Rules For Classification And Construction

Part 1 Seagoing Ships

RULES FOR MACHINERY INSTALLATIONS

Volume III

January 2025 Edition

Biro Klasifikasi Indonesia

www.bki.co.id

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Amendments to the preceding Edition are marked by red colour and expanded text.

However, if the changes involves the whole section or sub section normally only the title will be in red colour.

Foreword

This Rules for Machinery Installations (Pt.1, Vol.III) January 2025 Edition replace the Rules for Machinery Installations (Pt.1, Vol.III) July 2024 Edition. In this edition, new amendments are introduced which are mainly derived from IACS publications, and inputs from BKI Branch Offices and Technical Division BKI Head Office

The summary of previous edition and amendments including the implementation date are indicated in Table below:

	Edition/ Rule Change Notice (RCN)	Effective Date	Link
1	Edition July 2024	1st July 2024	🔗
2	Consolidated Edition 2024	–	🔗
3	RCN No.4, October 2023	1st January 2024	🔗
4	RCN No.3, April 2023	1st July 2023	🔗
5	RCN No.2, October 2022	1st January 2023	🔗
6	RCN No.1, April 2022	1st July 2022	🔗
7	Consolidated Edition 2022	–	🔗
8	RCN No.2 Nov 2021	1st January 2022	🔗
9	RCN No.1 May 2021	1st July 2021	🔗
10	Consolidated Edition 2021	–	🔗
11	RCN No.1 July 2020	1st July 2020	🔗
12	Edition 2019	1st July 2019	🔗
13	RCN No.1 October 20218	1st January 2019	🔗
14	Edition 2018	1st July 2018	🔗

A summary of amendments to the previous edition, including the implementation date for each section, is presented in **Table 1 - Amendments incorporated in This Notice**.

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Further queries or comments concerning this rules are welcomed through communication to BKI Head Office.

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Rules Amendment Notice

Table 1 - Amendments incorporated in This Notice

These amendments will come into force on 1st January 2025, except stated otherwise as indicated in the Table.

Paragraph	Title/Subject	Status/Remark
Section 2 Internal Combustion Engines and Air Compressor		
2.F.	**Safety Devices**	
2.F.1.1.3	Speed control and engine protection against over-speed	To add new requirements for electronic speed governor of main engine when form the part of remote control system [IACS UR M3 Rev.7]
2.H.	**Starting Equipment**	
2.H.2.6	Starting with compressed air	To add new requirements concerning starting arrangement of internal combustion engine in accordance with IACS UR M61 Rev.3
2.H.6	Capacity and availability of compressed air for essential services	To add new requirements concerning capacity and availability of compressed air for essential services in according to IACS UR M84
2.O.	**Gas-Fuelled Engines**	
2.O.1.2	—	To detailed the scope of gas-fuelled engine section, and to accommodate the engine using fuel with main component methane such as bio or synthetic methane (IACS UR M78 Rev.2)
2.O.1.3	—	Renumbering
2.O.1.4	—	To add provision for specify the state of gas supplied to engine (IACS UR M78 Rev.2)
2.O.1.5	—	Renumbering and to add provision that enable the combination of any variation of dual-fuel engine and single fuel gas engine (IACS UR M78 Rev.2)
2.O.1.6	—	To add new provision to prohibit the use of gas engine for emergency applications (IACS UR M78 Rev.2)
2.O.3.6	Certified safe equipment	To add definition of certified safe equipment according to IACS UR M78 Rev.2
2.O.3.7	Explosion relief device	To add definition of explosion relief device according to IACS UR M78 Rev.2
2.O.3.8	High pressure gas	To add definition of high pressure gas according to IACS UR M78 Rev.2
2.O.3.9	Low pressure gas	To add definition of low pressure gas according to IACS UR M78 Rev.2
2.O.3.10	Pre-mixed engine	To add definition of pre-mexid engine according to IACS UR M78 Rev.2

Paragraph	Title/Subject	Status/Remark
Section 2 Internal Combustion Engines and Air Compressor		
2.O.5	Documents to be submitted, Table 2.11	To supersede the list of documents to be submitted for approval of DF and SF (IACS UR M78 Rev.2)
2.O.6.1	Scope of the risk analysis	To supersede the gas valve unit to double block and bleed valves (IACS UR M78 Rev.2)
2.O.6.4 1)	Gas-Fuelled Engines	To add gas admission valves in the risk analysis for the failure of the gas related system in accordance with IACS UR M78 Rev.2
2.O.6.4.7)	—	To include the scavenge space, cooling water system, etc in area in which gas may be presence (IACS UR M78 Rev.2)
2.O.7.1.2	—	To add new requirements concerning the documentation of strength of component in accordance with IACS UR M78 Rev.2
2.O.7.4.2.8	—	To add new requirements concerning change over to oil fuel mode in accordance with IACS UR M78 Rev.2
2.O.7.6	Two-stroke engines	To add new requirement for gas fuelled two stroke engine in accordance with IACS UR M78 Rev.2
2.O.8.5.1.4	—	To add new requirement for criteria in designing of gas piping in accordance with IACS UR M78 Rev.2
2.O.8.5.1.4	—	To add new requirement for criteria in designing of gas piping in accordance with IACS UR M78 Rev.2
2.O.8.5.1.5	—	To add new requirement for type approval of connection in accordance with IACS UR M78 Rev.2
2.O.8.5.1.6	—	To add new requirement for single walled or high-pressure gas pipe in accordance with IACS UR M78 Rev.2
2.O.8.5.1.7	—	To add new requirement for low pressure double walled gas pipe in accordance with IACS UR M78 Rev.2
2.O.8.5.1.8	—	To add new requirement for secondary enclosures for gas pipes in accordance with IACS UR M78 Rev.2
2.O.8.5.1.9	—	To add new requirement for single walled gas vent pipe in accordance with IACS UR M78 Rev.2
2.O.8.5.1.10	—	To add new requirement for gas vent pipes in accordance with IACS UR M78 Rev.2
2.O.8.5.1.11	—	To add new requirement for secondary enclosure in accordance with IACS UR M78 Rev.2
2.O.8.5.1.12	—	To add new requirement for approval of flexible bellows in accordance with IACS UR M78 Rev.2
2.O.8.5.1.13	—	To add new requirement to specify the items that will encounter in actual service of engine in accordance with IACS UR M78 Rev.2

Paragraph	Title/Subject	Status/Remark
Section 2 Internal Combustion Engines and Air Compressor		
2.O.8.5.1.14	—	To add new requirement for verification of high cycle fatigue due to vibration in accordance with IACS UR M78 Rev.2
2.O.8.5.4.1	Normal "double wall" Arrangement	To add supersede the requirements for pressure test of double wall in accordance with IACS UR M78 Rev.2
2.O.8.5.5	Charge air system and exhaust gas system on the engine	To add new requirements for charge air system and exhaust gas system in accordance with IACS UR M78 Rev.2
2.O.8.5.6.3	—	To add new requirements of sealing arrangement of gas admission valve in accordance with IACS UR M78 Rev.2
2.O.8.8	Table 2.13	To add new instrumentation item for gas-fuelled engine in accordance with IACS UR M78 Rev.2
2.O.8.9.4	—	To add new requirements for explosion relief system in accordance with IACS UR M78 Rev.2
2.O.8.9.4	—	To add new requirements for explosion relief system in accordance with IACS UR M78 Rev.2
2.O.9.2.3.6	—	To add new requirements for cranckcase ventilation in accordance with IACS UR M78 Rev.2
2.O.9.3.2.5	—	To add new requirements for detailed evaluation of explosion relief valve in accordance with IACS UR M78 Rev.2
2.O.10.1.2	Type of engine	To add new definition of engine type in accordance with IACS UR M78 Rev.2
2.O.10.1.5	Measurements and records	To add new requirements concerning the gas concentration measurement in gas-fuelled engine in accordance with IACS UR M78 Rev.2
2.O.10.1.6	Stage A – Internal tests	To add new requirements concerning the verification of influence of methane number of gas fuel for dual fuel engine in accordance with IACS UR M78 Rev.2
2.O.10.1.7	Stage B – witnessed tests	To add new requirements concerning the witnessed test of duel fuel engine in accordance with IACS UR M78 Rev.2
2.O.10.1.9	Engine type approval certificate	To add new requirements concerning the type approval certificate of gas-fuelled engine in accordance with IACS UR M78 Rev.2
2.O.10.2	Factory Acceptance Test	To add new requirements concerning the factory acceptance test of gas-fuelled engine in accordance with IACS UR M78 Rev.2
2.O.10.3	Shipboard trials	To add new requirements concerning additional test of the gas-fuelled engine during ship board trials in accordance with IACS UR M78 Rev.2
2.O.11	Certification of Engine Components	To add new requirements concerning the certification of gas-fuelled engine in accordance with IACS UR M78 Rev.2

Paragraph	Title/Subject	Status/Remark
Section 12 Fire Protection and Fire Extinguishing Equipment		
12.G.	**High-Pressure CO_2 Fire Extinguishing Systems**	
12.G.1.1.1	Machinery, boiler and cargo pump spaces	To align the requirement of CO_2 capacity with FSS Code Ch.5.2.2.1.3.1
12.P.	**Equipment for the Transport of Dangerous Goods**	
12.P.1.2	Documents to be submitted	To add plans, drawings and documents to be submitted to BKI
12.Q.	**Carriage of Solid Bulk Cargoes**	
12.Q.6.7.2	Openings for continuous ventilation	To add new requirements for means of closure for continuous ventilation or ventilation all the time in accordance with IACS UI SC89 Rev.5
Section 14 Steering Gears, Rudder Propeller Units, Lateral Thrust Units, Winches, Hydraulic Control Systems, Fire Door Control Systems, Stabilizers, Water Jets		
14.A.	**General**	
14.A.5.2.4	—	Corrigenda for the formula (4) of thread root diameter of the bolt.
Section 17 Spare Parts		
17.C.	**Volume of Spare Parts**	
17.C.1, 17.C.2	—	To add new requirements for determination of the spare parts volume by risk-based approach in accordance with IACS UI SC89 Rev.5
Table 17.1, Table 17.2, Table 17.3, Table 17.4, Table 17.5	Table 17.1, Table 17.2, Table 17.3, Table 17.4, Table 17.5	To add new requirements related to control, alarm and safety system in accordance with IACS Rec.27 Rev.2, Rec.28 Rev.2, Rec.29 Rev.2, Rec.30 Rev.2.

Table of Contents

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Section 1 General Rules and Instructions

A. General

1. The Rules for Machinery Installations apply to the propulsion installations of ships classed by Biro Klasifikasi Indonesia including all the auxiliary machinery and equipment necessary for the operation and safety of the ship

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

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

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

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

Such machinery may be marked by the Notation **"EXP."** affixed to the Character of Classification and be subjected to intensified survey, if sufficiently reliable proof cannot be provided of its suitability and equivalence in accordance with A.3.

5. In the instances mentioned in A.3.. and A.4.. BKI is entitled to require additional documentation to be submitted and special trials to be carried out.

6. In addition to the Rules, BKI reserves the right to impose further requirements in respect of all types of machinery where this is unavoidable due to new findings or operational experience, or BKI may permit deviations from the Rules where these are specially warranted.

7. 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.13691 Regulation 21 of SOLAS Chapter II-2 [1)] as amended by IMO resolutions up to MSC.421(98). A qualitative failure analysis for propulsion and steering for new passenger ships are explained in detail in I.

8. National Rules or Regulations outside BKI's Rules remain unaffected.

9. For the interpretation of International Convention and Code, Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) is to be observed.

[1)] Applicable to passanger ships with keel laying on or after 1 July 2010

B. Documents for Approval

1. Before the start of manufacture, plans showing the general arrangement of the machinery installation together with all drawings of parts and installations subject to testing, to the extent specified in the following Sections are each to be submitted in electronic format.

2. The drawings shall contain all the data necessary for approval. Where necessary, calculations and descriptions of the plant are to be submitted.

3. Once the documents submitted have been approved by BKI they are binding on the execution of the work. Any subsequent modifications require BKI's approval before being put into effect.

4. Where a product has been tested and certified based on standards yielding at least equivalent results as required by the applicable BKI Rules, subject certificate including its relevant supplements, if applicable, are to be submitted. In such cases, BKI reserves the right to request additional supportive design evaluation documents, as appropriate.

C. Ambient Conditions

1. Operating conditions, general

1.1 The selection, layout and arrangement of all shipboard machinery, equipment and appliances shall be such as to ensure faultless continuous operation under the ambient conditions specified in Tables 1.1 to Table 1.4

BKI 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.

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

Table 1.1: Inclinations

<table>
<tr><th rowspan="3">Installations, Components</th><th colspan="4">Angle of Inclination [°] [2)]</th></tr>
<tr><th colspan="2">Athwart ship</th><th colspan="2">Fore-and-aft</th></tr>
<tr><th>static</th><th>dynamic</th><th>static</th><th>dynamic</th></tr>
<tr><td>Main and auxiliary machinery</td><td>15</td><td>22,5</td><td>5 [4)]</td><td>7,5</td></tr>
<tr><td>Ship's safety equipment, e.g. emergency power installations, emergency fire pumps and their drives</td><td rowspan="2">22,5 [3)]</td><td rowspan="2">22,5 [3)]</td><td rowspan="2">10</td><td rowspan="2">10</td></tr>
<tr><td>Switchgear, electrical and electronic appliances [1)] and remote control systems</td></tr>
</table>

1) No undesired switching operations or functional changes are to occur.
2) Athwart ships and fore-and-aft inclinations may occur simultaneously.
3) On ships for the carriage of liquefied gases and chemicals the emergency power supply must also remain operational with the ship flooded to a final athwart ships inclination up to a maximum of 30°, See the Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Section 5, SC 290.
4) Where the length of the ship exceeds 100 m, the fore-and-aft static angle of inclination may be taken as $500/L$ degrees.

Table 1.2: Water Temperature

Coolant	Temperature [°C]
Seawater	+ 32 [1)]
Charge air coolant inlet to charge air cooler	+ 32 [1)]

1) BKI may approve lower water temperatures for ships operating only in special geographical areas.

Table 1.3: Air Temperature

at atmosphere pressure = 1000 mbar
and relative humidity = 60 %

Installations, components	Location, arrangement		Temperature range [°C]
Machinery and electrical installations [1]	in	enclosed spaces	0 to 45 [2]
	on	Machinery components, boilers	According to specific local conditions
	in	spaces, subject to higher or lower temperatures	
	on	the open deck	-25 to + 45

[1] Electronic appliances shall be designed and tested to ensure trouble free operation even at a constant air temperature of + 55°C

[2] BKI may approve lower air temperatures for ships designed only for service in particular 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 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

2. Shipboard accelerations

2.1 Main propulsion and steering machinery and auxiliary machinery that is essential to the propulsion and steering, and the safety of the ship shall be capable of operation under the effects of acceleration and motions.

2.2 The requirements in .C.3. to .C.5. apply where documented evidence of equipment suitability is specifically required by this Rules for such equipment or requested by BKI.

3. Documentation

3.1 For ships subject to the SOLAS Convention, ship builders are to identify and document the ship accelerations and motions periods to which machinery and equipment might be subjected to. The expected accelerations and ship motions periods are to be within machinery and equipment manufacturers requirements. The estimations are to consider vessel type, machinery or equipment location and expected service conditions.

4. Evaluation of equipment suitability

4.1 Machinery and equipment manufacturers are to submit evidence to BKI that their machinery or equipment can operate under the required static and dynamic conditions stated in Table O.8.5.1.14 and at least at the levels of shipboard accelerations as stated in .C.3. and/or specified in the relevant Rules. Documentation of satisfactory performance shall take the form of:

4.1.1 Report of testing under representative conditions; or

4.1.2 Report of theoretical verification using recognised computational techniques accompanied by detailed and relevant validation data: or

4.1.3 Historical data which provides relevant demonstration of satisfactory experience in service.

5. Installation and operation

5.1 Machinery and equipment manufacturers are to submit details of the requirements/recommendations for installation of the machinery and equipment onboard to ensure satisfactory operation in service under the required static and dynamic conditions as described in Table O.8.5.1.14 and at least at the levels of shipboard accelerations as stated in .C.3. and/or specified in the relevant Rules.

Note:

Consideration should be given for positioning machinery in order to minimize the dynamic load on bearings due to ship motion.

5.2 Shipbuilders are to submit details demonstrating that the installation of the machinery and equipment onboard is in accordance with manufacturer's requirements/recommendations.

6. Vibrations

6.1 General

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

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

Guidance for Recommendations (Pt.1, Vol.AC) Sec.9, R -167 may be taken into account for identify the vibration issues and recommended remedial measures.

