mm] according to Section 5 C.2

= 1.2 for geared direct oil engine drives

$C_{isf,s}$ = Ice class strengthening factor (not to be taken less than 1)

c_e = $0.89 \cdot C_{isf,s}$ (not to be taken less than 1)

Q = peripheral force at the mean joint diameter of a shrink fit [N]

$$C_{isf,s} = \sqrt[3]{S_t \cdot \left(1 + \frac{85 \cdot m_{ice}}{P_w^{0.6} \cdot n^{0.2}}\right)}$$

$C_{isf,s}$ is to be calculated according to item 1.2, the higher value of the connected shaft ends has to be taken for the coupling

P_w = Main engine power [kW]

Other symbols are to be defined in accordance with Section 5, C.5.

n_2 = Propeller shaft speed [min⁻¹]

T has to be introduced as positive value, if the propeller thrust increases the surface pressure at the taper. Change of direction of the axial force is to be neglected as far as performance and thrust are essentially less.

T has to be introduced as negative value, if the axial force reduces the surface pressure at the taper, e.g. for tractor propellers.

$$f = \left(\frac{\mu_0}{S}\right)^2 - \theta^2$$

2.2 Operation at a resonance

For direct coupled propulsion plants with a barred speed range it has to be confirmed by separate calculation that the vibratory torque in the main resonance is transmitted safely. For this proof the safety against slipping for the transmission of torque shall be at least $S = 2.0$, the coefficient C_A may be set to 1.0.

For this additional proof the respective influence of the thrust shall be disregarded.

3. Propellers

3.1 General

The propellers of ships with ICE-B must be made of the cast copper alloys or cast steel alloys specified in Section 8.

3.2 Strengthening

3.2.1 Blade sections

$$t_{inc,p} = \text{Increased thickness of blade section [mm]}$$

$$= C_{isf,p} \cdot t$$

$$t = \text{Blade section thickness in accordance with Section 8 C.2}$$

If $C_{isf,p} \leq C_{Dyn}$ then

$$t_{inc,p} = t$$

If $C_{isf,p} > C_{Dyn}$ then

$$t_{inc,p} = \frac{C_{isf,p}}{C_{Dyn}} \cdot t$$

$C_{isf,p}$ = Ice class strengthening factor (not to be taken less than 1)

$$C_{isf,p} = \sqrt[3]{P_t^2 \cdot \left(1 + \frac{21 \cdot z \cdot m_{ice}}{P_w^{0.6} \cdot n_2^{0.2}}\right)}$$

P_t = 0.62 for solid propellers

= 0.72 for controllable pitch propellers

In the case of ducted propellers, the values of P_t may be reduced by 15 %.

z = Number of blades

For m_{ice} , P_w , n_2 refer to item 1.2

C_{Din} = Dynamic factor in accordance with Section 8, formula (3)

3.2.2 Blade tips

$$t_{tip} = 10 \cdot \sqrt[5]{\frac{D}{C_w}} \cdot \left(\frac{D}{500} + t_{inc}\right)$$

t_{tip} = Strengthened blade tip [mm]

t_{inc} = Increase in thickness [mm] (To be taken as 10 for ICE-B)

D = Propeller diameter [mm]

C_w = Material factor [N/mm²], refer to Section 8, Table 8.1

In the case of ducted propellers, the thickness of the blade tips may be reduced by 15 %.

3.2.3 Leading and trailing edges

The thickness of the leading and trailing edges of reversible propellers and the thickness of the leading edge of controllable pitch propellers must be equal for ICE-B to at least 35 % of the blade tip thickness when measured at a distance of $1.25 t_{tip}$ from the edge of the blade. For ducted propellers, the strengthening at the leading and trailing edges has to be based on the non-reduced tip thickness according to formula in 3.2.2.

3.2.4 Blade wear

If the actual thickness in service is below 50 % at the blade tip or 90 % at other radii of the values obtained from 3.2, respective counter measures have to be taken. Ice strengthening factors according to 3.2 will not be influenced by an additional allowance for abrasion.

Note: If the propeller is subjected to substantial wear, e.g. abrasion in tidal flats or in case of dredgers, a wear allowance should be added to the blade thickness determined in order to achieve an adequate service time with respect to 3.2.4.

3.2.5 Additional Requirements

These requirements are given in addition to those given by Finnish Swedish Ice Class Requirements.

3.2.6 Propeller mounting

Where the propeller is mounted on the propeller shaft by the oil injection method, the necessary contact pressure P_E [N/mm²] in the area of the mean taper diameter is to be determined by formula:

$$P_E = \frac{\sqrt{\theta^2 \cdot T^2 + f \cdot (C_A^2 \cdot C_e^6 \cdot Q^2 + T^2)} - \theta \cdot T}{A \cdot f}$$

T has to be introduced as positive value, if the propeller thrust increases the surface pressure at the taper. Change of direction of propeller thrust is to be neglected as far as performance and thrust are essentially less.

T has to be introduced as negative value, if the propeller thrust reduces the surface pressure at the taper, e.g. for tractor propellers.

$$f = \left(\frac{\mu_0}{S}\right)^2 - \theta^2$$

For directly coupled propulsion plants with a barred speed range it has to be confirmed by separate calculation that the vibratory torque in the main resonance is transmitted safely.

ce = ice class reinforcement factor in accordance with formula given in item 2.1.

Other symbols are to be defined in accordance with Section 8.

In the case of flanged propellers, the required diameter d_{SE} of the alignment pin is to be determined by applying formula below:

$$d_{SE} = C_{isf,s}^{1.5} \cdot d_s$$

d_{SE} = Reinforced root diameter of alignment pin [mm]

d_s = Diameter of alignment pin for attaching the propeller [mm] in accordance with Section 5, C.4.2, formula (4)

$C_{isf,s}$ = Ice class reinforcement factor in accordance with formula given in item 1.2

Other symbols are to be defined in accordance with Section 8.

4. Gears

4.1 General

Gears in the main propulsion plant of ships with ICE-B are not to be strengthened.

5. Sea chests and discharge valves

Sea chests and discharge valves are to be designed in accordance with Section 16, I.2.

6. Steering gear

The dimensional design of steering gear components is to take account of the rudderstock diameter specified in the Part A Chapter 1 Hull Section, Section 14 and 18.

7. Electric propeller drive

For ships with electrical propeller drive, see Part B Chapter 5 Electrical Installations Section 13.

E. Miscellaneous Machinery Requirements**1. Starting arrangements**

The capacity of the air receivers is to be sufficient to provide without reloading not less than 12 consecutive starts of the propulsion engine, if this has to be reversed for moving astern, or 6 consecutive starts if the propulsion engine does not have to be reversed for moving astern.

If the air receivers serve any purposes other than starting the propulsion engine, they must have additional capacity sufficient for such purposes.

The capacity of the air compressors must be sufficient for charging the air receivers from atmospheric to full pressure in one (1) hour, except for a ship with the ice class ICE-B4, if its propulsion engine has to be reversed for going astern, in which case the compressor must be able to charge the receivers in half an hour.

2. Sea inlet and cooling water systems

The cooling water system is to be designed to secure the supply of cooling water when navigating in ice.

For this purpose, at least one cooling water inlet chest is to be arranged as follows:

1. The sea inlet is to be situated near the centreline of the ship and well aft, if possible.
2. Guidance for designing the volume of the chest is to be around one cubic metre for every 750 kW in engine output of the ship, including the output of auxiliary engines necessary for the operation of the ship.
3. The chest is to be sufficiently high to allow ice to accumulate above the inlet pipe.
4. A pipe for discharge cooling water, allowing full capacity discharge, is to be connected to the chest.
5. The open area of the strainer plates is not to be less than four (4) times the inlet pipe sectional area.

If there are difficulties in meeting the requirements of paragraphs 2 and 3 above, two smaller chests may be arranged for alternating the intake and discharge of cooling water. Otherwise, the arrangements and situation are to be as above.

Heating coils may be installed in the upper part of the sea chest.

Arrangements for using ballast water for cooling purposes may be useful as a reserve in terms of ballast, but cannot be accepted as a substitute for an inlet chest as described above.

SECTION 20

TANKERS

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A. General

1. Scope

1.1 These requirements apply to tankers for the carriage of flammable toxic, corrosive or otherwise hazardous liquids. International and national regulations remain unaffected.

1.2 For the purposes of these Rules, tankers are:

- a)** Ships for the carriage of liquids in tanks which form part of the hull, and
- b)** Ships with fixed tanks independent of the hull and used for the carriage of liquids.

1.3 In addition to the general Rules for tankers in subsection B:

- a)** Tankers for the carriage of oil cargoes are subject to the provisions of subsection C,
- b)** Tankers for the carriage of hazardous chemicals in bulk are subject to the provisions of Chapter 8 - Chemical Tankers,
- c)** Tankers for the carriage of liquefied gases in bulk are subject to the provisions of Chapter 10 - Liquefied Gas Tankers.
- d)** For inert gas plants subsection D.

2. Definitions

For the purposes of this Section, the **cargo area** includes cargo tank, hold spaces for independent cargo tanks, tanks and spaces adjacent to cargo tanks, cofferdams, cargo pump rooms and the area above these spaces.

For the purposes of this Section, **separate** piping and venting systems are those which can, when necessary, be isolated from other piping systems by removing spool pieces or valves and blanking the pipe ends.

For the purposes of this Section, **independent** piping

and venting systems are those for which no means for the connection to other systems are provided.

3. Documents for Approval

3.1 According to the type of ship, at least the documents (schematic plans, detail / arrangement drawings) specified in 3.2 together with all the information necessary for their assessment are to be submitted to **BCS** in triplicate for approval.

3.2 For ships for the carriage of flammable liquids and chemicals:

- Cargo piping system including the location of cargo pumps and their driving machinery;
- Gastight shaft penetrations for pumps and fans;
- Cargo tank vent system with pressure-vacuum relief valves including flame arresters and cargo tank vapour return and collecting pipes;
- Cargo tank gauging/sounding devices, level/overflow alarms and temperature indicating equipment;
- Bilge and ballast water systems for the cargo area;
- Ventilation equipment for spaces in the cargo area;
- Heating and steaming-out lines for cargo tanks;
- Fire fighting/extinguishing equipment for the cargo area;
- Fixed cargo tank cleaning system;
- Remote-controlled valves system including their actuating equipment;
- Details of the liquid cargoes to be carried;
- Details of the materials coming into contact with the cargoes or their vapours;

- Pressure drop calculation of the venting system based on the maximum loading/unloading rates;
- Gas freeing arrangements for cargo and ballast tanks and cofferdams;
- VOC Management Plan for tankers carrying crude oil
- Emergency release systems for bow loading piping and SPM arrangements;
- Inert gas plant and system for cargo tanks, inerting of ballast tanks;
- Mechanically driven fans in the cargo area;
- Safety equipment in pump rooms, temperature monitoring of cargo pump bearings/housing etc.;
- Gas detection system in pump room.

4. References to Further Rules

BCS Rules for the Classification and Construction of Seagoing Steel Ships.

- 4.1 For the ships hull: Chapter 1 - Hull, Sections 28.
- 4.2 For pipelines, pumps, valves and fittings: Section 16.
- 4.3 For fire extinguishing and fire protection: Section 18.
- 4.4 For electrical equipment: Chapter 5 - Electrical Installations, Section 15.
- 4.5 Attention is also drawn to compliance with the provisions of the International Convention for the Prevention of Pollution from Ships of 1973 and of the relevant Protocol of 1978 (MARPOL 73/78), Annex I and II.

B. General Requirements for Tankers

1. Cargo Pumps

1.1 Location

1.1.1 Cargo pumps are to be located on deck, in the cargo tanks or in special pump rooms separated from other ship's spaces by gastight decks and bulkheads. Pump rooms may be accessible only from the cargo area and may not be connected to engine rooms or spaces which contain sources of ignition.

1.1.2 Penetrations of pump room bulkheads by shafts are to be fitted with gastight seals. Provision must be made for lubricating the seals from outside the pump room.

Overheating of the seals and the generation of sparks are to be avoided by appropriate design and the choice of suitable materials.

Where steel bellows are used in gastight bulkhead penetrations, they are to be subjected to a pressure test at 5 bar prior to fitting.

1.2 Equipment and operation

1.2.1 Cargo pumps are to be protected against overpressure by means of relief valves discharging the cargo into the suction line of the pump.

Where at the flow $Q=0$, the discharge pressure of centrifugal pumps does not exceed the design pressure of the cargo line system, relief valves may be dispensed with if temperature sensors are fitted in the pump housing which stop the pump or activate an alarm in the event of overheating.

1.2.2 It must be possible to control the capacity of the cargo pumps both from the pump room and from a suitable location outside this room.

Means are to be provided for stopping cargo pumps from a position above the tank deck.

1.2.3 At all pump operating positions and cargo handling positions on deck, pressure gauges for monitoring pump pressures are to be fitted. The maximum permissible working pressure is to be indicated by a red mark on the scale.

1.2.4 The drain pipes of steam-driven pumps and steam lines must terminate at a sufficient height above the bilge bottom to prevent the ingress of cargo residues.

1.3 Drive

1.3.1 Drive motors are to be installed outside the cargo area. Exceptions are steam-driven machines where the steam temperature does not exceed 220 °C.

1.3.2 Hydraulic cargo pump driving machinery (e.g. for submerged pumps) may be installed inside the cargo area.

1.3.3 For electric motors used to drive cargo pumps see Chapter 5 - Electrical Installations, Section 15.

2. Cargo Line System

2.1 Line installation

2.1.1 Cargo line systems must be permanently installed and completely separated from other piping systems. In general they may not extend beyond the cargo area. For bow and stern cargo lines see C.5. (oil tankers) and Seagoing Ships, Chapter 8 - Chemical Tankers, Section 3.7 (chemical tankers).

2.1.2 Cargo lines are to be so installed that any remaining cargo can be drained into the cargo tanks. Filling pipes for cargo tanks are to extend down to the bottom of the tank.

2.1.3 Expansion bends, expansion bellows and other approved expansion joints are to be fitted as necessary.

2.1.4 Seawater inlets must be separated from cargo lines by two stop valves, one of which is to be locked in the closed position.

2.1.5 Seawater inlets and outlets (sea-chests) for

ballast and cargo systems are to be arranged separately.

2.2 Design of cargo lines

2.2.1 For the design of cargo lines see Section 16,C. Minimum wall thickness to be in accordance with Table 16.7, group N. Possible delivery heads of shore based pumps and gravity tanks shall be taken into account.

2.2.2 Welding is the preferred method of connecting cargo lines.

Cargo oil pipes shall not pass through ballast tanks. Exemptions for short lengths of pipes may be approved by **BCS** on condition that item. 4.3.4 is applied analogously .

2.3 Valves, fittings and equipment

2.3.1 Hose connections are to be made of cast steel or other ductile materials and are to be fitted with shutoff valves and blind flanges.

2.3.2 Extension rods for stop valves inside cargo tanks are to be fitted with gastight deck penetrations and open/closed indicators. All other cargo stop valves are to be so designed as to indicate whether they are open or closed.