6.1.2 For vibrations generated by an engine or other device the intensity shall not exceed defined limits. The purpose is to protect the vibration generators, the connected assemblies, peripheral equipment and hull components from additional, excessive vibration stresses liable to cause premature failures or malfunctions.

6.1.3 The following provisions relate the vibrations in the frequency range from 2 to 300 Hz. The underlying assumption is that vibrations with oscillation frequencies below 2 Hz can be regarded as rigidbody vibrations while vibrations with oscillation frequencies above 300 Hz normally occur only locally and may be interpreted as structure-borne noise. 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.

6.0.1 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, consideration is to be extended to the whole available working speed range and, where appropriate, to the whole power range.

6.1.4 The procedure described below is largely standardized. Basically, a substitution quantity is formed for the vibration stress or the intensity of the exciter spectrum (see. C.6.2.1). This quantity is then compared with permissible or guaranteed values to check that it is admissible.

6.1.5 The procedure mentioned in C.6.1.4 takes only incomplete account of the physical facts. The aim is to evaluate the true alternating stresses or alternating forces. No simple relationship exists between the actual loading 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.

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

6.2 Assessment

6.2.1 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 stress. The same criterion is used to evaluate the intensity of the vibration spectrum produced by a vibration exciter (see. C.6.1.2).

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

$$V_{eff} = \frac{1}{\sqrt{2}} \cdot \hat{s} \cdot \omega = \frac{1}{\sqrt{2}} \cdot \nu = \frac{1}{\sqrt{2}} \cdot \frac{\hat{a}}{\omega} \quad (1)$$

in which

$\hat{s}$	=	vibration displacement amplitude
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:

$$V_{eff} = \sqrt{V^2_{eff_1} + V^2_{eff_2} + ...V^2_{eff_n}} \quad (2)$$

in which v_{effi} is the effective value of the vibration velocity of the i-th harmonic component. Using formula (1), 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 (1) for purely sinusoidal oscillations or by formula (2) for any periodic oscillation.

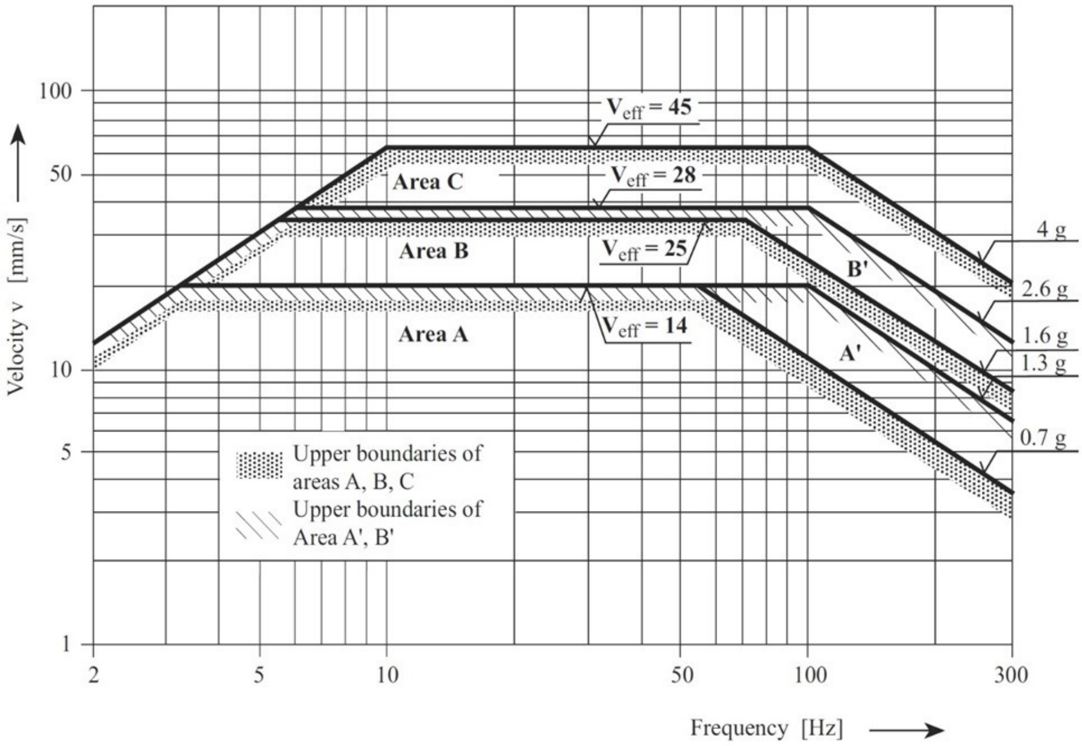

Figure 1.1: Areas for the assessment of vibration loads

6.2.2 The assessment of vibration loads is generally based on areas **areas A**, **B** and **C**, which are enclosed by the boundary curves shown in Fig. 1.1. The boundary curves of **areas A**, **B** and **C** are indicated in Table 1.5. If the vibration to be assessed comprises several harmonic components, the effective value according to 2.2.1 is to be applied. The assessment of this value is to take account of all important harmonic components in the range from 2 to 300 Hz.

6.2.3 **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 load corresponding to the boundary curve of **area A**.

Otherwise, with BKI's consent, steps are to be taken (vibration damping etc.) to reduce the actual vibration load to the permissible level.

6.2.4 Because they act as vibration exciters, reciprocating machines are to 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 turbocharger and lubricating oil pumps) and adjacent machines or plant (e.g. generators, transmission systems and pipes) may, for the purpose of these Rules and with due regard to the limitations stated in 2.1.6, be assessed using the substitution quantities presented in 2.2.1

Table 1.5: Numerical definition of the area boundaries shown in Fig. 1.1

Areas		A	B	C	A'	B'
$\hat{s}$	[mm]	< 1	< 1	< 1	< 1	< 1
v	[mm/s]	< 20	< 35	< 63	< 20	< 40
V_{eff}	[mm/s]	< 14	< 25	< 45	< 14	< 28
$\hat{a}$	[9,81 m/s^2]	< 0,7	< 1,6	< 4	< 1,3	< 2,6

.1 In every case the manufacturer of reciprocating machines has to guarantee permissible vibration loads for the important directly connected peripheral equipment. The manufacturer of the reciprocating machine is responsible to BKI for proving that the vibration loads are within the permissible limits in accordance with 2.3.

.2 Where the vibration loads of reciprocating machines lie within the **area A'**, separate consideration or proofs relating to the directly connected peripheral equipment (see. 2.2.4) are not required. The same applies to machines and plant located in close proximity to the generator (2.2.4)

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

If the permissible vibration loads of individual directly connected peripheral appliances in accordance with 2.2.4.1 lie below the boundary curve of **area B**, admissibility shall be proved by measurement of the vibration load which actually occurs.

.3 If the vibration loads of reciprocating machines lie outside **area A'** but are still within **area B'**, it shall 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 loads 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 loads than those defined by the boundary curve of **area B**.

If the permissible vibration loads of individual directly connected peripheral appliances or machines in accordance with 2.2.4.1 lie below the stated values, admissibility shall be proved by measurement of vibration load which actually occurs.

.4 If the vibration loads of reciprocating machines lie outside **area B'** but are still within **area C**, it is necessary to ensure that the vibration loads on the directly connected peripheral appliances still remain within **area C**. If this condition cannot be met, the important peripheral appliances are to be in accordance with 2.3 be demonstrably designed for the higher loads.

Suitable measures (vibration damping etc.) are to be taken to ensure reliable prevention of excessive vibration loads on adjacent machines and appliances. The permissible loads stated in 2.2.4.3 (**area B** or a lower value specified by the manufacturer) continue to apply to these units.

.5 For directly connected peripheral appliances, BKI may approve higher values than those specified in 2.2.4.2, 2.2.4.3 and 2.2.4.4 where these are guaranteed by the manufacturer of the reciprocating machine in accordance with 2.2.4.1 and are proved in accordance with 2.3. Analogously, the same applies to adjacent machines and appliances where the relevant manufacturer guarantees higher values and provides proof of these in accordance with 2.3.

6.2.5 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 load may, notwithstanding 2.2.3, be assessed according to the limits of **area B**. The design of such equipment shall allow for the above mentioned increased loads.

6.3 Proofs

6.3.1 Where in accordance with 2.2.4.1, 2.2.4.4, and 2.2.4.5 BKI is asked to approve higher vibration load values, all that is normally required for this is the binding guarantee of the admissible values by the manufacturer or the supplier

6.3.2 BKI reserves the right to call for detailed proofs (calculations, design documents, measurements, etc.) in case where this is warranted.

6.3.3 Type approval in accordance with Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol. W), Sec.3.T is regarded as proof of admissibility of the tested vibration.

6.3.4 BKI may recognize long-term trouble free operation as sufficient proof of the required reliability and operational dependability.

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

6.4 Measurement

6.4.1 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 in 2.2.4 .2 to 2.2.4 .4 are met. Where circumstances warrant this, BKI may also require proofs based on measurements for smaller outputs.

6.4.2 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.

6.4.3 BKI 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.

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

6.4.4 The assessment of the vibration stresses affecting or generated by reciprocating machines normally relates to the location in which the vibration loads are greatest. Fig. 1.2 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.

6.4.5 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 2.2.

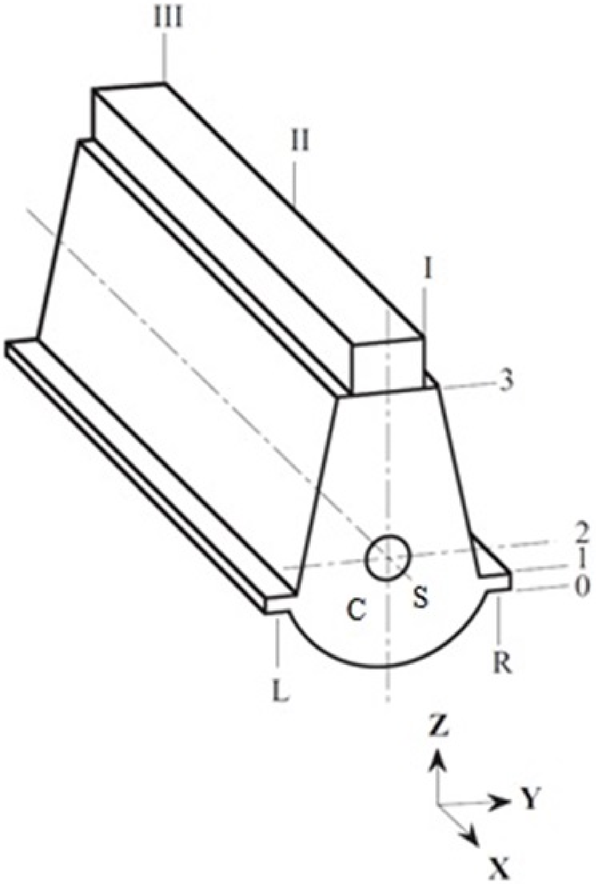

Figure 1.2: Schematic representation of in-line piston engine

Side for measurement	**L**	left side looking towards coupling flange
	R	right side looking towards coupling flange
Measuring height	**0**	bed
	1	base
	2	crankshaft height
	3	frame top
Measuring point over engine length	**I**	coupling side (CS)
	II	engine centre
	III	opposite side to coupling (CGS)

6.4.6 The records of the measurements for the points at which the maximum loads occur are to be submitted to BKI together with a tabular evaluation.

D. Design and Construction of the Machinery Installation

1. Dimensions of components

1.1 All parts are to be capable of withstanding the stresses and loads peculiar to shipboard service, e.g. those due to movements of the ship, vibrations, intensified corrosive attack, temperature changes and wave impact, and shall be dimensioned in accordance with the requirements set out in the present Volume.

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

1.2 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 over-stressing 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.

2. Materials

All components shall comply with Rules for Materials (Pt.1, Vol. V).

3. Welding

The fabrication of welded components, the approval of companies and the testing of welders are subject to Rules for Welding (Pt.1, Vol. VI).

4. Tests

4.1 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 BKI.

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

4.2 BKI 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.

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

4.4 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 BKI Surveyor.

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

4.5 For the requirements during sea trials see Guidance for Sea Trials of Motor Vessels (Pt.1, Vol.B).

5. 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.

6. Availability of machinery

6.1 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.

The **"dead ship"** condition means that the entire machinery installation including the electrical power supply is out of operation and 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.

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.

6.2 In case of **"dead ship"** condition it is to 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 Rules for Electrical Installations (Pt.1, Vol.IV), Sec.3.C.1.4)

7. Control and regulating

7.1 Machinery is to 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.

7.1.1 For the control equipment of main engine and system essential for operation see Rules for Electrical Installations (Pt.1, Vol. IV) Sec.9.B.4.

7.2 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 break in a regulating or control circuit, steps shall 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 governed is not increased and
- no unintentional start-up sequences are initiated.

7.3 Manual operationManual operation

Every functionally important, automatically or remote controlled system shall also be capable of manual operation.

8. Propulsion plant

8.1 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 reversed, and
- the propulsion unit or the propeller shaft can be stopped.

8.2 Remote controls

The remote control of the propulsion plant from the bridge is subject to Rules for Automation (Pt.1, Vol.VII).

8.3 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, see Section 4, D.5.9

9. Turning appliances

9.1 Machinery is to be equipped with suitable and adequately dimensioned turning appliances.

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

9.3 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 installations warning devices may be provided alternatively.

10. Operating and maintenance instructions

10.1 Manufacturers of machinery, boilers and auxiliary equipment shall 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.

11. Markings, 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 labelled.

12. Fuels

12.1 The flash point 2 [2)] of liquid fuels for the operation of boilers and diesel engines may not be lower than 60 °C.

For emergency generating sets, however, use may be made of fuels with a flash point of ≥ 43 °C.

12.2 In exceptional cases, for ships intended for operation in limited geographical areas or where special precautions subject to the BKI's approval are taken, fuels with flash points between 43 °C and 60 °C may also be used. This is conditional upon the requirement that the temperatures of the spaces in which fuels are stored or used shall invariably be 10 °C below the flash point.

12.3 The use of gaseous fuels taken from the cargo is subject to Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol.IX).

12.4 For the use of gas as fuel, which is not taken from the cargo, Guidelines for the Use of Gas as Fuel for Ships (Pt.1, Vol.1) are to be observed.

13. Refrigerating installations

Refrigerating installations for which no Refrigerating Installations Certificate is to be issued are subject to Rules for Refrigeration (Pt.1, Vol.VIII) Sec.1, C., D., F., J.1, M.1.5 and M.2.3.

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 systems and equipment:

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

- 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 gear is to be protected from the 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 are to be dimensioned 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 are to be installed in such a way that they can be isolated.

Lines leading to pressure gauges are to 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 are to 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 are to be adequately lit to ensure that control and monitoring instruments can be easily read. In this connection see Rules for Electrical Installations (Pt.1, Vol.IV), Section 11.

5. Bilge wells/bilges

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

5.2 Bilges beneath electrical machines are to 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"** are to be equipped with at least 2 indicators for bilge level monitoring.
- Other unmanned machinery rooms, such as bow thruster or steering gear compartments arranged below the load waterline are irrespective of Class Notation " **OT** " to be equipped at least with 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.

7. Noise abatement

In compliance with the relevant national regulations, care is to be taken to ensure that operation of the ship is not unacceptably impaired by engine noise.

F. Safety Equipment and Protective Measures

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 the following:

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 no thermal insulation is provided, e.g. pressure lines to air compressors.

2. When using hand cranks for starting internal combustion engines, steps 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.

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

4. In operating spaces, anti-skid floor plates and floor-coverings are to be used.

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

6. Glass water level gauges for steam boilers are to be equipped with protection devices.

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

7. Safety valves and shut-offs are to be capable of safe operation. Fixed steps, stairs or platforms are to be fitted where necessary.

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

9. Steam and feed water lines, exhaust gas ducts, boilers and other equipment and pipelines carrying steam or hot water are to be effectively insulated. Insulating materials are to 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. Voice communication

Means of voice 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 (Pt.1, Vol.IV) Sec.9.C.5.).

2. Engineer alarm

From the engine room or the engine control room it shall be possible to activate an alarm in the engineers living quarters (see also Rules for Electrical Installations (Pt.1, Vol.IV) Sec.9.C.5.3).

3. Engine telegraph

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

In the case of multiple-shaft installations, a telegraph shall 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 16.

5. Design of communication and signalling 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 is to be clearly indicated on the propulsion plant control platform.

Signalling devices are to 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, signalling and alarm systems, see Rules for Electrical Installations (Pt.1, Vol.IV), Sec.9 and Rules for Automation (Pt.1, Vol.VII).