2.3.3 Emergency operating mechanisms are to be provided for stop valves which are actuated hydraulically or pneumatically. Hand-operated pumps which are connected to the hydraulic system in such a way that they can be isolated may be regarded as emergency operating mechanisms.

An emergency operating mechanism controlled from the deck can be dispensed with provided that the cargo tank can be emptied by another line or the shutoff valve is located in the adjacent tank.

2.3.4 At the positions for monitoring the cargo loading and discharging operations, the cargo lines are to be fitted with pressure gauges with a red mark denoting the maximum permissible working pressure.

2.3.5 Provision must be made for the safe draining, gas-freeing and cleaning of the cargo line system.

2.3.6 Design of integrated cargo and ballast systems are subject to the requirements in Chapter 5 - Electrical Installation, Section 15, A.8

3. Tank Heating and Steaming Out Lines

3.1 Tank heating

This is subject to the appropriate rules concerning the heating of fuels, Section 16, V.2.5

3.2 Valves and fittings for the tank heating system

Steam lines to the individual heating coils of the cargo tanks are to be fitted with screw-down non-return valves. Means of testing the condensate for ingress of oil are to be fitted before the stop valves in the heating coil outlets.

3.3 Condensate return

The condensate from the heating system is to be returned to the feed water system via observation tanks.

Condensate observation tanks are to be arranged and equipped such that cargo residues in the condensate will not constitute a hazard in engine room or other gas safe spaces. Vent pipes must be fitted with flame arresters complying with B.6 and shall be led to the open deck in a safe position.

3.4 Tank heating with special heat-transfer media

3.4.1 Thermal oil systems are subject to the requirements in Section 13 and 16, Q.

3.4.2 A secondary circuit system is to be provided which is entirely located in the cargo area.

A single-circuit system may be approved if:

- The expansion vessel mentioned in Section 13, C.3 is so arranged that at the minimum liquid level in the expansion vessel, the

pressure in the thermal oil system with the thermal fluid circulating pump inoperative is at least 0,3 bar higher than the static pressure of the cargo,

- All shutoff valves between the cargo tanks and the expansion vessel can be locked in the open position, and
- A means of detecting flammable gases in the expansion vessel is provided. The use of a portable unit may be approved.

3.5 Steaming out lines

Steam lines for steaming out cargo tanks and cargo lines are to be fitted with screw-down non-return valves.

3.6 Tank heating systems on chemical tankers

These are additionally subject to the requirements of the Chapter 8 - Chemical Tankers.

4. Bilge and Ballast Systems

4.1 Calculation of the bilge pipe diameter

4.1.1 Bilge systems for the cargo area are to be separated from those of other areas.

Bilge systems for the cargo area are to be located in the cargo area.

Bilge systems for machinery spaces are subject to Section 16, N.2.3.

4.1.2 For spaces in the cargo area of combination carriers the bilge system is to be designed in accordance with Section 16, N.2.2.

4.1.3 For spaces for independent tanks on tankers according to A.1.2. b) the diameters of the main and branch bilge lines are calculated as follows:

$$d_H = 1,68 \cdot \sqrt{(B+H) \ell_2 - (b+h) \ell_{T2}} + 25 \quad [\text{mm}]$$

$$d_Z = 2,15 \cdot \sqrt{(B+H) \ell - (b+h) \ell_T} + 25 \quad [\text{mm}]$$

where

d_H	=	Inside diameter of main bilge line, [mm]
d_z	=	Inside diameter of branch bilge line, [mm]
B	=	Breadth of ship, [m]
H	=	Moulded depth of ship, [m]
ℓ_2	=	Total length of cargo area, [m]
ℓ	=	Length of watertight compartment, [m]
b	=	Maximum breadth of cargo tanks, [m]
h	=	Maximum depth of cargo tanks, [m]
ℓ_{T2}	=	Total length of all cargo tanks, [m]
ℓ_T	=	Length of tanks in the watertight compartment. [m]

The capacity of each bilge pump is to be calculated according to Section 16, N.3.1. At least two bilge pumps are to be provided.

4.1.4 When separate bilge pumps, e.g. ejectors are provided for compartments with watertight bulkheads the pump capacity is to be evaluated as specified in 4.1.3 and is to be divided according the length of the individual compartments. For each compartment two bilge pumps are to be fitted of a capacity of not less than 5 m³/h each.

4.1.5 Spaces for independent tanks are to be provided with sounding arrangements.

When ballast or cooling water lines are fitted in spaces for independent tanks bilge level alarms are to be provided.

4.2 Bilge pumping of cargo pump rooms and cofferdams in the cargo area

4.2.1 Bilge pumping equipment is to be located in the cargo area to serve the cargo pump rooms and cofferdams. A cargo pump may also be used as a bilge pump. On oil tankers used exclusively for the carriage of flammable liquids with flash points above 60 °C,

cargo pump rooms and cofferdams may be connected to the engine room bilge system.

4.2.2 Where a cargo pump is used as bilge pump, measures are to be taken, e.g. by fitting screw-down non-return, valves, to ensure that cargo cannot enter the bilge system. Where the bilge line can be pressurized from the cargo system, an additional non-return valve is to be fitted.

4.2.3 Means must be provided for pumping the bilges when special circumstances render the pump room inaccessible. The equipment necessary for this is to be capable of being operated from outside the pump room or from the pump room casing above the tank deck (freeboard deck).

4.3 Ballast systems in the cargo area

4.3.1 Means for ballasting segregated ballast tanks adjacent of cargo tanks must be located in the cargo area and are to be independent of piping systems forward and aft of the cofferdams.

4.3.2 On oil tankers the fore peak tank may be connected to the above ballast systems under following conditions:

- The fore peak tank is considered as a hazardous area
- The hazardous zones as defined in IEC 60092-502 are to be considered around the air vent pipes

A1 Areas on open deck, or semi-enclosed spaces on open deck, within 3 m. of cargo tank ventilation outlets which permit the flow of small volumes of vapour or gas mixtures caused by thermal variation are defined as Zone 1 as specified by IEC 60092-502 para 4.2.2.7.

A2 Areas within 2 m. beyond the zone specified in A1 above are to be considered Zone 2 (as opposed to 1.5 m. as specified by IEC 60092-502 para 4.2.3.1).

A3 Electrical equipment or cables shall not normally be installed in hazardous areas.

Where essential for operational purposes, electrical equipment may be installed in accordance with IEC 60092-502: Electrical installations in ships - Tankers - Special features.

- Means are to be provided on the open deck for the measurement of flammable gas concentrations inside the peak tank by a suitable portable instrument,
- Access openings and sounding arrangements to this space are to be located on the open deck. In case where the fore peak is separated by a cofferdam from the cargo tanks a bolted manhole may be permitted in an enclosed space with the following warning notice:

“This manhole may only be opened after the tank has been proven gas free or electrical equipment in this space which is not of certified safe type has been isolated”.

4.3.3 On oil tankers there must be 2 pumps for ballasting segregated ballast tanks. If there is one pump, an additional inductor or an emergency discharge connection through a spool piece to cargo pumps may be provided. A non-return device in the ballast system shall be provided to prevent the backflow of cargo into ballast tanks. The spool piece together with a warning notice shall be mounted in a conspicuous location in pump room.

Ballast water is to be discharged in accordance with MARPOL 73/78 Annex I Reg.30.

4.3.4 Ballast water pipes, sounding and air pipes shall not pass through cargo oil tanks. Exemptions for short lengths of pipe may be approved by **BCS** on condition that the following is complied with:

- a) Minimum wall thicknesses

up to ND 50 mm. 6,3 mm.

up to ND 100 mm. 8,6 mm.
up to ND 125 mm. 9,5 mm.
up to ND 150 mm. 11,0 mm.
up to ND 200 mm. and larger 12,5 mm.