H. Essential Equipment

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 hear 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 firefighting 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 pumps

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

I. Failure Analysis for Propulsion and Steering on Passenger Ships

1. For ships having at least two independent means of propulsion and steering to comply with SOLAS requirements for a safe return to port, the following conditions apply:

1.1 Provide knowledge of the effects of failure in all the equipment and systems due to fire in any space or flooding of any watertight compartment that could affect the availability of the propulsion and steering.

1.2 Provide solutions to ensure the availability of propulsion and steering upon such failures in item 1.1.

2. Ships not required to satisfy the safe return to port concept will require the analysis of failure in single equipment and fire in any space to provide knowledge and possible solutions for enhancing availability of propulsion and steering.

3. The qualitative failure analysis is to consider the propulsion and steering equipment and all its associated systems which might impair the availability of propulsion and steering.

4. The qualitative failure analysis should include:

1) Propulsion and electrical power prime movers, e.g., diesel engines and electric motors.
2) Power transmission systems, e.g. shafting, bearings, power converters, transformers, and slip ring systems.
3) Steering gear such as rudder actuator or equivalent for azimuthing propulsor, rudder stock with bearings and seals, rudder, power unit and control gear, local control systems and indicators, remote control systems and indicators, and communication equipment.

4) Propulsors, e.g. propeller, azimuthing thruster, and water jet

5) Main power supply systems, e.g. electrical generators and distribution systems, cable runs, hydraulic, and pneumatic

6) Essential auxiliary systems, e.g. compressed air, oil fuel, lubricating oil, cooling water, ventilation, and fuel storage and supply systems

7) Control and monitoring systems, e.g. electrical auxiliary circuits, power supplies, protective safety systems, power management systems, and automation and control systems.

8) Support systems, e.g. lighting and ventilation.

To consider the effects of fire or flooding in a single compartment, the analysis is to address the location and layout of equipment and systems.

5. Failure Criteria

5.1 Failures are deviations from normal operating conditions such as loss or malfunction of a component or system such that it cannot perform an intended or required function.

5.2 The qualitative failure analysis should be based on single failure criteria, (not two independent failures occurring simultaneously).

5.3 Where a single failure cause results in failure of more than one component in a system (common cause failure), all the resulting failures are to be considered together.

5.4 Where the occurrence of a failure leads directly to further failures, all those failures are to be considered together.

6. Verification of Solutions

6.1 The shipyard is to submit a report to class societies that identifies how the objectives have been addressed. The report is to include the following information:

1) Identify the standards used for analysis of the design.

2) Identify the objectives of the analysis.

3) Identify any assumptions made in the analysis.

4) Identify the equipment, system or sub-system, mode of operation of the equipment

5) Identify probable failure modes and acceptable deviations from the intended or required function

6) Evaluate the local effects (e.g. fuel injection failure) and the effects on the system as a whole (e.g. loss of propulsion power) of each failure mode as applicable.

7) Identify trials and testing necessary to prove conclusions.

Note:
All stakeholders (e.g., class, owners, shipyard and manufacturers) should as far as possible be involved in the development of the report.

6.2 The report is to be submitted prior to approval of detail design plans. The report may be submitted in two parts:

1) 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 is to include a structured assessment of all essential systems supporting the propulsion plant after a failure in equipment, fire or flooding in any compartment casualty.

2) A final report detailing the final design with a detailed assessment of any critical system identified in the preliminary report.

6.3 Verification of the report findings are to be agreed between the class society and the shipyard.

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Section 2 Internal Combustion Engines and Air Compressors

A. General

1. Scope

The requirements contained 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 O.

2. Ambient conditions

In determining the power of all engines used on board ships with an unlimited range of service, the following ambient conditions are to be used:

Barometric pressure	1000	mbar
Suction air temperature	45	°C
Relative humidity of air	60	%
Seawater temperature	32	°C

The defined seawater temperature has especially to be considered as inlet temperature to coolers for charge air coolant operating seawater.

Note:
The engine manufacturer shall not be expected to provide simulated ambient reference conditions at a test bed.

3. Rated Power

3.1 Diesel engines are to be designed such that their rated power when running at rated speed according to the definitions of the engine manufacturer at ambient conditions as defined in 2 can be delivered as a continuous power. Diesel engines are to be capable of operating continuously within power range ① in Fig. 2.1 and intermittently in power range ②. The extent of the power ranges are to be stated by the engine manufacturer

3.2 Continuous power is to be understood as the standard service power which an engine is capable of delivering continuously, provided that the maintenance prescribed by the engine manufacturer is carried out, in the maintenance intervals stated by the engine manufacturer.

3.3 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 the BKI.

3.4 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.

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

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

3.7 For main engines, a power diagram (Fig. 2.1) is to be prepared showing the power ranges within which the engine is able to operate continuously and for short periods under service conditions.

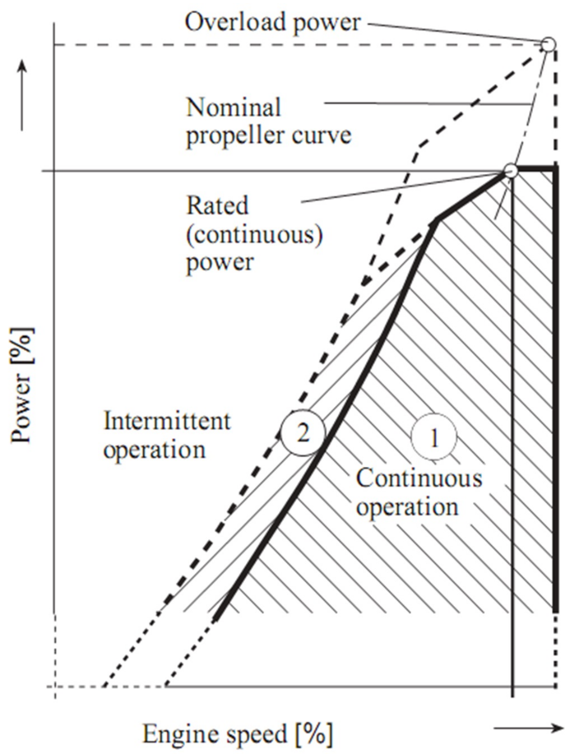


Figure 2.1: Example of a power diagram

4. Fuels

4.1 The use of liquid fuels is subject to the requirements contained in Section 1, D.12.

4.2 For fuel treatment and supply, see Section 11, G.

4.3 The use of gaseous fuels is subject to the requirements in Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol.IX), Section 16, respectively Guidelines for The Use of Gas as Fuel for Ships (Pt.1, Vol.1).

4.4 Regarding the use of low sulphur fuel the engine manufacturers' recommendations with respect to e.g. fuel change-over process, lubricity, viscosity and compatibility are to be observed.

5. Accessibility of engines

Engines are to be so arranged in the engine room that all the assembly holes and inspection ports provided by the engine manufacturer for inspections and maintenance are accessible. A change of components, as far as practicable on board, shall be possible. Requirements related to space and constructions have to be considered for the installation of the engines.

6. Electronic components and systems

6.1 For electronic components and systems which are necessary for the control of internal combustion engines the following items have to be observed:

6.1.1 Electronic components and systems have to be type approved according to Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W) Sec. 3.T.

6.1.2 For computer systems, Rules for Electrical Installations (Pt.1, Vol.IV), Section 10 has to be observed.

6.1.3 For main propulsion engines one failure of an electronic control system shall not result in a total loss or sudden change of the propulsion power. In individual cases, BKI may approve other failure conditions, whereby it is ensured that no increase of ship's speed occurs.

6.2 The non-critical behavior in case of a failure of an electronic control system has to be proven by a structured analysis (e.g FMEA), which has to be provided by the system's manufacturer. This shall include the effects on persons, environment and technical condition.

6.3 Where the electronic control system incorporates a speed control, F.1.3 and Rules for Electrical Installations (Pt.1, Vol.IV), Sec. 9, B.8 have to be observed.

7. Local control station

7.1 For the local control station, I has to be observed.

7.2 The indicators named in I shall be realized in such a way that one failure can only affect a single indicator. Where these indicators are an integral part of an electronic control system, means shall be taken to maintain these indications in case of failure of such a system.

7.3 Where these indicators are realized electrically, the power supply of the instruments and of the electronic system has to be realized in such a way to ensure the behaviour stated in 7.2.

B. Document for Approval

1. General

For each engine type the drawings and documents listed in Table 2.1 and Table 2.2 shall, wherever applicable, be submitted by the engine manufacturer to BKI for Approval or Reference. Where considered necessary, BKI may request further documents to be submitted. This also applies to the documentation of design changes according to 4. The documents shall be submitted in form of electronic format for approval.

2. Engines manufactured under license

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

- comparison of all the drawings and documents as per Table 2.1 and Table 2.2 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 and Table 2.2 together with the licensor's declaration of consent to the modifications,
- a complete set of drawings shall be submitted as a basis for the tests and inspections.

3. Definition of a Diesel engine type

3.1 The type specification of an internal combustion engine is defined by the following data:

- manufacturer's type designation
- cylinder bore
- stroke
- injection method (direct, indirect)
- valve and injection operation (by cams or electronically controlled)
- kind of fuel (liquid, dual-fuel, gaseous)
- working cycle (4-stroke, 2-stroke)
- method of gas exchange (naturally aspirated or supercharged)
- cylinder power, speed and cylinder pressure.
- method or pressure charging (pulsating pressure system or constant-pressure charging system)
- charge air cooling system (e.g. with or without intercooler)
- cylinder arrangement (in-line or V-type)

3.2 Description of Diesel engine type

The definition of engine rated speed are described below:

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

For further application, the exceptions are stated otherwise and are indicated.

4. Design modification

Following initial approval of an engine type by BKI, only those documents listed in Table 2.1 and Table 2.2 require to be resubmitted for examinations which embody important design modifications.

5. Approval of engine components

The procedures for approval of engine components are in accordance with the requirements stipulated in the Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W).

Table 2.1: Document to be submitted for Reference

No.	Description
1	Engine particulars (e.g. Data sheet with general engine information)
2	Engine cross section
3	Engine longitudinal section
4	Bedplate and crankcase of cast design
5	Thrust bearing assembly [1)]
6	Frame/ framebox/ gearbox of cast design [2)]
7	Tie rod
8	Connecting rod
9	Connecting rod, assembly [3)]
10	Crosshead, assembly [3)]
11	Piston rod, assembly [3)]
12	Piston, assembly [3)]
13	Cylinder jacket/ block of cast design [2)]
14	Cylinder cover, assembly [3)]
15	Cylinder liner
16	Counterweights (if not integral with crankshaft), including fastening
17	Camshaft drive, assembly [3)]
18	Flywheel
19	Fuel oil injection pump
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
For electronically controlled engines, construction and arrangement of:	
21	Control valves
22	High pressures pumps
23	Drive for high pressure pumps
24	Operation and service manuals [4)]
25	FMEA (for engine control system) [5)]
26	Production specifications for castings and welding (sequence)
27	Evidence of quality control system for engine design and in service maintenance
28	Quality requirements for engine production
29	Type Approval certification for environmental tests, control components [6)]

[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.

[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.

[5)] 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.

[6)] Tests are to demonstrate the ability of the control, protection and safety equipment to function as intended under the specified testing conditions per Rules for Electrical Installations (Pt.1, Vol.IV) Sec.9.

Table 2.2: Document to be submitted for Approval

No.	Description
1	Bedplate and crankcase of welded design, with welding details and welding instructions
2	Thrust bearing bedplate of welded design, with welding details and welding Instructions [1]
3	Bedplate/oil sump welding drawings [1]
4	Frame/framebox/gearbox of welded design, with welding details and instructions [1][2]
5	Engine frames, welding drawings [1][2]
6	Crankshaft, details, each cylinder No.
7	Crankshaft, assembly, each cylinder No.
8	Crankshaft calculations (for each cylinder configuration) according to Section 2,C
9	Thrust shaft or intermediate shaft (if integral with engine)
10	Shaft coupling bolts
11	Material specifications of main parts with information on non-destructive material tests and pressure tests [3]
Schematic layout or other equivalent documents on the engine of:	
12	Starting air system
13	Fuel oil system
14	Lubricating oil system
15	Cooling water system
16	Hydraulic system
17	Hydraulic system (for valve lift)
18	Engine control and safety system
19	Shielding of high pressure fuel pipes, assembly [4]
20	Construction of accumulators (common rail) (for electronically controlled engine)
21	Construction of common accumulators (common rail) (for electronically controlled engine)
22	Arrangement and details of the crankcase explosion relief valve (see Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use, (Pt.1, Vol.W) Sec.3.I)
23	Calculation results for crankcase explosion relief valves (see Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use, (Pt.1, Vol.W) Sec.3.I)
24	Details of the type test program and the type test report [7]
25	High pressure parts for fuel oil injection system [6]
26	Oil mist detection and/or alternative alarm arrangements (see Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use, (Pt.1, Vol.W) Sec.3.J)
27	Details of mechanical joints of piping systems (see Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use, (Pt.1, Vol.W) Sec.3.Q)
28	Documentation verifying compliance with inclination limits (see Section 1)
29	Documents as required in Rules for Eletrical Installations (Pt.1, Vol.IV) Sec.10.

[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 BKI 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 m^3 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.

C. Crankshaft Calculation

1. General

These Rules for the design of crankshafts are to be applied to I.C. engines for propulsion and auxiliary purposes, where the engines are capable of continuous operation at their rated power when running at rated speed. Where a crankshaft design involves the use of surface treated fillets, or when fatigue parameter influences are tested, or when working stresses are measured, the relevant documents with calculations/ analysis are to be submitted to BKI in order to demonstrate equivalence to the Rules.

2. Field of Application

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

3. Principles of calculation

3.1 Design methods

3.1.1 Crankshafts are to be designed to withstand the stresses occurring when the engine runs at rated power and the documentation has to be submitted for approval.

The design of crankshafts is based on an evaluation of safety against fatigue in the highly stressed areas. The calculation is also based on the assumption that the areas exposed to highest stresses are:

— fillet transitions between the crankpin and web as well as between the journal and web,

— outlets of crankpin oil bores.

When journal diameter is equal or larger than the crankpin one, the outlets of main journal oil bores are to be formed in a similar way to the crankpin oil bores, otherwise separate documentation of fatigue safety may be required.

Calculation of crankshaft strength consists initially in determining the nominal alternating bending (see C.5.1) and nominal alternating torsional stresses (see C.5.2) which, multiplied by the appropriate stress concentration factors (see .C.6.), result in an equivalent alternating stress (uni-axial stress) (see .C.8.). This equivalent alternating stress is then compared with the fatigue strength of the selected crankshaft material (see .C.9. This comparison will show whether or not the crankshaft concerned is dimensioned adequately (see .C.10.)

3.1.2 Outside the end bearings, crankshafts designed according to the regulations specified in C.3.1.1 may be adapted to the diameter of the adjoining shaft d by a generous fillet r ($r \geq 0{,}06 \cdot d$) or a taper.

3.1.3 Design methods for application to crankshafts of special construction and to the crankshafts of engines of special type are to be agreed with BKI.

3.2 Shrink joints of built-up crankshafts

The shrink joints of built-up crankshafts are to be designed in accordance with this sub-section.

3.3 Screw joints

3.3.1 Split crankshafts

Only fitted bolts may be used for assembling split crankshafts.

3.3.2 Power-end flange couplings

The bolts used to connect power-end flange couplings are normally to be designed as fitted bolts in accordance with Section 4.D.4

If the use of fitted bolts is not feasible, BKI may agree to the use of an equivalent frictional resistance transmission. In these cases the corresponding calculations are to be submitted for approval.

3.4 Torsional vibration, critical speeds

Section 16.

4. Drawing and particulars to be submitted

For the calculation of crankshafts, the documents and particulars listed below are to be submitted:

- crankshaft drawing (which must contain all data in respect of the geometrical configurations 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 [r/min]
- direction of rotation (see. Figure .2.2)
- firing order with the respective ignition intervals and, where necessary,
- V-angle α_V[°] (see Figure .2.2)

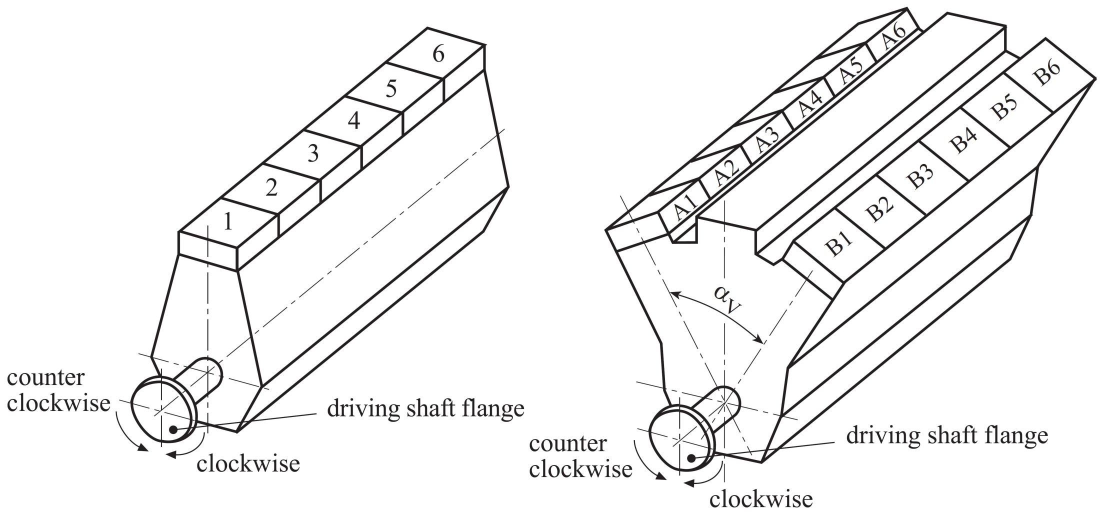


Figure 2.2: Designation of the cylinders

- cylinder diameter [mm]
- stroke [mm]
- maximum net cylinder pressure P_{max} [bar]
- charge air pressure [bar]
  (before inlet valves or scavenge ports, whichever applies)
- connecting-rod length L_H [mm]
- all individual reciprocating masses acting on one crank [kg]
- digitized gas pressure curve presented at equidistant intervals [bar versus Crank Angle] (at least every 5° CA)
- for engines with articulated-type connecting-rod (see Figure .2.3)
  - distance to link point L_A[mm]
  - link angle α_N[°]
- connecting-rod length L_N[mm]

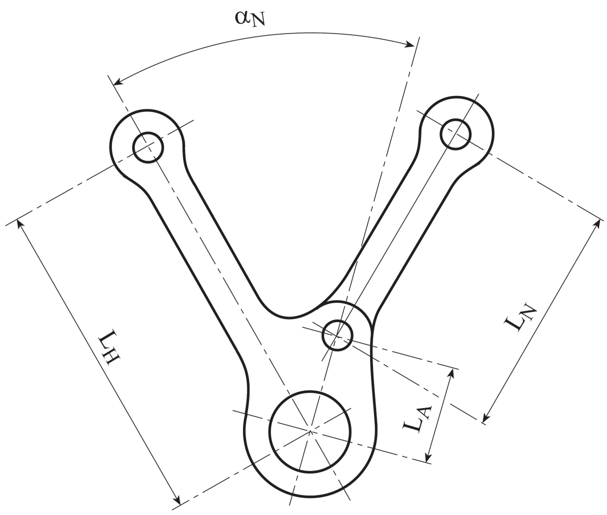


Figure 2.3: Articulated-type connecting-rod

- details of crankshaft material
  - material designation (according to ISO,EN,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 break [%]
    - elongation A_5[%]
    - 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 Annex G.
- Particulars of alternating torsional stress calculations, see item C.5.2.

5. Calculation of Stresses

5.1 Calculation of alternating stresses due to bending moments and radial forces

5.1.1 Assumptions

The calculation is based on a statically determined system, composed of a single crankthrow supported in the centre of adjacent main journals and subject to gas and inertia forces. The bending length is taken as the length between the two main bearing midpoints (distance L_3, see Figure .2.4 and Figure .2.5).

The bending moments M_{BR}, 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 Figure .2.4).

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 Figure .2.5).

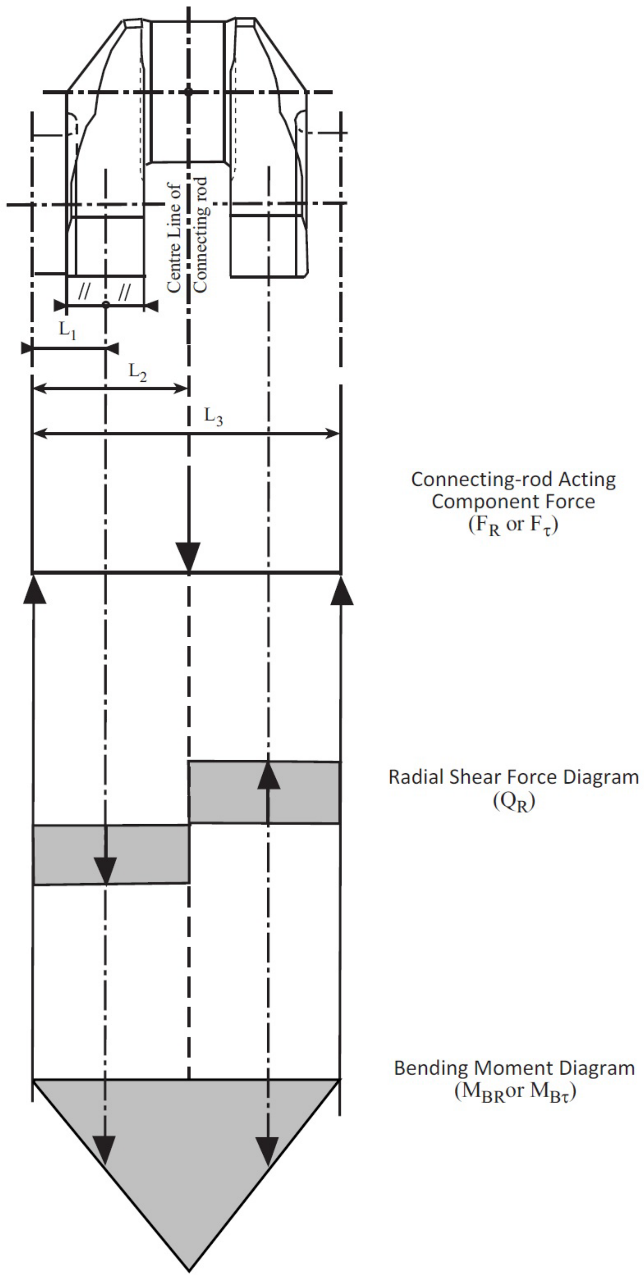


Figure 2.4: Crankthrow for in-line engine

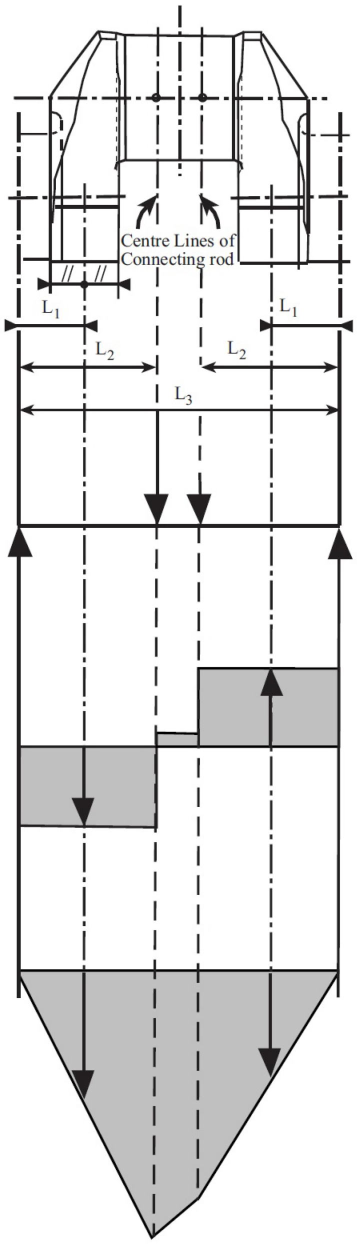


Figure 2.5: Crank throw for Vee engine with 2 adjacent connecting rods

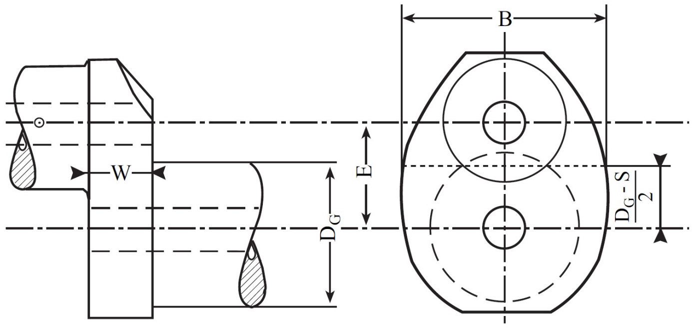
L1 = Distance between main journal centre line and crank web centre (see also Figure .2.6 for crankshaft without overlap)
L2 = Distance between main journal centre line and connecting-rod centre
L3 = Distance between two adjacent main journal centre lines

.1 Bending moments and radial forces acting in web

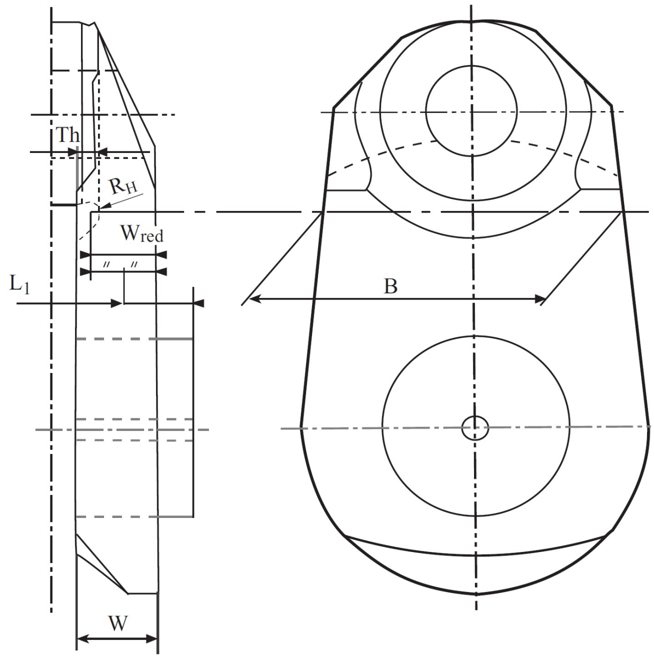
The bending moment M_{BRF} and the radial force Q_{RF} are taken as acting in the centre of the solid web (distance L_1) and are derived from the radial component of the connecting-rod force.

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

Mean stresses are neglected.



Overlapped crankshaft



Crankshaft without overlap

Figure 2.6: Reference area of crankweb cross section

.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.

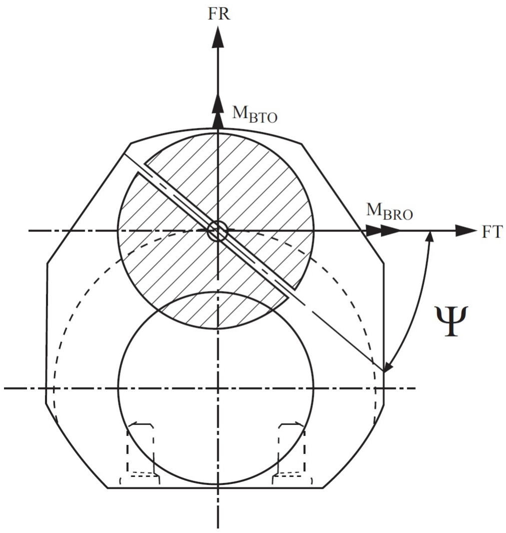


Figure 2.7: Crankpin section through the oil bore

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

M_{BTO} = 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.

5.1.2 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} defined in .1 and .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) hall 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 = considered as alternating force, moment or stress
X_{max} = maximum value within one working cycle
X_{mim} = minimum value within one working cycle

.1 Nominal alternating bending and compressive stresses in web cross section

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

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

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

where:

σ_{BFN} = nominal alternating bending stress related to the web [N/mm^2]

M_{BRFN} = alternating bending moment related to the centre of the web (see Figure .2.4 and Figure .2.5) [Nm]

$$M_{BRFN} = \pm \frac{1}{2}[M_{BRFmax} - M_{BRFmin}]$$

W_{eqw} = section modulus related to cross-section of web [mm^3]

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

Ke = empirical factor considering to some extent the influence of adjacent crank and bearing restraint with:
Ke = 0,8 for 2-stroke engines
Ke = 1,0 for 4-stroke engines

σ_{QFN} = nominal alternating compressive stress due to radial force related to the web [N/mm^2]

Q_{RFN} = alternating radial force related to the web (see Figure .2.4 and Figure .2.5) [N]

$$Q_{RFN} = \pm \frac{1}{2}[Q_{RFmax} - Q_{RFmin}]$$

F = area related to cross-section of web [mm^2]

$$F = B \cdot W$$

.2 Nominal alternating bending stress in outlet of crankpin oil bore

The calculation of nominal alternating bending stress is as follows:

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

Where:

σ_{BON} = nominal alternating bending stress related to the crank pin diameter [N/mm^2]

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

$$M_{BON} = \pm \frac{1}{2}[M_{BOmax} - M_{BOmin}] \text{ with,}$$

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

ψ = angular position (see Figure .2.7) [°]

W_e = section modulus related to cross-section of axially bored crankpin [mm^3]

$$W_e = \frac{\pi}{32}\left[\frac{D^4 - D_{BH}^4}{D}\right]$$

5.1.3 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:

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

Where:

σ_{BH} = alternating bending stress in crankpin fillet [N/mm^2]

α_B = stress concentration factor for bending in crankpin fillet (determination - see .C.6.)

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

$$\sigma_{BG} = \pm(\beta_B \cdot \sigma_{BFN} + \beta_Q \cdot \sigma_{QFN})$$

Where:

σ_{BG} = alternating bending stress in journal fillet [N/mm^2]

β_B = stress concentration factor for bending in journal fillet (determination see .C.6.)

β_Q = stress concentration factor for compression due to radial force in journal fillet (determination - see .C.6.)

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

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

Where:

σ_{BO} = alternating bending stress in outlet of crankpin oil bore [N/mm^2]

γ_B = stress concentration factor for bending in crankpin oil bore (determination see .C.6.)

5.2 Calculation of alternating torsional stresses

5.2.1 General

The calculation for nominal alternating torsional stresses is to be undertaken by the engine manufacturer according to the information contained in C.5.2.2.

The manufacturer shall specify the maximum nominal alternating torsional stress.

5.2.2 Calculation of nominal alternating torsional stresses

The maximum and minimum torques are to be ascertained for every mass point of the complete dynamic system and for the entire speed range by means of a harmonic synthesis of the forced vibrations from the 1^{st} order up to and including the 15^{th} order for 2-stroke cycle engines and from the 0.5^{th} order up to and including the 12^{th} order for 4-stroke cycle engines. Whilst doing so, allowance must be made for the damping that exists in the system and for unfavourable conditions (misfiring [1] 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.

[1] Misfiring is defined as cylinder condition when no combustion occurs but only compression cycle.

Where barred speed ranges are necessary, they shall be arranged so that satisfactory operation is possible despite their existence. There are to be no barred speed ranges above a speed ratio of $\lambda \geq 0{,}8$ for normal firing conditions.

The values received from such calculation are to be submitted to BKI.

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

$$\tau_N = \pm \frac{M_{TN}}{W_P} \cdot 10^3$$

$$M_{TN} = \pm \frac{1}{2} [M_{Tmax} - M_{Tmin}]$$

$$W_P = \frac{\pi}{16} \left(\frac{D^4 - {D_{BH}}^4}{D} \right) \text{ or } W_P = \frac{\pi}{16} \left(\frac{{D_G}^4 - {D_{BG}}^4}{D_G} \right)$$

where:

τ_N = nominal alternating torsional stress referred to crankpin or journal [N/mm^2]

M_{TN} = maximum alternating torque [Nm]

W_P = polar section modulus related to cross-section of axially bored crankpin or bored journal [mm^3]

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

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

For the purpose of the crankshaft assessment, the nominal alternating torsional stress considered in further calculations is the highest calculated value, according to above method, occurring at the most torsionally loaded mass point of the crankshaft system.

Where barred speed ranges exist, the torsional stresses within these ranges are not to be considered for assessment calculations.

The approval of crankshaft will be based on the installation having the largest nominal alternating torsional stress (but not exceeding the maximum figure specified by engine manufacturer).

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

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

The calculation of stresses is to be carried out for the crankpin fillet, the journal fillet and the outlet of the crankpin oil bore.

For the crankpin fillet:

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

Where:

τ_H = alternating torsional stress in crankpin fillet [N/mm^2]

α_T = stress concentration factor for torsion in crankpin fillet (determination see .C.6.)