- b) Only completely welded pipes or equivalent are permitted.

- c) Where cargoes other than petroleum products are carried, relaxation from these Rules may be approved by **BCS**.

5. Ventilation and Gas-Freeing

5.1 Ventilation of cargo and ballast pump rooms in the cargo area

5.1.1 Pump rooms are to be ventilated by mechanically driven fans of the extraction type capable of at least 20 changes of air per hour. Fresh air is to be induced into the pump room from above. These ventilation systems shall not be connected to the ventilation systems of other spaces in the ship.

5.1.2 The exhaust duct is to be so installed that its suction opening is close to the bottom of the pump room. An emergency suction opening is to be located about 2 m. above the pump room floor. This opening is to be fitted with a means of closing which can also be operated from the main deck.

The emergency opening is to be of sufficient size to enable at least 3/4 of the necessary volume of exhaust air to be extracted with the bottom opening closed.

Further requirements see C.3, Oil Tankers or Chapter 8 - Chemical Tankers, Section 12 respectively.

5.2 Gas-freeing of cargo tanks, double hull spaces, ballast tanks, pipe tunnels and cofferdams

5.2.1 Provision must be made for the gas-freeing of tanks, double hull spaces ballast tanks, pipe

tunnels and cofferdams. Portable fans complying with 5.3 may be used. Where fans are permanently fitted for gas-freeing of tanks having connections to cargo oil lines, measures are to be taken, e.g. by removing spool pieces of the ventilation ducting or by using blank flanges, to ensure that neither cargo nor vapours can penetrate into the fans when not in use.

5.2.2 The inlet openings in cargo tanks used for gas-freeing or purging must be located either immediately below deck or not higher than 1 m. above the tank bottom.

5.2.3 Outlet openings for gas-freeing cargo tanks are to be located as far as possible from air/inert gas inlet openings at a height of at least 2 m. above the deck.

The gas/air mixtures are to be discharged vertically.

5.2.4 Outlet openings for gas-freeing of cargo tanks must be so designed that, taking into account the capacity of the fan, the exit velocity of the gas/air is at least 20 m/s.

5.2.5 On ships with inert gas systems, the free area of the vent openings shall be so designed that an exit velocity of at least 20 m/s is maintained if 3 cargo tanks are simultaneously purged with inert gas.

5.2.6 The openings for gas-freeing are to be fitted with screw-down covers.

5.2.7 Vent openings in accordance with 5.4.8 may also be used for gas-freeing of cargo tanks.

5.3 Design and construction of mechanically driven fans in the cargo area

5.3.1 Ventilation duct intakes and outlets are to be fitted with protective screens with a mesh size not exceeding 13 mm.

5.3.2 Overheating of the mechanical components of fans and the creation of sparks is to be avoided by

appropriate design and by the choice of suitable materials. The safety clearance between the fan housing and the impeller shall not be less than 1/10 of the inner impeller bearing diameter, limited to a minimum of 2 mm. and is to be such as to preclude any contact between the housing and the rotor. The maximum clearance need not to be more than 13 mm. The above requirement also applies to portable fans.

5.3.3 Following materials or combination of materials for impeller/housing may be used:

- Non-metallic materials **(1)** (plastic material having sufficient electric conductivity) with each other or with steel (incl. galvanized, stainless);
- Non-ferrous materials having good heat conductivity (bronze, brass, copper not aluminium) with each other or with steel (incl. galvanized stainless);
- Steel (incl. galvanized, stainless) with each other if a ring of adequate size made of above non-metallic/non-ferrous material is fitted in way of the impeller, or if a safety clearance of at least 13 mm. is provided;
- Aluminium or magnesium alloys with each other or with steel (incl. galvanized, stainless) only, if a non-ferrous ring having a good heat conductivity, i.e. copper, brass, of adequate size is fitted in way of the impeller.

The Following combinations of materials for impellers and housings are not considered spark proof and are not permitted:

- Impellers of an Aluminium alloy or magnesium alloy and a ferrous housing, irrespective of tip clearance

(1) *The electrical resistance of non-metallic materials must not exceed 10⁶ Ohm unless special measures are taken to prevent electrostatic charges at the surface of the material.*

- Impellers of a ferrous material and housings made of an aluminium alloy, irrespective of tip clearance
- Any combination of ferrous impeller and housing with less than 13 mm tip clearance, other than permitted by impellers and housings of austenitic stainless steel

5.3.4 Fan drives are subject to the requirements in B.1.3. Electric motors are to be located outside the vent ducts.

5.4 Venting of cargo tanks

5.4.1 Openings in cargo tanks are to be so located and arranged that no ignitable gas mixtures can be formed in closed spaces containing sources of ignition or in the vicinity of sources of ignition on deck.

5.4.2 The venting of cargo tanks may be effected only through approved pressure/vacuum relief devices which fulfil the following functions:

- a) Passage of large air or gas volumes during cargo loading/unloading and ballast operations, and
- b) The flow of small volumes of air or gas during the voyage.

5.4.3 Venting arrangements may be fitted individually on each tank or may be connected to a common header system or to the inert gas system.

5.4.4 Where the venting arrangements of more than one tank are connected to a vent header system, a shutoff device is to be provided at each tank. Where stop valves are used, they must be provided with locking arrangements.

5.4.5 When shutoff devices according to 5.4.4 are provided, devices must continue to permit the flow caused by thermal variations in a cargo tank in accordance with 5.4.2.b. Also shutoff devices shall continue to permit the passage of large volumes of vapour, air or inert gas mixtures during cargo loading

and ballasting, or during discharging in accordance with 5.4.2.a.

Note: See also C.4.1.2.

5.4.6 Venting arrangements are to be connected to the top of each cargo tank in such a way that, under normal conditions of trim and list, they are self-draining into the cargo tanks. Where a self-draining arrangement is impossible, permanently installed means for draining the vent lines to a cargo tank shall be provided.

5.4.7 Where flammable liquids with a flash point of 60 °C or below are carried, the inlet and outlet openings of venting systems are to be fitted with approved flame arresters in accordance with 6.

5.4.8 Vents for the discharge of large volumes of air or gas during cargo and ballast handling operations are to be designed in accordance with the following principles:

- a) Depending on the height of the vents, these shall allow the free flow of vapour mixtures or achieve a minimum velocity of 30 m/s.
- b) The vapour mixtures are to be discharged vertically upwards.
- c) The clear section of vents shall be designed in accordance with the maximum loading rate taking into account a gas evolution factor of 1,25.

5.4.9 Cargo tanks are to be provided with a high level alarm independent of the gauging device or with equivalent means to guard against liquid rising in the venting system to a height exceeding the design head of the cargo tanks.

5.4.10 Pressure and vacuum valves may be set higher during voyage for the prevention of cargo losses than for controlled venting during loading.

5.4.11 Pressure/vacuum valves which are located in masthead risers may be fitted with a by-pass

arrangement which can be opened during cargo operations. Indicators must clearly show whether the by-pass valve is in the open or closed position.

5.4.12 Using the pressure/vacuum relief devices it must be possible to depressurize the cargo tanks completely. Indicators must clearly show whether the device is open or closed.

5.4.13 The design, height and location of tank vents shall be determined with regard to the cargoes for which the ship is intended (see Subsection C. and the Rules for Chemical Tankers).

5.4.14 In the design of pressure and vacuum valves and the determination of their opening pressures attention is to be paid to:

- The maximum loading and unloading rate,
- The gas evolution factor,
- The flow resistance in the venting system and
- The permissible tank pressures.

For chemical tankers see also Chapter 8 –Chemical Tankers.

5.4.15 Where static flame arresters, e.g. flame screens and detonation arresters, are used, due attention is to be paid to the fouling caused by the cargo.

5.4.16 Vent headers may be used as vapour return lines. Vapour return line connections are to be fitted with shutoff valves and blind flanges.

5.4.17 Vent headers are to be provided with means of safe draining.

5.4.18 Where vapour return is required by MARPOL 73/78, Annex VI, Regulation 15 (Volatile organic compounds), additional requirements contained in IMO MSC/Circ. 585 are to be observed. Details are to be determined with **BCS** on case to case basis.

Note:

Tankers calling US ports are required to be equipped with vapour control systems according to TITLE 46 CFR, PART 39 USCG which are adequately certified.

5.5 Ventilation of other ship's spaces

Where arranging the ventilation intakes and outlets for the superstructure and machinery spaces, due attention is to be paid to the position of tank and pump room vents.

6. Devices to Prevent the Passage of Flames

6.1 Devices to prevent the passage of flames such as flame arresters, **(2)** flame screens, detonation arresters and high-velocity vents are subject to approval by **BCS**.

6.2 Flame arresters must be made of material which is resistant both to the cargo and to seawater.

The arrester elements are to be so designed that fastenings are protected against loosening under service conditions. The arrester elements must be replaceable.

6.3 Flame arresters are to be protected against damage and the entry of seawater and rain.

6.4 The effectiveness of flame arresters shall be verified by an institution recognized by **BCS**.

6.5 High-velocity vents with an efflux velocity of not less than 30 m/s for the removal of vapour mixtures from the immediate vicinity of the ship may be used as flame arresters provided that they have been tested by an institution recognized by **BCS**.

6.6 High-velocity vents may be used for controlled venting instead of pressure-relief valves.

(2) *Flame arresting devices must conform to the IMO standard in accordance with MSC/Circular 677, as amended.*

7. Tank Level Indicators

7.1 Level gauges

7.1.1 Tanks with a controlled venting system are to be equipped with closed level gauges approved by **BCS**.

7.1.2 In addition, such tanks are to be equipped with one of the sounding systems described in 7.2 and 7.3.

7.2 Ullage ports

7.2.1 Sounding and ullage ports must be capable of being closed by watertight covers.

7.2.2 These covers are to be self-closing after the sounding operation.

7.2.3 Sounding and ullage ports and other openings in cargo tanks, e.g. for the introduction of tank cleaning and ventilating equipment, may not be located in enclosed or semi-enclosed or semi-enclosed spaces.

7.2.4 Ullage openings must not be used for pressure equalization in accordance with SOLAS Reg.II-2/4.5.3.3

7.2.5 Ullage openings do not include cargo tank openings that are fitted with standpipe arrangements with its own manually operated shutoff valves

7.3 Sounding pipes

7.3.1 Sounding pipes must terminate sufficiently high above the tank deck to avoid cargo spillage during sounding.

7.3.2 Provision is to be made for the watertight closure of sounding pipes by self-closing covers,

7.3.3 The distance of the sounding pipe from the tank bottom may not be greater than 450 mm.

7.3.4 Cargo oil tank sounding and air pipes shall not run through ballast tanks. Exemptions are subject to item. 4.3.4 analogously.

7.4 Sampling equipment

Equipment for taking samples of the cargo from pressurized tanks is subject to approval by **BCS**.

8. Tank Cleaning Equipment

8.1 Fixed tank cleaning equipment is subject to approval by **BCS**. It is to be installed and supported in such a way that no natural resonance occurs under any operating conditions of the ship.

8.2 The foundations or supports of the equipment are to be so designed that they are fully capable of withstanding the reaction forces set up by the washing medium.

8.3 Tank cleaning equipment is to be made of steel. Other materials may be used only with the approval of **BCS**.

8.4 Tank washing equipment is to be bonded to the ship's hull.

8.5 Tankers equipped for washing with crude oil are to be fitted with an inert gas system in accordance with Subsection D.

9. Precautions Against Electrostatic Charges, Generation of Sparks and Hot Surfaces

9.1 Precautions against electrostatic charges

9.1.1 The entire cargo system as well as permanently installed equipment in the cargo area, e.g. pneumatically operated winches, hydraulic drives and ejectors, are to be bounded to the ship's hull.

9.1.2 Cargo hoses, compressed air hoses, tank washing hoses or other hoses used within cargo tanks or on deck within the cargo tank area are to be equipped with bounding arrangements over their entire length including the couplings.

9.1.3 Means are to be provided for the earthing of portable ventilators to the ship's hull prior to use.

9.2 Materials for tank covers

Removable covers made of steel, brass or bronze may be used.

Aluminium and glass reinforced plastic (GRP) are not allowed.

9.3 Precautions against sparks from engine and boiler exhaust

Outlets of exhaust gas lines from main/auxiliary engines and from boilers and other burner equipment shall be located at a sufficient height above deck.

The horizontal distance to the cargo area shall not be less than 10 m.

This distance may be reduced to 5 m. provided that approved spark arresters for internal combustion engine and spark traps for boiler/other burner equipment exhaust gas lines are fitted.

9.4 Protection against sparks

In deviation to Chapter 1 - Hull, Section 28, E.4.2 (prohibition of aluminium paints) hot-dipped aluminium pipes may be used in ballast tanks, inerted cargo tanks and on the open deck where protected against mechanical impact.

9.5 Protection against hot surfaces

On oil tankers, the steam and heating media temperatures shall not exceed 220 °C. On gas carriers and chemical tankers the maximum temperature is to be adjusted to take into account the temperature class of the cargoes.

10. Gas Detecting Equipment

Gas detectors are to be carried on board as follows (on tankers with inert gas plant see also D.4.2):

two (2) instruments each for

- Flammable vapours,

- Toxic vapours, where applicable,

- Oxygen.

Cargo tanks are to be fitted with connections for measuring the tank atmosphere.

11. Tests

After installation, cargo systems and heating systems together with their valves and fittings are to be subjected to a hydraulic pressure test at 1,5 times of the maximum permissible working pressure, provided that the test pressure shall be at least 5 bar.

12. Tankers Engaged Exclusively in the Carriage of Oil and Flammable Cargoes with a Flash Point Above 60 °C

In general item. 1.1, 1.3, 2.1.1, 3.4.2, 4.3.1, 4.3.2, 5.2.2, 5.2.3, 5.2.4, 5.2.5, 5.2.7, 5.3, 5.4, 6. and 7.1 of Section B are not applicable in the case of oil tankers exclusively carrying flammable liquids with a flash point above 60 °C.

C. Tankers for the Carriage of Oil and Other Flammable Liquids Having a Flash Point of 60°C or Below (3)**1. General**

This section applies in addition to the general rules in item. B.

1.1 Inerting of cargo tanks

Tankers of 20,000 DWT and upwards constructed on or after 1 July 2002 but before 1 JULY 2016, and tankers of 8,000 DWT and upwards constructed on or after 1 JULY 2016 are to be equipped with a permanently installed inert gas system in accordance with Subsection D.

For tankers not covered by this item 1.1, see D, 9.

(3) *Oil cargo having a flash point of 60 °C or below (closed cup test) and a vapour pressure which is below atmospheric pressure.*

2. Inerting of Double Hull Spaces

2.1 On oil tankers, required to be fitted with inert gas systems, suitable connections for the supply of inert gas shall be provided on double hull spaces. Where necessary, fixed purge pipes arranged such to take into account the configuration of these spaces shall be fitted.

Note : Double-hull spaces required to be fitted with suitable connections for the supply of inert gas as per item 2.1 are all ballast tanks and void spaces of double-hull and double-bottom spaces adjacent to the cargo tanks, including the forepeak tank and any other tanks and spaces under the bulkhead deck adjacent to cargo tanks, except cargo pump-rooms and ballast pump-rooms.