τ_N = nominal alternating torsional stress related to crankpin diameter [N/mm^2]

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

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

Where:

τ_G = alternating torsional stress in journal fillet $[N/mm^2]$

β_T = stress concentration factor for torsion in journal fillet (determination see .C.6.)

τ_N = nominal alternating torsional stress related to journal diameter $[N/mm^2]$

For the outlet of crankpin oil bore:

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

Where:

σ_{TO} = alternating stress in outlet of crankpin oil bore due to torsion $[N/mm^2]$

γ_T = stress concentration factor for torsion in outlet of crankpin oil bore (determination see .C.6.)

τ_N = nominal alternating torsional stress related to crankpin diameter $[N/mm^2]$

6. Evaluation of Stress Concentration Factors

6.1 General

The stress concentration factors are evaluated by means of the formulae according to C.6.2 to C.6.4 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 (Forschungsvereinigung Verbrennungskraftmaschinen) 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 Annex E may be undertaken.

All crank dimensions necessary for the calculation of stress concentration factors are shown in Figure .2.8.

The stress concentration factor for bending (α_B, β_B) is defined as the ratio of the maximum equivalent stress (VON MISES) - occurring in the fillets under bending load - to the nominal bending stress related to the web cross-section (see Annex C).

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 factor for torsion (α_T, β_T) is defined as the ratio of the maximum equivalent shear stress occurring in the fillets under torsional load – to the nominal torsional stress related to the axially bored crankpin or journal cross-section (see Annex C).

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 (see Annex D).

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 BKI 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 C.6.2 to C.6.4.

Annex E and Annex F 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.

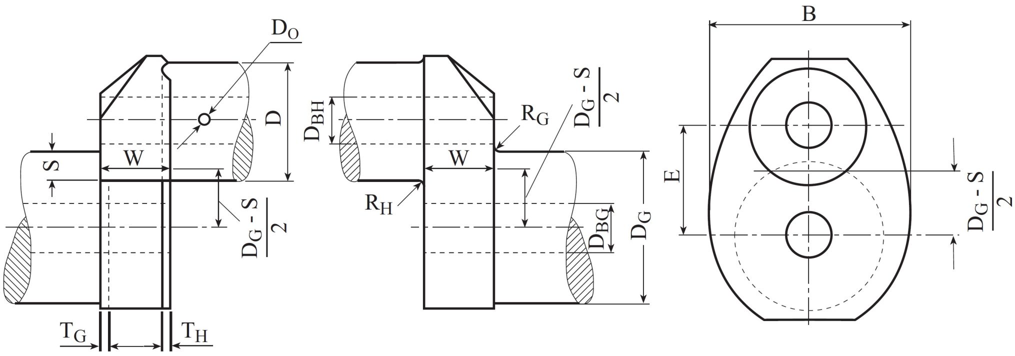


Figure 2.8: Crank dimensions necessary for the calculation of stress concentration factors

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 fillet [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:

$$W_{red} = W-(T_H-R_H)$$ [refer to Figure .2.6]

— web width B must be taken in way of crankpin fillet radius centre according to Figure .2.6

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

Crankpin fillet	Journal fillet
r = R_H**/D**	**r =** R_G**/D**
s = S/D w = W/D crankshafts with overlap 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.

6.2 Crankpin fillet

The stress concentration factor for bending (α_B) is:

$$\alpha_B = 2,6914 \cdot f(s,w) \cdot f(w) \cdot f(b) \cdot f(r) \cdot f(d_G) \cdot f(d_H) \cdot f(recess)$$

Where:

$f(s,w) = -4{,}1883 + 29{,}2004 \cdot w - 77{,}5925 \cdot w^2 + 91{,}9454 \cdot w^3 - 40{,}0416 \cdot w^4 + (1-s) \cdot (9{,}5440 - 58{,}3480 \cdot w + 159{,}3415\ w^2 - 192{,}5846 \cdot w^3 + 85{,}2916 \cdot w^4) + (1-s)^2 \cdot (-3{,}8399 + 25{,}0444 \cdot w - 70{,}5571 \cdot w^2 + 87{,}0328 \cdot w^3 - 39{,}1832 \cdot w^4)$

$f(w) = 2{,}1790 \cdot w^{0,7171}$

$f(b) = 0{,}6840 - 0{,}0077 \cdot b + 0{,}1473 \cdot b^2$

$f(r) = 0{,}2081 \cdot r^{(-0,5231)}$

$f(d_G) = 0{,}9993 + 0{,}27 \cdot d_G - 1{,}0211 \cdot d_G^2 + 0{,}5306 \cdot d_G^3$

$f(d_H) = 0{,}9978 + 0{,}3145 \cdot d_H - 1{,}5241 \cdot d_H^2 + 2{,}4147 \cdot d_H^3$

$f(recess) = 1 + (t_H + t_G) \cdot (1{,}8 + 3{,}2 \cdot s)$

The stress concentration factor for torsion (α_T)is :

$$\alpha_T = 0,8 \cdot f(r,s) \cdot f(b) \cdot f(w)$$

Where:

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)	=	$w^{(-0,145)}$

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

The stress concentration factor for bending (β_B) is:

$$\beta_B = 2,7146 \cdot f_B(s,w) \cdot f_B(w) \cdot f_B(b) \cdot f_B(r) \cdot f_B(d_G) \cdot f_B(d_H) \cdot f(recess)$$

Where:

$f_B(s,w)$	=	$-1,7625 + 2,9821 \cdot w - 1,5276 \cdot w^2 + (1-s) \cdot (5,1169 - 5,8089 \cdot w + 3,1391 \cdot w^2)$ $+ (1-s)^2 \cdot (-2,1567 + 2,3297 \cdot w - 1,2952 \cdot w^2)$
$f_B(w)$	=	$2,2422 \cdot w^{0,7548}$
$f_B(b)$	=	$0,5616 + 0,1197 \cdot b + 0,1176 \cdot b^2$
$f_B(r)$	=	$0,1908 \cdot r^{(-0,5568)}$
$f_B(d_G)$	=	$1,0012 - 0,6441 \cdot d_G + 1,2265 \cdot {d_G}^2$
$f_B(d_H)$	=	$1,0022 - 0,1903 \cdot d_H + 0,0073 \cdot {d_H}^2$
f(recess)	=	$1 + (t_H + t_G) \cdot (1,8 + 3,2 \cdot s)$

The stress concentration factor for compression (β_Q) due to the radial force is:

$$\beta_Q = 3,0128 \cdot f_Q(s) \cdot f_Q(w) \cdot f_Q(b) \cdot f_Q(r) \cdot f_Q(d_H) \cdot f(recess)$$

Where:

$f_Q(s)$	=	$0,4368 + 2,1630 \cdot (1-s) - 1,5212 \cdot (1-s)^2$
$f_Q(w)$	=	$\dfrac{w}{0,0637 + 0,9369 \cdot w}$
$f_Q(b)$	=	$-0,5 + b$
$f_Q(r)$	=	$0,5331 \cdot r^{(-0,2038)}$
$f_Q(d_H)$	=	$0,9937 - 1,1949 \cdot d_H + 1,7373 \cdot {d_H}^2$
f(recess)	=	$1 + (t_H + t_G) \cdot (1,8 + 3,2 \cdot s)$

The stress concentration factor for torsion (β_T) is:

$$\beta_T = \alpha_T$$

if the diameters and fillet radii of crankpin and journal are the same. If crankpin and journal diameters and/or radii are of different sizes

$$\beta_T = 0,8 \cdot f(r,s) \cdot f(b) \cdot f(w)$$

Where:

f(r,s), f(b) and f(w) are to be determined in accordance with C.6.2. (see calculation of α_T), however, the radius of the journal fillet is to be related to the journal diameter:

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

6.4 Outlet of crankpin oil bore

The stress concentration factor for bending (γ_B) is:

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

The stress concentration factor for torsion (γ_T) is:

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

7. Additional Bending Stresses

In addition to the alternating bending stresses in fillets (see C.5.1.3) 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 Table 2.3:

Table 2.3: Additional bending stress

Type of engine	σ_{add} [N/mm^2]
Crosshead engines	±30(*)
Trunk piston engines	±10
(*) The additional stress of ± 30 N/mm² is composed of two components: 1) an additional stress of ± 20 N/mm^2 resulting from axial vibration 2) an additional stress of ± 10 N/mm^2 resulting from misalignment / bed plate deformation	

It is recommended that a value of ± 20 N/mm^2 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.

8. Calculation of Equivalent Alternating Stress

8.1 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 Annex C).

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 Annex D).

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.

8.2 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 joural fillet

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

For the outlet of crankpin oil bore:

$$\sigma_V = \pm\frac{1}{2}\sigma_{BO} \cdot \left[1 + 2\sqrt{1 + \frac{9}{4}\left(\frac{\sigma_{TO}}{\sigma_{BO}}\right)^2}\right]$$

Where:

σ_V = equivalent alternating stress [N/mm^2]

for other parameters see items C.5.1.3, C.5.2.3 and .C.7.

9. Calculation of Fatigue Strength

The fatigue strength is to be understood as that value of equivalent alternating stress (Von Mises) which a crankshaft can permanently withstand at the most highly stressed points. The fatigue strength may be evaluated by means of the following formulae.

Related to the crankpin diameter:

$$\sigma_{DW} = \pm k \cdot (0,42 \cdot \sigma_B + 39,3) \cdot \left[0,264 + 1,073 \cdot D^{-0.2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{R_X}}\right]$$

With:

R_X = R_H in the fillet area

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

Related to the journal diameter:

$$\sigma_{DW} = \pm k \cdot (0,42 \cdot \sigma_B + 39,3) \cdot \left[0,264 + 1,073 \cdot D_G{}^{-0.2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{R_G}}\right]$$

Where:

σ_{DW} = allowable fatigue strength of crankshaft [N/mm^2]

k = factor for different types of 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 BKI approved cold rolling process

σ_B = minimum tensile strength of crankshaft material [N/mm^2]

For other parameters see C.6.3.

When a surface treatment process is applied, it must be approved by BKI. Guidance for calculation of surface treated fillets and oil bore outlets is presented in Annex G.

These formulae are subject to the following conditions:

— 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.

— for calculation purposes R_H, R_G or R_X are to be taken as not 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 Annex F.

In any case the experimental procedure for fatigue evaluation of specimens and fatigue strength of crankshaft assessment have to be submitted for approval to BKI (method, type of specimens, number of specimens (or crankthrows), number of tests, survival probability, confidence number, etc.).

10. Acceptability Criteria

The sufficient dimensioning of a 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:

$$\sigma = \frac{\sigma_{DW}}{\sigma_V}$$

Where:

Q = acceptability factor

Adequate dimensioning of the crankshaft is ensured if the smallest of all acceptability factors satisfies the criteria:

$$Q \geq 1,15$$

11. Calculation of Shrink-Fits of Semi-Built Crankshafts

11.1 General

All crank dimensions necessary for the calculation of the shrink-fit are shown in Figure .2.9.

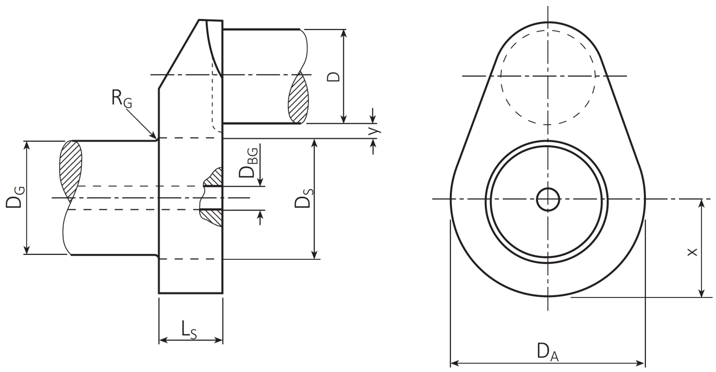


Figure 2.9: Crankthrow of semi-built crankshaft

Where:

D_A = outside diameter of web [mm] or
twice the minimum distance x between centre-line of journals and outer contour of web, whichever is less

D_S = shrink diameter [mm]

D_G = journal diameter [mm]

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

L_S = length of shrink-fit [mm]

R_G = fillet radius of journal [mm]

y = distance between the adjacent generating lines of journal and pin [mm]
$y \geq 0{,}05 \cdot D_S$
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-fit on the fatigue strength at the crankpin fillet.

Respecting the radius of the transition from the journal to the shrink diameter, the following should be complied with:

$$R_G \geq 0,015 \cdot D_G$$

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 C.11.3 and C.11.4.

In the case where C.11.2 condition cannot be fulfilled then C.11.3 and C.11.4 calculation methods of Z_{min} and Z_{max} are not applicable due to multi zone plasticity problems.

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

11.2 Maximum permissible hole in the journal pin

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

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

Where:

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_{Tmax} in accordance with C.5.2 [Nm]

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/mm^2]

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

11.3 Necessary minimum oversize of shrink fit

The necessary minimum oversize is determined by the greater value calculated according to:

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

and

$$Z_{min} \geq \frac{4000}{\mu \cdot \pi} \cdot \frac{S_R \cdot M_{max}}{E_m \cdot D_S \cdot L_S} \cdot \frac{1 - {Q_A}^2 \cdot {Q_S}^2}{(1 - {Q_A}^2) \cdot (1 - {Q_S}^2)}$$

Where:

Z_{min} = minimum oversize [mm]

E_m = Young's modulus [N/mm^2]

σ_{SW} = minimum yield strength of material for crank web [N/mm^2]

Q_A = web ratio, $Q_A = \frac{D_S}{D_A}$

Q_S = shaft ratio, $Q_S = \frac{D_{BG}}{D_S}$

11.4 Maximum permissible oversize of shrink fit

The maximum permissible oversize is calculated according to:

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

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

D. Materials

1. Approved materials

1.1 The mechanical characteristics of materials used for the components of diesel engines shall conform to Rules for Materials (Pt.1, Vol.V). The materials approved for the various components are shown in Table 2.3 together with their minimum required characteristics and material certificates.

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

2. Certification of Engine Component

2.1 General

The engine manufacturer is to have a quality control system that is suitable for the actual engine types to be certified by BKI. The quality control system is also to apply to any sub-suppliers. BKI 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. BKI requires that certain parts are verified and documented by means of BKI Certificate (BC), Work Certificate (W) or Test Report (TR).

2.2 BKI Certificate (BC)

This is a document issued by BKI 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 on 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).

2.3 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 on 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 BKI Certificate and endorsed by BKI if:

- the test was witnessed by BKI Surveyor; or
- an ACS agreement is in place between the BKI 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 BKI and independent from the manufacturer and/or material supplier

2.4 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.

2.5 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 by BKI, 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.

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

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

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.

3. Parts to be documented

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

3.2 Symbols used are listed in Table 2.4 A summary of the required documentation for the engine components is listed in Table 2.5

Table 2.4: Symbols used in Table 2.5

Symbol	Description
C	chemical composition
CD	crack detection by MPI or DP
CH	crosshead engines
D	cylinder bore diameter (mm)
GJL	grey cast iron
GJS	spheroidal graphite cast iron
GS	cast steel
M	mechanical properties
BC	BKI certificate
TR	test report
UT	ultrasonic testing
W	work certificate
X	visual examination of accessible surfaces by the Surveyor

3.3 For components and materials not specified in Table 2.5, consideration will be given by BKI upon full details being submitted and reviewed.