2.2 Where such spaces are connected to a permanently fitted inert gas distribution system, suitable means (e.g. a second water seal and check valve) shall be provided to prevent cargo vapours entering the double hull space.

2.3 Where no permanent distribution system is installed, a sufficient number of means for connecting to these spaces shall be provided on the inert gas main.

3. Ventilation of Spaces in the Cargo Area

3.1 Cargo and ballast pump spaces are to be equipped with mechanical ventilation systems of extraction type capable of at least 20 changes of air per hour.

3.2 The air intakes and outlets are to be located as far away from each other as possible to prevent recirculation of dangerous cargo vapours.

3.3 The air intakes and outlets are to be located at a horizontal distance of at least 3 metres from openings of accommodation areas, service and machinery spaces, control stations and other spaces outside the cargo area.

3.4 The height of the air intakes and outlets above the weather deck shall be at least 3 metres.

3.5 Air outlets are to be located at a height of 2 m above the gangway, where the distance between the outlets and this gangway is less than 3 m.

3.6 Suitable portable instruments for measuring oxygen and flammable vapours in the spaces mentioned under B.5.2 shall be provided. The gas detector instruments required under B.10 may be accepted for this purpose. In selecting these

instruments due attention shall be paid to their suitability for use in combination with the fixed sampling pipelines mentioned below.

Where measurement in double hull spaces cannot be carried out reliably using flexible sampling hoses, fixed sampling pipelines adapted to the configuration of these spaces shall be provided. Materials and dimensions of the fixed lines shall be such as to prevent any restriction of their function. Plastic pipes shall be electrically conductive.

4. Venting of Cargo Tanks

4.1 Cargo tanks are to be equipped with redundant venting devices in accordance with B.5.4. Both devices shall comply with the requirements as set out in B.5.4.2.a).

4.1.1 In case it is necessary to separate tanks or tank groups from a common system for cargo/ballast operations these tanks or tank groups shall be equipped with redundant venting devices as per 4.1.

4.1.2 Instead of redundant devices as per 4.1 each cargo tank may be equipped with a single vent system on condition that each cargo tank is equipped with over/under pressure sensors having indicators in the cargo control room or in a location where the cargo operations are controlled. Alarms shall be activated in above location when excessive over/under pressures occur.

For ships that apply pressure sensors in each tank as an alternative secondary means (redundant device as

per 4.1) of venting, the settings are to be fixed and not arranged for blocking or adjustment in operation.

In this respect;

- A P/V breaker fitted on the IG main may be utilised as the required secondary means of venting where the cargo is homogenous or for multiple cargoes where the vapours are compatible and do not require isolation.
- The height requirements of SOLAS Reg. II-2/4.5.3.4.1 and 11.6.2 and the requirements for devices to prevent the passage of flame of SOLAS Reg. II-2/4.5.3.3 are not applicable to the P/V breaker provided the settings are above those of the venting arrangements required by SOLAS Reg. II-2/11.6.1.
- Where the venting arrangements are of the free flow type and the masthead isolation valve is closed for the unloading condition, the IG systems will serve as the primary under-pressure protection with the P/V breaker serving as the secondary means.
- Inadvertent closure or mechanical failure of the isolation valves required by SOLAS Reg. II-2/4.5.3.2.2 and the FSS Code, Ch. 15, 2.3.2.2 need not be considered in establishing the secondary means where the cargo is homogenous or for multiple cargoes where the vapours are compatible and do not require isolation since:
 - i) The valves are operated under the control of the responsible ship's officer and a clear visual indication of the operational status of the valves is required by SOLAS Reg. II-2/4.5.3.2.2, as amended, and
 - ii) The possibility of mechanical failure of the valves is remote due to their simplicity.

- In the event of inadvertent closure or mechanical failure of the isolation valves required by SOLAS Reg. II-2/4.5.3.2.2, the secondary means shall be capable of preventing over-pressure or under-pressure.
- For ships that apply pressure sensors in each tank as an alternative secondary means of venting as per SOLAS Reg. II-2/11.6.3.2, the setting of the over-pressure alarm shall be above the pressure setting of the P/V-valve and the setting of the under-pressure alarm shall be below the vacuum setting of the P/V-valve. The alarm settings are to be within the design pressures of the cargo tanks. The settings are to be fixed and not arranged for blocking or adjustment in operation.

Note:

An exception is permitted for ships that carry different types of cargo and use P/V valves with different settings, one setting for each type of cargo. The settings may be adjusted to account for the different types of cargo.

4.2 Vent openings are to be fitted with flame arresters in accordance with B.6

4.3 Vent openings for loading and discharging operations are to be located at a horizontal distance of at least 10 m. from the following:

- Air intakes or openings to enclosed spaces which contain sources of ignition;
- Deck machinery **(4)** and equipment liable to constitute a source of ignition.

(4) *Electrical equipment fitted in compliance with IEC Publication 60092- Electrical installations in ships - Part 502: Tankers - Special features is not considered a source of ignition or ignition hazard.*

The following minimum heights of cargo tank vent openings above the tank deck and/or above the fore-and-aft gangway-when fitted within a distance of 4 m. of this gangway- are to be maintained:

- a) Outlet openings of high-velocity vents: 2 m.
- b) Outlet openings of other vents 6 m.

4.4 Openings for the relief of small quantities of vapours are also to be according to Item 4.3.

4.5 The openings pressure for loading or voyage respectively of the relief valves shall be adjusted not to exceed the values " p_v " or " p_{vmin} " used for the cargo tank strength calculation in Chapter 1 - Hull, Section 5

4.6 Slop tanks are to be equipped with the same venting arrangement as cargo tanks.

5. Bow and Stern Cargo Lines

5.1 Cargo lines for loading or unloading over the bow or stern may be approved on following conditions:

5.2 Outside the cargo area, bow and stern cargo lines may only be located on the open deck.

5.3 Pipelines forward and aft of the cargo area must have welded connections. Flanged connections to valves, fittings and compensators may be permitted where necessary. The pipelines must be clearly marked and must be fitted with shutoff valves in the cargo area. When they are not in service, it must be possible to segregate the pipelines at this point by detachable spool pieces and blank flanges or by two series-mounted valves which can be locked in the closed position and have an intermediate drain.

5.4 The shore connection is to be fitted with a shutoff valve and blank flange. The blank flange may be dispensed with if a suitable patent hose coupling is fitted.

5.5 Spray shields are to be provided at the shore connection except where the loading manifold is located

outboard. Collecting trays are to be fitted underneath transfer manifolds.

5.6 Means are to be provided by which pipelines outside the cargo area can be safely drained into a cargo tank and be rendered inert.

5.7 Means of communication are to be provided between the cargo control station and the shore connection.

5.8 The following foam fire-extinguishing equipment in accordance with Section 18, D.4 is to be provided for bow and stern cargo equipment:

- An additional monitor for protecting the manifold area,
- An applicator for protecting the cargo line forward or aft of the cargo area.

5.9 Electrical appliances within a distance of 3 m beyond the cargo shore connection must meet the requirements stated in Chapter 5 - Electrical Installations, Section 15.

5.10 Bow and stern cargo equipment must be so arranged that it does not hinder the launching of lifeboats. The launching station is to be suitably protected against cargo escaping from damaged pipes or cargo hoses.

5.11 Tankers with bow equipment for handling oil cargoes at single-point moorings at sea must meet the following requirements in addition to 5.1 to 5.10:

- a) A fixed water spraying system is to be provided covering the areas of chain stoppers and hose couplings.
- b) Air pipes to the fore peak are to be sited as far as possible from the gas dangerous areas.
- c) An emergency quick release system is to be provided for the cargo hose and ship's moorings system. The points of separation of which are to be located outside the ship's hull (see also Chapter 1 - Hull, Section 28).