Table 2.5: Summary of required documentation for engine components

Part 4)5)6)7)8)	Material Properties 1)	NDE 2)	Hydraulic testing 3)	Dimensional inspection, including surface condition	Visual Inspection	Applicable to engines	Component certificate
Welded bedplate	W(C+M)	W(UT+CD)			Fit-up+post-welding	All	BC
Bearing transverse girders GS	W(C+M)	W(UT+CD)			X	All	BC
Welded frame box	W(C+M)	W(UT+CD)			Fit-up+post-welding	All	BC
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	BC
Engine block GJL			W 10)			>400 kW/cyl	

Table 2.5 Summary of required documentation for engine components *(continued)*

Part[4)5)6)7)8)]	Material Properties[1)]	NDE[2)]	Hydraulic testing[3)]	Dimensional inspection, including surface condition	Visual Inspection	Applicable to engines	Component certificate
Cylinder liner	W(C+M)		W[10)]			D>300mm	
Cylinder head GJL			W			D>300mm	
Cylinder head GJS			W			D>300mm	
Cylinder head GS	W(C+M)	W(UT+CD)	W		X	D>300mm	BC
Forged cylinder head	W(C+M)	W(UT+CD)	W		X	D>300mm	BC
Piston crown GS	W(C+M)	W(UT+CD)			X	D>400mm	BC
Forged piston crown	W(C+M)	W(UT+CD)			X	D>400mm	BC
Crankshaft: made in one piece	BC(C+M)	W(UT+CD)		W	Random, of fillets and oil bores	All	BC
Semi-built Crankshaft (Crank throw, forged main journal and journals with flange)	BC(C+M)	W(UT+CD)			Random, of fillets and fillets and shrink fittings	All	BC
Exhaust gas valve cage			W			CH	
Piston rod	BC(C+M)	W(UT+CD)			Random	D>400mm CH	BC
Cross head	BC(C+M)	W(UT+CD)			Random	CH	BC
Connecting rod with cap	BC(C+M)	W(UT+CD)		W	Random, of fillets all surfaces, in particular those shot peened	All	BC
Coupling bolts for crankshaft	BC(C+M)	W(UT+CD)		W	Random, of interference fit	All	BC
Bolts and studs for main bearings	W(C+M)	W(UT+CD)				D>300mm	BC

Table 2.5 Summary of required documentation for engine components *(continued)*

Part [4][5][6][7][8]	Material Properties[1]	NDE[2]	Hydraulic testing[3]	Dimensional inspection, including surface condition	Visual Inspection	Applicable to engines	Component certificate
Bolts and studs for cylinder heads	W(C+M)	W(UT+CD)				D>300mm	BC
Bolts and studs for connecting rods	W(C+M)	W(UT+CD)		TR of thread making		D>300mm	BC
Tie rod	W(C+M)	W(UT+CD)		TR of thread making	Random	CH	BC
High pressure fuel injection pump body	W(C+M)		W			D>300mm	
	W(C+M)		TR			D ≤ 300 mm	
High pressure fuel injection valves (only for those not autofretted)			W			D>300mm	
			TR			D≤300mm	
High pressure fuel injection pipes including common fuel rail	W(C+M)		W (for those that are not autofretted)			D>300mm	
	W(C+M)		TR (for those that are not autofretted)			D≤300mm	
High pressure common servo oil system	W(C+M)		W			D>300mm	
			TR			D≤300mm	
Cooler, both sides[9]	W(C+M)		W			D> 300mm	
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	

Table 2.5 Summary of required documentation for engine components *(continued)*

Part [4)5)6)7)8)]	**Material Properties**[1)]	**NDE**[2)]	**Hydraulic testing**[3)]	**Dimensional inspection, including surface condition**	**Visual Inspection**	**Applicable to engines**	**Component certificate**
Engine driven pumps (oil, water, fuel, bilge) other than high pressure fuel injection pump body and pumps for hydraulic drive of valves			W			>800 kW/cyl	
Bearings for main, crosshead, and crankpin	TR(C)	TR (UT for full contact between base material and bearing metal)		W		>800 kW/cyl	

[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 Magnetic Particle Inspection (MPI) or Dye Penetrant (DP). When certain NDE method on the finished component is impractical (for example UT for items 12/13), the NDE method can be performed at earlier appropriate stages in the production of the component, see M72.1.2

[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 elsewhere in the IACS URs.

[5)] For turbochargers, see Section 3.III.C.

[6)] Crankcase explosion relief valves are to be type tested in accordance with F.4.1

[7)] Oil mist detection systems are to be type tested in accordance with F.4.3

[8)] For speed governor and overspeed protective devices, see Rules for Automation (Pt.1, Vol.VII)

[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 fuction of containing the water which is in contact with the cylinder or cylinder liner.

NDE: Non-Destructive Examination

3.4 In addition, material tests are to be carried out on pipes and parts of the starting air system and other pressure systems forming part of the engine, see Section 11.

3.5 Materials for charge air coolers are to be supplied with manufacturer test reports.

3.6 Welded seams of important engine components may be required to be subjected to approve methods of testing.

3.7 Where there is reason to doubt the soundness of any engine component, non-destructive testing by approved methods may be required in addition to the tests mentioned above.

3.8 Crankshafts welded together from forged or cast parts are subject to BKI's special approval. Both the manufacturers and the welding process shall be approved. The materials and the welds are to be tested.

E. Tests and Trials

1. Approval of engine manufacturer's work shops

1.1 Every workshop where engines are assembled and tested has to be approved by BKI when:

— the workshop is newly set up,

— a new production line is started,

— a new engine type is introduced, or

— a new production process is implemented.

1.2 Requirements for approval of engine manufacturer's workshops:

— the manufacturer's works are to be audited by BKI.

— 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.

Note:
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 BKI.

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 BKI.

2. Manufacturing inspections

2.1 In general, the manufacture of engines with BKI is subject to supervision by BKI. The scope of supervision should be agreed between the manufacturer and BKI.

2.2 Where engine manufacturers have been approved by BKI as "Suppliers of Mass Produced Engines", these engines are to be tested in accordance with Guidance for The Approval and Type Approval of Materials and Equipment for Marines Use (Pt.1, Vol. W) Section 5.

3. Pressure tests

The individual components of internal combustion engines are subject to pressure tests at the pressures specified in Table 2.6. BKI Certificates are to be issued for the results of the pressure tests.

Table 2.6: Pressure test [1)]

Component		Test Pressure, P_p [bar] [2)]
Cylinder cover, cooling water space[3)]		7
Cylinder liner, over whole length of cooling water space[5)]		7
Cylinder jacket, cooling water space		4 , at least 1,5 · $p_{e,perm}$
Exhaust valve, cooling water space		4 , at least 1,5 · $p_{e,perm}$
Piston, cooling water space (after assembly with piston rod, if applicable)		7
Fuel injection system	Pump body, pressure side	1,5 · $p_{e,perm}$ or $p_{e,perm}$ + 300 (whichever is less)
	Valves	1,5 · $p_{e,perm}$ or $p_{e,perm}$ + 300 (whichever is less)
	Pipes	1,5 · $p_{e,perm}$ or $p_{e,perm}$ + 300 (whichever is less)
Hydraulic system	High pressure piping for hydraulic drive of exhaust gas valves	1,5 · $p_{e,perm}$
Exhaust gas turbocharger, cooling water space		4 , at least 1,5 · $p_{e,perm}$
Exhaust gas line, cooling water space		4 , at least 1,5 · $p_{e,perm}$
Coolers, both sides[4)]		4 , at least 1,5 · $p_{e,perm}$
Engine-driven pumps (oil, water, fuel and bilge pumps)		4 , at least 1,5 · $p_{e,perm}$
Starting and control air system		1,5 · $p_{e,perm}$ before installation

[1)] In general, items are to be tested by hydraulic pressure. Where design or testing features may require modification of these test requirements, special arrangements may agree.
[2)] $p_{e,perm}$ [bar] = maximum allowable working pressure in the part concerned.
[3)] For forged steel cylinder covers test methods other than pressure testing may be accepted, e.g. suitable non-destructive examination and dimensional control exactly recorded.
[4)] Charge air coolers need only be tested on the water side.
[5)] For centrifugally cast cylinder liners, the pressure test can be replaced by a crack test.

4. Type approval testing (TAT)

Engines for installation on board ship must have been type tested by BKI. For this purpose a type approval test in accordance with Guidance for The Approval and Type Approval of Materials and Equipment for Marines Use (Pt.1, Vol.W) Sec.3.H is to be performed.

5. Work Trial (Factory Acceptance Test)

5.1 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.

5.2 Records

5.2.1 The following environmental test conditions are to be recorded:

- Ambient air temperature
- Ambient air pressure
- Atmospheric humidity

5.2.2 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
- Charge air temperature
- Charge air pressure
- Turbocharger speed

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

5.2.4 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.

5.2.5 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.

5.3 Test loads

5.3.1 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 the Society when the overall scope of tests is found to be equivalent.

5.3.2 Propulsion engines driving propeller or impeller only.

1) 100% power (MCR) at corresponding speed n_0:
at least 60 min.

2) 110% power at engine speed $1{,}032 \cdot n_0$:
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.

3) Approved intermittent overload (if applicable):
testing for duration as agreed with the manufacturer.

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.

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 BKI. In that case, the fuel delivery system is to be blocked to that power.

5.3.3 Engines driving generators for electric propulsion.

1) 100% power (MCR) at corresponding speed n_0:
at least 60 min.

2) 110% power at engine speed n_0:
15 min. - after having reached steady conditions.

3) Governor tests for compliance with F.1.1.1 and F.1.1.2 are to be carried out.

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 on-board. 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.

5.3.4 Engines driving generators for auxiliary purposes.

Tests to be performed as in 5.3.3 above

5.3.5 Propulsion engines also driving power take off (PTO) generator.

1) 100% power (MCR) at corresponding speed n_0:
at least 60 min.

2) 110% power at engine speed n_0:
15 min. - after having reached steady conditions.

3) Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.

4) 90% (or normal continuous cruise power), 75%, 50% and 25% power in accordance with the nominal propeller curve or at constant speed n, 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 on-board. 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.

5.3.6 Engines driving auxiliaries.

1) 100% power (MCR) at corresponding speed n_0:
at least 30 min.

2) 110% power at engine speed n_0:
15 min. - after having reached steady conditions.

3) Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.

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.

5.4 Turbocharger matching with engine

5.4.1 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.

5.4.2 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).

.1 For 4 (four)-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).

.2 For 2 (two)-stroke engines:

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

1) 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).

2) 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).

3) 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.

5.5 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 BKI for selected cases based on the FMEA required in .B.5. above.

5.6 Component inspections

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

6. Shipboard trials

6.1 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). See also Guidance for Ship Trials of Motor Vessels (Pt.1, Vol.B)

6.2 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.

6.3 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.

6.4 Test loads

6.4.1 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.

6.4.2 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).

6.4.3 Propulsion engines driving fixed pitch propeller or impeller.

1) At rated engine speed n_0:
   at least 4 hours.

2) At engine speed 1,032 · n_0
   (if engine adjustment permits, see 5.3.1): 30 min.

3) At approved intermittent overload (if applicable):
   testing for duration as agreed with the manufacturer.

4) Minimum engine speed to be determined.

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 4.5.1 for additional requirements in the case of a barred speed range.

6.4.4 Propulsion engines driving controllable pitch propellers.

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.

2) At approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.

3) With reverse pitch suitable for manoeuvring, see 6.5.1 for additional requirements in the case of a barred speed range.

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

1) At 100% power (rated electrical power of generator):
   at least 60 min.

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.

3) Demonstration of the generator prime movers' and governors' ability to handle load steps as described in F.1.1.2.

6.4.6 Propulsion engines also driving power take off (PTO) generator.

1) 100% engine power (MCR) at corresponding
   speed n0: at least 4 hours.

2) 100% propeller branch power at engine speed n_0:
   (unless already covered in A): 2 hours.

3) 100% PTO branch power at engine speed n_0:
   at least 1 hour.

6.4.7 Engines driving auxiliaries.

1) 100% power (MCR) at corresponding speed n_0:
   at least 30 min.

2) Approved intermittent overload: testing for duration as approved.

6.5 Torsional vibrations

6.5.1 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 bare speed range. Steady fuel index means an oscillation range less than 5% of the effective stroke (idle to full index).

6.6 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.

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 electrical generator shall 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 shall 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 BKI.

1.1.3 When electronic speed governors of main internal combustion engines form part of a remote control system, they are to comply 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 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 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 Guidance for Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W) Sec.3.V.4.

1.2 Engines driving electrical generators

1.2.1 Each diesel engine used to drive an electrical main or emergency generator shall be fitted with a governor which will prevent transient frequency variations in the electrical network in excess of ± 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 over-speed 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 shall 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 shall be suitable and designed for the special requirements of the ship's electrical system.Where two stages load application is required, 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 Figure .2.10) is acceptable on condition that

- the ship's electrical system is designed for 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 test 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 demonstrated.

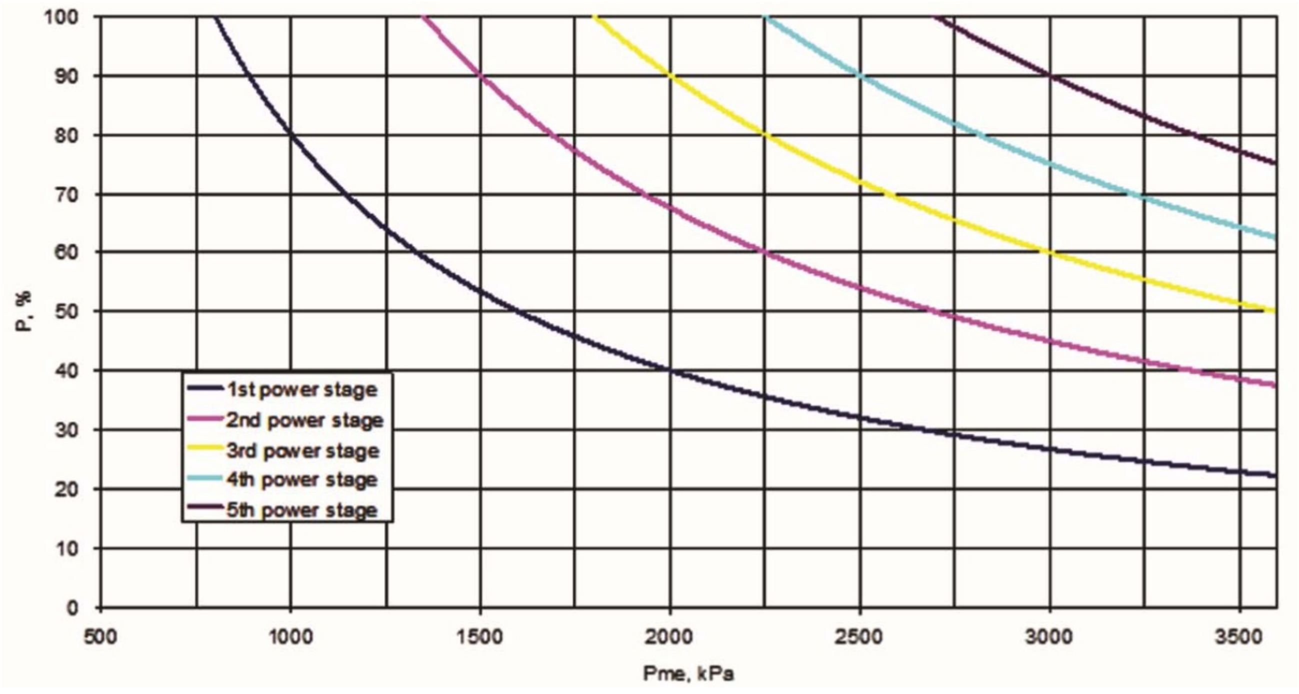


Figure 2.10: Limiting curves for loading 4-stroke diesel engines step by step from no load to rated power as function of the brake mean effective pressure

1.2.4 Speeds shall be stabilized and in steady-state condition within five seconds, inside the permissible range for the permanent speed variation δ_r.

The steady-state condition is considered reached when the permanent speed variation does not exceed ± 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 Installations (Pt.1, Vol.IV), Sec. 1,F.1.

1.2.6 Generator sets which are installed to serve stand-by circuits are to satisfy the corresponding requirements even when the engine is cold. It is assumed that the start-up and loading sequence is completed after about 30 seconds.

1.2.7 Emergency generator sets must satisfy the governor conditions as per items 1.2.1 and 1.2.2 even when:

1) their total consumer load is applied suddenly, or

2) 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 shall 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 shall 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.

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.

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 Rules for Electrical Installations (Pt.1, Vol.IV) Sec. 9, B.9.

1.3.2 Requirements applying to main engines

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. To ensure continuous speed control or immediate resumption of control after a fault at least one of the following requirements is to be satisfied:

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

For multiple engine propulsion plants requirements in Section 1, D.8.3 are to be observed.

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

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

1.3.3 Requirements applying to auxiliary engines for driving electrical generators

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

In the event of a fault of components or functions which are essential for the speed control in the governor system, the speed demand output shall be set to ”0” (i.e the fuel admission in the injection pump shall 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 Rules for Electrical Installations (Pt.1, Vol.IV) Sec. 3, B.1.9)

2. Crankcase airing and venting

2.1 Crankcase airing

The airing of crankcases and any arrangement which could produce air intake within the crankcase is not allowed. For gas engines, see Rules for Ship Carrying Liquefied Gases in Bulk (Pt.1, Vol.IX), Sec. 16.

2.2 Crankcase venting

2.2.1 Where crankcase venting systems are provided their clear opening is to be dimensioned such as small as possible.

2.2.2 Where provision has been made for the forced extracting the lubricating oil mist, e.g. for monitoring the oil mist concentration, the vacuum in the crankcase is not to exceed 2,5 mbar.

2.2.3 The vent pipes and oil drain pipes of two or more engines shall not be combined. Exemptions may be approved if an interaction of the combined systems is inhibited by suitable means.

2.2.4 In case of two-stroke engines the lubricating oil mist from the crankcase shall not be admitted into the scavenge manifolds respectively the air intake pipes of the engine.

3. crankcase safety devices

3.1 Relief valves

3.1.1 Crankcase safety devices have to be type approved in a configuration that represents the installation arrangements that will be used on an engine according to the requirements defined in Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use, (Pt.1, Vol.W) Sec. 3.I

3.1.2 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 m^3.

All separated spaces within the crankcase e.g. gear or chain casings for camshafts or similar drives, are to be equipped with additional safety devices if the volume of these spaces exceeds 0,6 m^3.

3.1.3 Engines with a cylinder bore of > 200 mm and $\leq$ 250 mm are to be equipped with at least one relief valve at each end of the crankcase. If the crankshaft has more than 8 throws, an additional relief valve is to be fitted near the middle of the crankcase.

Engines with a cylinder bore of > 250 mm and $\leq$ 300 mm are to have at least one relief valve close to each alternate crank throw, with a minimum number of two.

Engines with a cylinder bore of > 300 mm are to have at least one safety valve close to each crank throw.

3.1.4 Each safety valve shall have a free relief area of at least 45 cm^2.

The total free relief area of all safety valves fitted to an engine to safeguard against overpressure in the crankcase shall not be less than 115 cm^2 per m^3 of crankcase gross volume.

Notes relating to 3.1.2 and 3.1.3

In estimating the gross volume of the crankcase, the volume of the enclosed fixed parts may be deducted.

A space communicating with the crankcase via a total free cross-sectional area of > 115 cm^2/m^3 of volume need not be considered as a separate space.

Each relief valve required may be replaced by not more than two relief valves of smaller cross-sectional area provided that the free cross-sectional area or each relief valve is not less than 45 cm^2.

3.1.5 The safety devices are to be of quick acting and self-closing devices to relief 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 affects 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.

3.1.6 The relief valves are to be provided with a flame arrester than permits crankcase pressure relief and prevents passage of flame following a crankcase explosion.

3.1.7 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

3.1.8 Safety devices are to be provided with a manufacturer's installation and maintenance manual that is pertinent to the size and type of device as well as on the installation on the engine. A copy of this manual is to be kept on board of the ship.

3.1.9 Plans showing details and arrangements of safety devices are to be submitted to approval.

3.2 Crankcase doors and sight holes

3.2.1 Crankcase construction and crankcase doors are to be of sufficient strength to withstand anticipated crankcase pressures that may arise during a crankcase explosion taking into account the installation of explosion relief valves required by F.4. Crankcase doors are to be fastened sufficiently securely for them not be readily displaced by a crankcase explosion.

3.2.2 Crankcase doors and hinged inspection ports are to be equipped with appropriate latches to effectively prevent unintended closing.

3.2.3 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 the crankcase doors or sight holes are not to be opened before a reasonable time, sufficient to permit adequate cooling after stopping the engine.

3.3 Oil mist detection/monitoring and alarm system (Oil mist detector)

3.3.1 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 alternative systems.

For 2-stroke crosshead engines alternative methods may not replace oil mist detectors. Oil mist detectors are required to be fitted.

3.3.2 For multiple engine installations each engine is to be provided with a separate oil mist detector and a dedicated alarm.

3.3.3 Oil mist detectors are to be type approved. The mechanical requirements are defined in Guidance for The Approval and Type Approval of Materials and Equipment for Marines Use (Pt.1, Vol.W) Sec.3 .J.

3.3.4 The oil mist detector is to be installed in accordance with the engine designer's and the system manufacturer's instructions and recommendations.

3.3.5 Function tests are to be performed on the engine set 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 BKI.

3.3.6 Alarms and shutdowns for the detector are to be in accordance with Table 2.7.

3.3.7 Functional failures at the devices and equipment are to be alarmed.

Table 2.7: Alarm and indicators

Description	Propulsion engines	Auxiliary engines	Emergency engines [10]
speed / direction of rotation	I		
engine over-speed [5]	A, S	A, S	A, S
lubricating oil pressure at engine inlet	I, L[9], S	I, L[9], S	I, L[9], S
lubricating oil temperature at engine inlet	I, H	I[5], H[5]	I[5], H[5]
fuel oil pressure at engine inlet	I, L	I	
fuel oil temperature at engine inlet [1]	I, A	I, A	
fuel oil leakage from high pressure pipes (fuel injection pipes and common rails)	A	A	A
cylinder cooling water pressure at engine inlet	I [4], L [4]	I [4], L [4]	I, L[5]
cylinder cooling water temperature at engine outlet	I, H	I, H, S	I, 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 outlet	I, H		
starting air pressure	I, L		
control air pressure	I, L		
exhaust gas temperature	I [2], H[8]		
Activation of oil mist detection arrangements (or activation of the temperature monitoring systems or equivalent devices of: — the engine main, crank and crosshead bearing oil outlet; or — the engine main, crank and crosshead bearing[6][7]	I, A, S[8]	I, A, S[8]	I, A, S[8]

[1] for engines running on heavy fuel oil only
[2] wherever the dimensions permit, at each cylinder outlet
[3] wherever the dimensions permit, at turbocharger inlet, otherwise at outlet
[4] monitoring of expansion tank level, with alarm at low level, is an acceptable alternative for engines with cylinder power < 130 kW
[5] only for engine output $\geq$ 220 kW
[6] for engine having an output $\geq$ 2250 kW or a cylinder bore >bore 300 mm
[7] alternative methods of monitoring may be approved by BKI
[8] slow down for engines having a rated speed less than 300 rpm
[9] only for an engine output > 37 kW
[10] applicable to reciprocating I.C. engines which use distillate marine fuels covered by ISO 8217:2017

I : Indicator
A: Alarm
H: Alarm for upper limit
L: Alarm for lower limit
S: Shutdown

3.3.8 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.

3.3.9 Where the detector includes the use of programmable electronic systems, the arrangements are in accordance with the requirements of Rules for Electrical Installations (Pt.1, Vol.IV), Sec. 10.

3.3.10 Where sequential oil mist detection/ monitoring arrangements are provided, the sampling frequency and time are to be as short as reasonably practicable.

3.3.11 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.

3.3.12 A copy of the documentation supplied with the system such as maintenance and test manuals are to be provided on board ship.

3.3.13 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.

3.3.14 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 BKI. 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
- 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

3.4 Active safety measures

Where it is proposed to use alternative active technologies to minimize the risk for a potential crankcase explosion, details of the arrangement and the function description are to be submitted to BKI for approval.

4. Safety devices in the starting air system

The following equipment is to be fitted to safeguard the starting air system against explosions due to failure of starting valves:

4.1 An isolation non-return valve is to be fitted to the starting air line serving each engine.

4.2 Engines with cylinder bores of > 230 mm are to be equipped with flame arrestors 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 airline to each engine.

4.3 Equivalent safety devices may be approved by BKI.

5. 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.

6. Safety devices in scavenge 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 11 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 BKI.

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 is 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 or other equivalent means approved by administrator in such a way that any leaking fuel is:

— safely collected

— drained away unpressurized, and

— effectively 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 of permanent assembly

2.2.4 Where, pipe sheaths in the form of hoses are provided as shielding, the hoses shall be demonstrably suitable for this purpose and approved by BKI.

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 re-circulation are also to be provided.

2.5 Fuel oil emulsions

For engines operated on emulsions 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 not feasible, 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 Change-over filters with two or more chambers are to be equipped with means enabling a safe pressure release before opening and a proper venting before re-starting of any chamber. Normally, shut-off devices are to be used. It shall be clearly visible, which chamber is in and which is out of operation.

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.

venting when put into operation

3.6 In addition the requirements of Section 8 have to be considered also for filters.

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 11, H. For piping arrangement, 2.1.5 is to be applied.

4.1.1 Engines which 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 combination of the oil drainage lines from the crankcases of two or more engines is not allowed.

4.1.3 The outlet ends of drain lines from the engine sump shall be below the oil level in the drain tank.

4.2 The equipment of engines fitted with lubricating oil pumps is subject to Section 11, 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 system 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 BKI.

5. Cooling system

5.1 For the equipment of engines with cooling water pumps and for the design of cooling water systems, see Section 11, I. and 11, 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 multi-engine installations having 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. Shut-off valves shall 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 in which oil-firing equipment is operated, Section 9.B is also to be complied with.

6. Charge air system

6.1 Exhaust gas turbocharger

6.1.1 The construction and testing of exhaust gas turbocharger are subject to Section 3.II in this Rules.

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 shall also be ensured during start-up and run-down of the exhaust gas turbochargers.

6.1.4 Even at low engine speeds, main engines shall 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, a stand-by charge air blower is to be installed or an equivalent device of approved design.

6.1.6 With main engines emergency operation shall be possible in the event of a turbocharger failure.

6.2 Charge air cooling

6.2.1 Means are to be provided for regulating the temperature of the charge air within the temperature range specified by the engine manufacturer.

6.2.2 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 (see Table 12.1) which is independent of the engine room fire extinguishing system.

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 shall be non-combustible.

7.2 General rules relating to exhaust gas lines are contained in Section 11, L.

H. Starting Equipment

1. General

Engine starting equipment shall enable engines to be started up from ”dead ship” condition according to Section 1, D.6.1 using only the means available on board.

1.1 Means are to be provided to ensure that auxiliary and emergency diesel engines can be started after black-out and ”dead-ship” condition. This is to be considered especially for electronically controlled engines (e.g. common rail).

2. Starting with compressed air

2.1 Starting air systems for main engines are to be equipped with at least two starting air compressors. At least one of the air compressors shall be driven independently of the main engine. The capacity of one of the said independently driven compressors or the combined capacity of independently driven compressors shall not be less than 50% of the total required.

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 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 BKI's agreement, be reduced according to the concept of the propulsion plant. The Guidance for Sea Trials of Motor Vessels (Pt.1, Vol.B) may be observed.

2.6 If starting air systems for auxiliaries or for supplying pneumatically operated regulating and maneuvering equipment or tyfon units, low-pressure compressed air systems, control systems, etc. 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 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 BKI.

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 Approximate calculation of the starting air supply

For the approximate calculation of the starting air supply the following formula may be used.

2.10.1 Starting air for installations with reversible engines

Assuming an initial pressure of 30 bar and a final pressure of 9,0 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 [dm^3]
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) [dm^3]
$P_{e,perm}$	=	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:

- for two-stroke engines: a = 0,4714
- for four-stroke engines: a = 0,4190

The following values of “b” are to be used:

- for two-stroke engines: b = 0,059
- for four-stroke engines: a = 0,056

The following values of ”c” are to be used:

- $c = 1$, where $P_{e,perm} = 30$bar
- $c = \frac{0,0584}{1 - e^{(0,11-0,05 \cdot \ln P_{e,perm})}}$, where $P_{e,perm} > 30$bar, if no pressure-reducing valve is fitted.

  $e = $ Euler’snumber$(2,718...)$

  Where $P_{e,perm} > 30$bar, if a pressure-reducing valve is fitted, which reduces the pressure $P_{e,perm}$ to the starting pressure P_A, the value of “c” shown in Figure .2.14 is to be used.

The following values of n_A are to be applied:

- $n_A = 0,06 \cdot n_0 + 14$ where $n_0 \leq 1000$
- $n_A = 0,25 \cdot n_0 - 176$ where $n_0 > 1000$
  n_0 = rated speed [rpm]

2.10.2 Starting air for installations with non-reversible 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 · J though not less than that needed for six start-up operations.

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 shall 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 in 2.4. or 2.5 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 shall 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 shall 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 shall be guaranteed under all weather and seaway conditions. Fire flaps required in air inlet and outlet openings shall only be closed in case of fire and are to be kept open at all other times. Warning signs to this effect are to be installed. In the case of automatic fire flap actuation dependent on the operation of the set warning signs are not required. Air inlet and outlet openings shall 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 BKI, the capacity of which is sufficient for at least three consecutive starts (compare Rules for Electrical Installations (Pt.1, Vol.IV), Sec. 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 maybe initiated manually.

4.6 The starters of emergency generator sets shall be used only for the purpose of starting the emergency generator 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 hand crank is not possible, the emergency fire-extinguisher set is to be fitted with a starting device approved by the BKI which enables at least 6 starts to be performed within 30 minutes, two of these being carried out within the first 10 minutes.

6. Capacity and availability of compressed air for essential services

6.1 Application

The following requirements apply to the supply of compressed air required by essential services onboard ships other than the supply of compressed air for engine starting.

6.2 Requirements

6.2.1 The arrangements for the supply of compressed air to essential services are to ensure that sufficient compressed air to satisfy the total demand of the essential services is available at all times during normal operation, during maintenance, and in the event of a failure of the compressed air system.

6.2.2 Where compressed air is supplied from the engine starting air system, either continuously in normal operation, or periodically during maintenance or in the event of a failure of the compressed air system, the required compressed air demand is not to reduce the capacity and availability of the engine starting air required by 2.H.1 to 2.H.3.

I. Control Equipment

1. General

For unmanned machinery installations, Rules for Automation (Pt.1, Vol.VII), is to be observed in addition to the following requirements.

2. Main Engines

2.1 Local control station

For local operation without remote control 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 2.6 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 2.6 are to be installed, see Rules for Automation (Pt.1, Vol.VII), Sec. 5.A.

2.3 Bridge/navigations centre.

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 showing:

— 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 engines installations up to a total output of 600 kW, simplification can be agreed with BKI.

3. Auxiliary and emergency engines

The controls according to Table 2.6 are to be provided as a minimum at the engine.

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. Furthermore, for the details layout of alarm and safety system and automated machinery installations, Rules for Automations (Pt.1, Vol.VII) shall be observed.

1.2 Within the context of these requirements, the word alarm is to be understood as 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 2.6.

K. Engine Alignment/Seating

1. Engines are to be mounted and secured to their shipboard foundations in conformity with Guidance for Seating of Diesel Engine Installation (Pt.1, Vol.U) as well as Section 4, D.5.8.

2. 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.

For the purpose of subsequent alignments, note is to be taken of:

— the draught/load condition of the vessel,

— the condition of the engine-cold/ preheated/ hot.

3. Where the engine manufacturer has not specified values for the permissible crank web deflection, assessment is to be based on BKI's reference values.

4. Reference values for crank web deflection

4.1 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 Figure .2.11.

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.

4.2 Notes on the measurement of crank web deflections

Crank web deflections are to be measured at distance

$$R + \frac{dw}{2}$$

from the crankpin centre line (see Figure .2.12) Crank web deflection Δ_a is only meaningful as measured between opposite crank positions (see Figure .2.12), 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.

4.3 Determining the crank web deflection length r_o

Explanatory notes on:

— solid forged and drop forged crankshafts in Figure .2.13, subfigures A, B and C;

— semi-built crankshafts, subfigure D.