- d) An operating manual must be carried on board which contains the necessary safety measures such as the operation of the emergency quick release system and the precautions in case of high tensions in the mooring system.

6. Combination Carriers

6.1 With the exception of oil residues in the slop tanks, the simultaneous carriage of bulk cargo and oil is not allowed.

6.2 The pipelines to the slop tanks are to be provided with spectacle flanges in combination with shutoff valves or alternatively spool pieces with two blank flanges each. When bulk cargo is being carried, the piping system of the slop tanks is to be separated from all other pipelines.

6.3 The slop tanks must be provided with an independent venting system.

6.4 A fixed pump is to be provided with a piping system for discharging slops. The discharge line is to be led directly to the deck and must be capable of being separated from all other systems by means of spool pieces during the carriage of bulk cargo.

The hose connection is to be fitted with a shutoff valve and a blank flange.

6.5 Slop tanks of combination carriers are to be provided with means of inerting or are to be connected to the fixed inert gas system (see Subsection D, 3.9).

6.6 Cofferdams adjacent to slop tanks shall have no pipe connections with cargo or ballast systems. Facilities must be provided to enable the cofferdams to be filled with water and to be drained (see also Chapter 1 - Hull, Section 28, J.3.).

6.7 Below deck cargo pipes shall not be located in hold spaces or ballast tanks. They shall be arranged in designated pipe ducts.

6.8 Where such ducts are situated within the assumed extent of damage, arrangements shall be made to avoid progressive flooding of other compartments not assumed to be damaged.

6.9 Ballast equipment for tanks located in the cargo area must be sited in the cargo area. It must not be connected with machinery spaces.

6.10 Cargo spaces and adjoining spaces must be capable of being ventilated by means of portable or fixed mechanical fans.

6.11 A fixed gas detection system of approved design with a visible and audible alarm is to be provided for cargo pump spaces, pipe ducts and cofferdams adjacent to slop tanks.

6.12 For all spaces and tanks not mentioned in 6.10 and 6.11 which are located in the cargo area, adequate means for verifying the absence of flammable vapours are to be provided on deck or in other easily accessible positions.

7. Safety Equipment in Cargo Pump Rooms

7.1 Temperature monitoring devices shall be fitted on cargo, ballast and stripping pump casings and on their gastight bulkhead shaft glands and bearings.

Visible and audible alarms shall be triggered in the cargo control room or the cargo control station.

7.2 Lighting in the pump room shall be interlocked with the pump room ventilation so that lights can only be switched on when the ventilation is in operation. Failure of the ventilation system shall not cause the lighting to go out. Emergency lighting, if fitted, shall not be interlocked.

7.3 A system for continuously monitoring the concentration of flammable vapours shall be fitted.

Sequential sampling is acceptable, if dedicated to the pump room sampling points only and the sampling time is reasonable short.

7.3.1 Sampling points or detector heads shall be fitted in suitable locations, e.g. in the exhaust ventilation duct and in the lower part of the pump room above the floor plates, recessed corners so that any possible leakage may be readily detected.

7.3.2 Where gas sampling piping is routed into gas safe spaces such as Cargo Control Room, Navigation Bridge or Engine Room following requirements are to be observed:

7.3.2.1 Gas sampling pipes shall be equipped with flame arresters. Sample gas outlets are to be arranged in the open at a safe location.

7.3.2.2 Bulkhead penetrations of sample pipes shall be of approved type. Manual isolating valves are to be fitted in each sampling line at the bulkhead on the gas safe side.

7.3.2.3 The gas detection equipment incl. sample piping, sample pumps, solenoids, analyser etc. shall be arranged in a totally enclosed steel cabinet with gasketed door being monitored for gas leakages by its own sampling point. At gas concentrations above 30% LEL, inside the cabinet the entire electrical equipment of the analyzing unit is to be shut down.

7.3.2.4 Where the cabinet as per 7.3.2.3 cannot be arranged direct on the bulkhead sample pipes shall be of steel or equivalent and without detachable connections except for the connections of bulkhead valves and the analysing unit. The pipes are to be routed on the shortest way through this space.

7.3.3 Visible and audible alarms in the pump room, cargo control room, engine control room and on the bridge shall be triggered if the concentration of flammable gases exceeds 10% of the lower explosive limit (LEL).

7.4 Bilge level monitoring devices shall be provided in all pump rooms, triggering visible and audible alarms in the cargo control room or the cargo control station and on the bridge.

8. Gas Measurement and Detection

8.1 Portable instrument

Every oil tanker is to be provided with at least two portable gas detectors capable of measuring flammable vapour concentrations in air (%LEL) and at least two portable O₂ analysers. Alternatively, at least two gas detectors, each capable of measuring both oxygen and flammable vapour concentrations in air (%LEL), are to be provided.

In addition, for tankers fitted with inert gas systems, at least two portable gas detectors are to be capable of measuring concentrations of flammable vapours in inerted atmosphere (% gas by volume).

8.2 Arrangements for gas measurement in double hull spaces and double bottom spaces.

8.2.1 Suitable portable instruments for measuring oxygen and flammable vapour concentrations in double hull spaces and double bottom spaces shall be provided. The instruments shall be suitable to be used in combination with 8.2.2 if applicable.

8.2.2 Where the atmosphere in double hull spaces and double bottom spaces cannot be reliably measured using flexible hoses, such spaces shall be fitted with permanent gas sampling lines. The arrangement of the permanent lines shall be adapted to the design of the double hull spaces and double bottom spaces.

8.2.3 Materials of construction and dimensioning of the gas sampling lines shall be such as to prevent restrictions. Where plastic pipes are used, they shall be electrically conductive.

8.3 Arrangement for fixed hydrocarbon gas detection systems in double hull spaces and double bottom spaces of oil tankers.

8.3.1 In addition to the requirements of 8.1 and 8.2 oil tankers of 20.000 DWT and above, constructed on or after 1 JULY 2012, shall be provided with a fixed

hydrocarbon gas detection system complying with the FSS Code for measuring hydrocarbon gas concentrations in all ballast tanks and void spaces of double hull and double bottom spaces adjacent to cargo tanks including the forepeak tank and any other tanks and spaces under the bulkhead deck adjacent to cargo tanks.

Note:

1. The term “cargo tanks” in the phrase “spaces adjacent to the cargo tanks” includes slop tanks except those arranged for the storage of oily water only.

2. The term “spaces” in the phrase “spaces under the bulkhead deck adjacent to cargo tanks” includes dry compartments such as ballast pump-rooms and bow thruster rooms and any tanks such as freshwater tanks, but excludes fuel oil tanks.

3. The term “adjacent” in the phrase “adjacent to the cargo tanks” includes ballast tanks, void spaces, other tanks or compartments located below the bulkhead deck located adjacent to cargo tanks and includes any spaces or tanks located below the bulkhead deck which form a cruciform (corner to corner) contact with the cargo tanks.

8.3.2 Oil tankers with constant operative inerting systems for such spaces need not be equipped with affixed hydrocarbon gas detection system. (See also BCS- G 131)

8.3.3 Cargo pump rooms are subject to the requirements of 7. and need not comply with the above.

D. Inert Gas Systems for tankers

1. General

1.1 An inert gas system complying with the applicable requirements of Ch. 15 of the FSS Code, as amended by MSC.367 (93), is to be fitted on tankers which 8,000 DWT and upwards and when carrying;

- Crude oil or petroleum products having a flashpoint not exceeding 60°C (closed cup test), as determined by an approved flashpoint apparatus, and a Reid vapour

pressure which is below the atmospheric pressure or other liquid products having a similar fire hazard or;

- Other than those referred to in the bullet above or liquefied gases which introduce additional fire hazards are intended to be carried, for which additional safety measures shall be required, having due regard to the provisions of the International Bulk Chemical Code, the Bulk Chemical Code, the International Gas Carrier Code and the Gas Carrier Code, as appropriate,

1.2. In applying the applicable requirements of Ch. 15 of the FSS Code, any use of the word "Administration " therein is to be considered as **BCS** . The inert gas system is to be operated in accordance with SOLAS regulation II-2/16.3.3, as amended by MSC . 365 (93). In applying SOLAS regulation II- 2/16.3.3.2, paragraph 2.2.1.2.4 of Ch. 15 of the FSS Code is to be complied with.

1.3 Tankers operating with a cargo tank cleaning procedure using crude oil washing shall be fitted with an inert gas system complying with the Fire Safety Systems Code and with fixed tank washing machines

1.4 Tankers required to be fitted with inert gas systems shall comply with provisions of item C.2.

1.5 The inert gas system shall be capable of inerting, purging and gas-freeing empty tanks and maintaining the atmosphere in cargo tanks with the required oxygen content.

1.6 Tankers fitted with a fixed inert gas system shall be provided with a closed ullage system.

1.7 An automatic control capable of producing suitable inert gas under all service conditions is to be fitted.

1.8 Subsequent surveys are to be carried out at the intervals as defined in **BCS**, Classification and Survey Rules.

1.9 Automatic shutdown of the inert gas system and its components parts are to be arranged on predetermined limits being reached, taking into account the provisions of FSS Code paragraphs 15.2.2.4, 15.2.3.2 and 15.2.4.2, and are to be in accordance with BCS-I SC284.

1.10 The inert gas main is to be fitted with branch piping leading to the cargo tank. Branch piping for inert gas is to be fitted with either stop valves or equivalent means of control for isolating each tank. Where stop valves are fitted, they are to be provided with locking arrangements. The control system is to provide unambiguous information (position indicators providing open/intermediate/closed status information) of the operational status in accordance with BCS-I SC285 of such valves to at least the control panel required in paragraph 15.2.2.4 of FSS Code.

1.11 Connections between the inert gas main and the cargo piping system, taking into account of FSS Code paragraphs 15.2.2.3.2.7 and 15.2.2.3.2.8, and are to be equipped with suitable isolating means in accordance with BCS-I SC62.

1.12 The operation status of the inert gas system is to be indicated in a control panel as required by FSS Code Chapter 15.2.2.4.1, and is to be in accordance with BCS-I SC286.

1.13 Audible and visual alarms as required by FSS Code Chapter 15.2.2.4.5 is to be in accordance with BCS-I SC287.

2. Additional Requirements for Nitrogen Generator Systems including Chemical Tankers

2.1 The following requirements apply where a nitrogen generator system is fitted on board as required by SOLAS regulation II-2/4.5.5.1. For the purpose, the inert gas is to be produced by separating air into its

component gases by passing compressed air through a bundle of hollow fibres, semi-permeable membranes or adsorber materials.

2.2 In addition to the applicable requirements of Ch. 15 of the FSS Code, as amended by MSC.367(93), the nitrogen generator system is to comply with SOLAS regulations II- 2/4.5.3.4.2, 4.5.6.3 and 11.6.3.4.

2.3 A nitrogen generator is to consist of a feed air treatment system and any number of membrane or adsorber modules in parallel necessary to meet paragraph 2.2.1.2.4 of Ch.15 of the FSS Code, as amended by MSC.367(93).

2.4 The nitrogen generator is to be capable of delivering high purity nitrogen in accordance with paragraph 2.2.1.2.5 of Ch.15 of the FSS Code, as amended by MSC.367(93). In addition to paragraph 2.2.2.4 of Ch.15 of the FSS Code, as amended by MSC.367(93), the system is to be fitted with automatic means to discharge "off-spec" gas to the atmosphere during start-up and abnormal operation.

2.5 The system is to be provided with one or more compressors to generate enough positive pressure to be capable of delivering the total volume of gas required by 2.2.1.2 of the FSS Code, as amended by MSC.367(93). Where two compressors are provided, the total required capacity of the system is preferably to be divided equally between the two compressors, and in no case is one compressor to have a capacity less than 1/3 of the total capacity required.

2.6 The feed air treatment system fitted to remove free water, particles and traces of oil from the compressed air as required by 2.4.1.2 of Ch.15 of the FSS Code, as amended by MSC.367(93), is also to preserve the specification temperature.

2.7 The oxygen-enriched air from the nitrogen generator and the nitrogen-product enriched gas from the protective devices of the nitrogen receiver are to be discharged to a safe location **(5)** on the open deck.

2.8 In order to permit maintenance, means of isolation are to be fitted between the generator and the receiver.

3. Nitrogen /Inert Gas Systems Fitted for Purposes other than Inerting Required by SOLAS Reg. II-2/4.5.5.1 and 4.5.5.2

3.1 This item applies to systems fitted on oil tankers, gas tankers or chemical tankers to which SOLAS regulations II-2/4.5.5.1 and 4.5.5.2 do not apply.

3.2 Paragraphs 2.2.2.2 (See also BCS-I SC284), 2.2.2.4, 2.2.4.2, 2.2.4.3, 2.2.4.5.1.1, 2.2.4.5.1.2, 2.2.4.5.4, 2.4.1.1, 2.4.1.2, 2.4.1.3, 2.4.1.4, 2.4.2.1 and 2.4.2.2 of Ch.15 of the FSS Code, as amended by MSC.367(93), as applicable apply to the systems.

3.3 The requirements of D.2 apply except items 2.1, 2.2, 2.3 and 2.5.

3.4 Materials used in inert gas systems are to be suitable for their intended purpose in accordance with **BCS**, Chapter 2, Material.

(5) “safe location” address the two types of discharges separately:

1. oxygen-enriched air from the nitrogen generator – safe locations on the open deck are:

- outside of hazardous area;
- not within 3 m of areas traversed by personnel; and
- not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets.

2. nitrogen-product enriched gas from the protective devices of the nitrogen receiver – safe locations on the open deck are:

- not within 3 m of areas traversed by personal: and
- not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets/outlets.

3.5 All the equipment is to be installed on board and tested under working conditions to the satisfaction of the Surveyor.

3.6 The two non-return devices as required by paragraph 2.2.3.1.1 of Ch.15 of the FSS Code, as amended by MSC.367(93) are to be fitted in the inert gas main. The non-return devices are to comply with 2.2.3.1.2 and 2.2.3.1.3 of Ch.15 of the FSS Code, as amended by MSC.367(93); however, where the connections to the cargo tanks, to the hold spaces or to cargo piping are not permanent, the non-return devices required by paragraph 2.2.3.1.1 of Ch.15 of the FSS Code, as amended by MSC.367(93) may be substituted by two non-return valves.

4. Inert Gas Storage Systems

4.1 General

Inert gas storage systems may also be provided for inerting the spaces surrounding tanks and for blanketing the cargo in the tanks. The stored quantity of gas must be sufficient to allow for losses of inert gas during the voyage.

4.2 Design

4.2.1 The inert gas may be stored in pressure vessels or cylinders. Pressure vessels are to be located in the cargo area on the open deck or in separate spaces. Pressure vessels and cylinders are subject to the requirements in Section 14.

The provisions of Section 18, G.2.2 and G.3 apply wherever relevant to the installation of pressure vessels and cylinders in closed spaces.

4.2.2 A pressure reducing valve backed up by a safety valve is to be fitted to pressure vessels and batteries of cylinders.