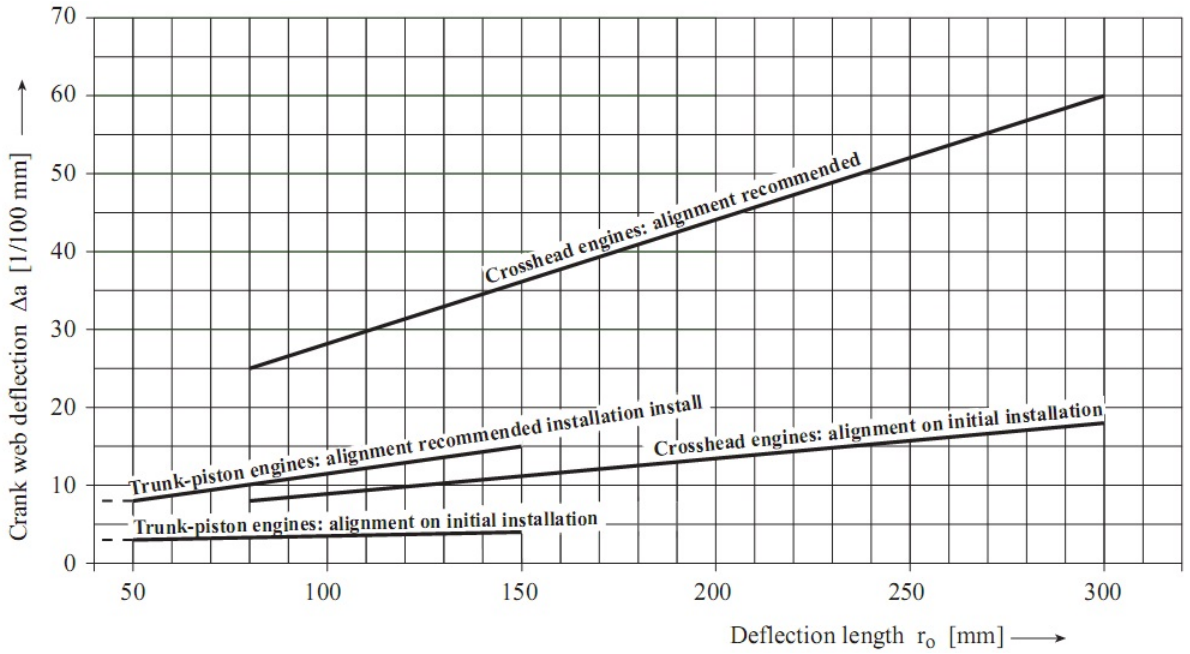


Figure 2.11: Reference values for crack web deflection

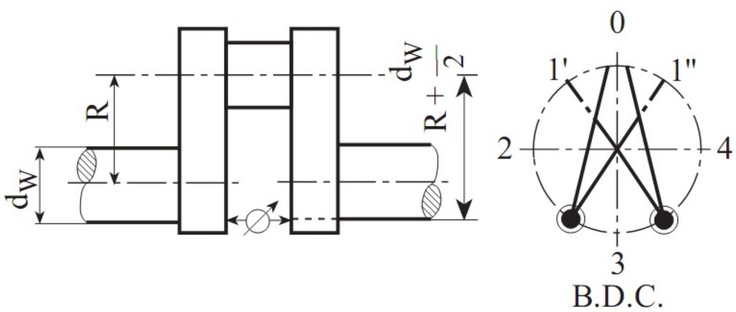


Figure 2.12: Measurements of crank web deflection

Symbols:

R	=	crank radius [mm]
H	=	stroke (2R) [mm]
dk	=	crank pin diameter [mm]
dw	=	journal diameter [mm]
dN	=	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]

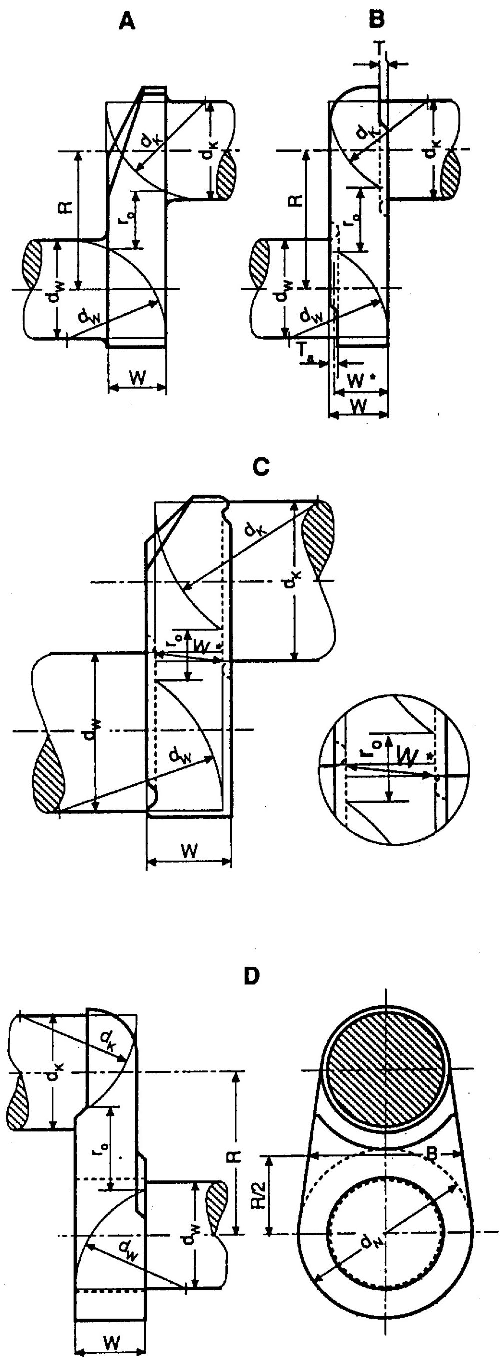


Figure 2.13: Types of forged (A, B and C) and semi built (D) crankshafts

s = pin/journal overlap [mm]

$$= \frac{d_k + d_w}{2} - R$$

Where there is a negative pin/journal overlap (s < 0), the deflection length r_o in accordance with subfigure A is determined by applying the formula:

$$r_o = 0,5(H + d_k + d_w) - W\left(\sqrt{\frac{2d_k}{W} - 1} + \sqrt{\frac{2d_w}{W} - 1}\right) \quad (1)$$

In case of web undercut, W in formula (1) is to be replaced by:

$$W^* = W - \frac{T_i + T_a}{2} \tag{2}$$

In the case of semi-built crankshafts in accordance with subfigure D, the value d_W in the radicand of formula (1) is to be replaced by:

$$d_W = \frac{1}{3}(d_N - d_W) + d_W \tag{3}$$

In case of web undercut, W* is also to be substituted for W in accordance with formula (2).

Where there is a positive pin/journal overlap (s ≥ 0) according to subfigure C, the value W in formula (1) is to be replaced by:

$$W^* = \sqrt{(W - T_i - T_a)^2 + [0,5(d_k + d_W - H)]^2} \tag{4}$$

For the conventional designs, where:

B/d_W = 1,37 to 1,51 in the case of solid forged crankshafts, and

B/d_W = 1,51 to 1,63 in the case of semi-built crankshafts, the influence of B in the normal calculation of r_o is already taken into account in the values of Δa in Figure .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 formula (1):

$$W^{**} = W^* \sqrt[3]{\frac{B}{d_W} - 0,44} \tag{5}$$

for solid forged crankshafts

$$W^{**} = W^* \sqrt[3]{\frac{B}{d_W} - 0,57} \tag{6}$$

or semi-built crankshafts

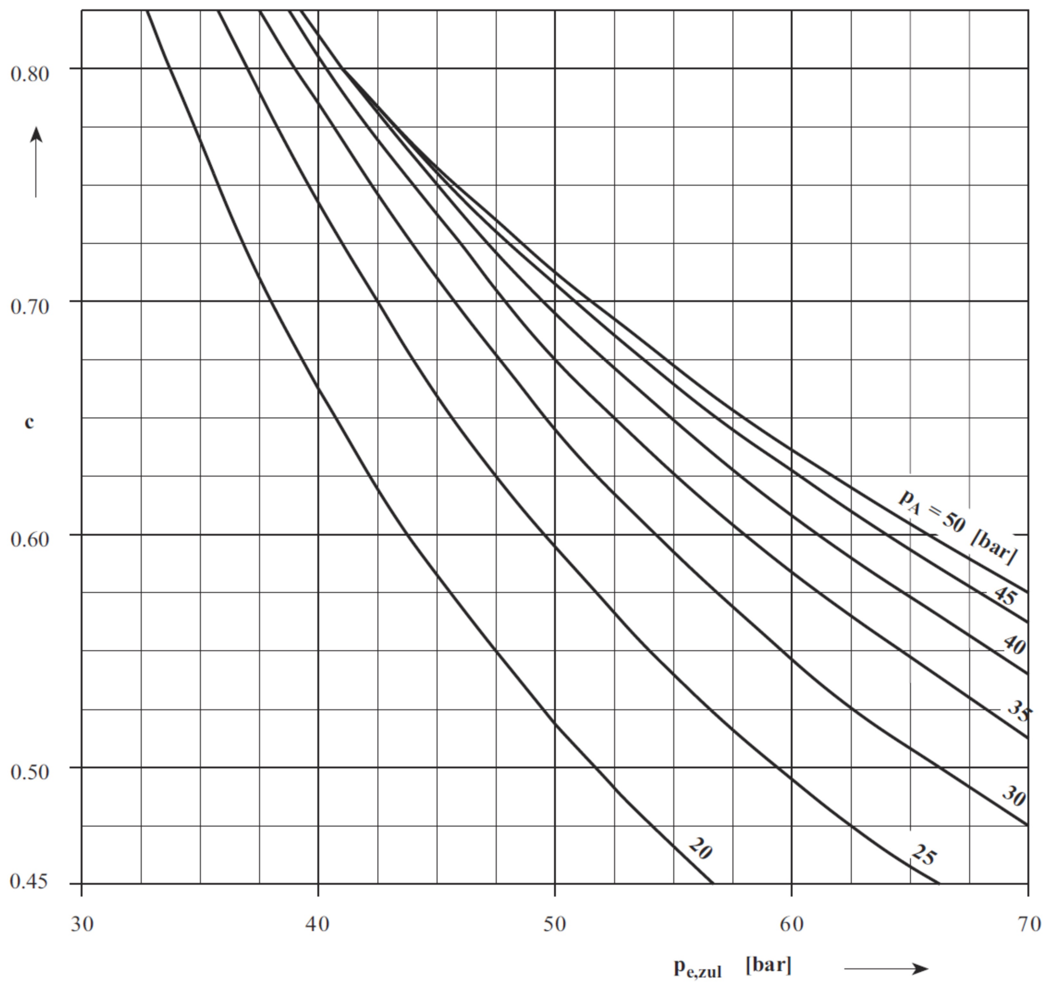


Figure 2.14: The Value of "c" where a pressure-reducing valve is fitted

L. Approximate Calculation of the Starting Air Supply

These calculations are integrated in H.2.10.

M. Air Compressors

1. General

1.1 Scope

These requirements apply to reciprocating compressors of the normal marine types. Where it is intended to install compressors to which the following requirements and calculation formula cannot be applied, BKI 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 BKI for each compressor type. The documents shall be submitted in form of electronic format for approval.

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 BKI.

2.2 Material testing

Material tests are to be performed on crankshafts with a calculated crank pin diameter of > 50 mm. For crank pin diameters of ≤ 50 mm a Manufacturer Inspection Certificates is 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 in two-stage compressors with separate pistons
	=	$1,4 \cdot D_{Hd}$ for two-stage compressors with a differential piston as in Figure .2.15
	=	$\sqrt{(D_{Nd})^2 - (D_{Hd})^2}$ for two-stage compressors with a differential piston as in Figure .2.16
p_c	=	design pressure PR, applicable up to 40 bar [bar]
H	=	piston stroke [mm]
L	=	distance between main bearing centers where one crank is located between two bearings. L is to be substituted by $L_2 = 0,85 \cdot L$ 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° for V or W type
	=	1,5, where the cylinders area at 60° for V or W type
	=	1,8, where the cylinders are at 45° for 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 Table 2.10.
R_m	=	minimum tensile strength [N/mm²]

3.2 Where increased strength is achieved by a favourable configuration of the crankshaft, smaller values of d_k may be approved.

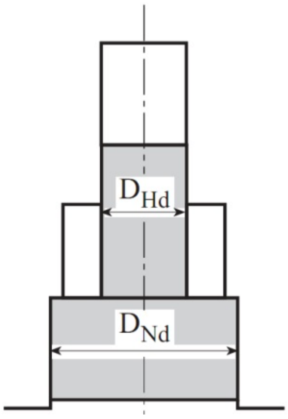


Figure 2.15:

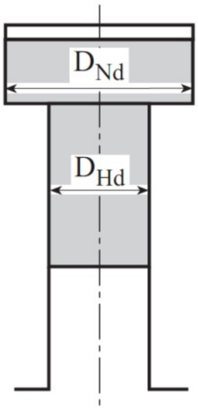


Figure 2.16:

Table 2.8: Values of C_1

z	1	2	4	6	≥ 8
C1	1,0	1,1	1,2	1,3	1,4

Table 2.9: Values of C_W for steel shafts

Rm	**Cw**
400	1,03
440	0,94
480	0,91
520	0,85
560	0,79
600	0,77
640	0,74
≥ 680	0,70
720 1)	0,66
≥ 760 1)	0,64
1) Only for drop-forged crankshafts	

Table 2.10: Values of C_W for nodular cast iron shafts

Rm	**Cw**
370	1,20
400	1,10
500	1,08
600	0,98
700	0,94
≥ 800	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 according 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 shall 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 shall 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 shall 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 shall 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 shall 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 after cooler.

4.3.4 Water traps, after coolers and the compressed air spaces between the stages shall be provided with discharge devices at their lowest points.

4.4 Name Plate

Every compressor is to carry a name plate with the following information:

— manufacturer

— year of construction

— effective suction rate [m^3/h]

— discharge pressure [bar]

— speed [Rpm]

— power consumption [kW].

5. Test

5.1 Pressure test

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 BKI and are to be presented for final inspection.

N. 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 as well as further IMO Guidelines ,as far as applicable, are to be observed. In case of wet exhaust gas cleaning systems (scrubber systems) IMO Resolution MEPC.184(59) applies.

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.

For diesel engine uses Selective Catalytic Reduction (SCR) to reduce the NO_X emission, the requirements in Guidance for Code and Convetion Interpretation (Pt.1, Vol.Y) Sec.9 MPC 125 should be ovserved.

2. Approval

Where an exhaust gas cleaning system is installed details of the arrangement and a description of the functionality are to be submitted to BKI for approval. To facilitate an efficient approval the documents shall be submitted in form of electronic format 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, safety concept addressing design,operational issues and operational features. An operation manual shall include instructions for maintenance, verification of parameters indicating the need for cleaning or replacement and instruction 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 BKI Surveyor, BKI will issue an Approval Certificate.

3. Layout

3.1 System layout and installation

Exhaust gas cleaning systems shall be separate for each combustion engine or combustion plant as a matter of principle. General requirements on the use of combustible materials and on structural fire protection are to be observed. 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 11.L shall be taken into account. The aftertreatment system is to be equipped with at least one inspection port. Exemptions may be granted for applications on small-bore high-speed mass produced engines.

Exhaust gas cleaning systems are to be accessible for inspection and maintenance. An exchange or removal of internal components shall be possible, where applicable.

3.2 Safety Concept

The safety concept is a document describing hazards associated with the design and operation of the exhaust gas cleaning system along with suitable measures to control the identified hazards. The safety concept shall be a self contained document covering the following:

— System description with schematic diagrams of the plant layout

Hazard analysis for design and operational aspects of the exhaust gas cleaning system. The following analysis shall address:

— Fresh water and sea water systems (e.g. high/low temperatures, system clogging, flooding)

— Process chemicals (e.g. storage, ventilation, high/low temperatures)

— Exhaust gas piping system (e.g. pressure fluctuations)

— Fire hazards

— Material selection

— Ship motions

— Control measures for all identified hazards

3.3 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.

3.4 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.

3.5 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).

3.6 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.

3.7 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.

3.8 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.

3.9 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. Where plastic piping is intended to be used in wet scrubber systems the requirements in Section 11. B.2.6 apply. The requirements relating to exhaust gas lines as contained in Section 11. L are to be observed, as applicable.

5. Handling of noxious process substances

5.1 Use of Selective Catalytic Reduction (SCR) and Storage

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.

The requirements for SCR reductants tanks with volume below of 500 L are left to the discretion of BKI. This discretion is only applicable to N.5.1.1

5.1.1 Reductant using urea based ammonia (e.g. 40%/60% urea/water solution)

.1 Where urea based ammonia (e.g. AUS 40 – aqueous urea solution specified in ISO 18611-1:2014) is introduced, the storage tank is to be arranged so that any leakage will be contained and prevented from making contact with heated surfaces. All pipes or other tank penetrations are to be provided with manual closing valves attached to the tank. Tank and piping arrangements are to be approved.

.2 The storage tank may be located within the engine room.

.3 The storage tank is to be protected from excessively high or low temperatures applicable to the particular concentration of the solution. Depending on the operational area of the ship, this may necessitate the fitting of heating and/or cooling systems. The physical conditions recommended by applicable recognized standards (such as ISO 18611-3:2014) are to be taken into account to ensure that the contents of the aqueous urea tank are maintained to avoid any impairment of the urea solution during storage.

.4 If a urea storage tank is installed in a closed compartment, the area is to be served by an effective mechanical ventilation system of extraction type providing not less than 6 air changes per hour which is independent from the ventilation system of accommodation, service spaces, or control stations. The ventilation system is to be capable of being controlled from outside the compartment. A warning notice requiring the use of such ventilation before entering the compartment shall be provided outside the compartment adjacent to each point of entry.

Alternatively, where a urea storage tank is located within an engine room a separate ventilation system is not required when the general ventilation system for the space is arranged so as to provide an effective movement of air in the vicinity of the storage tank and is to be maintained in operation continuously except when the storage tank is empty and has been thoroughly ventilated.

The requirements above also apply to closed compartments normally entered by persons:

1) when they are adjacent to the urea integral tanks and there are possible leak points (e.g. manhole, fittings) from these tanks; or

2) when the urea piping systems pass through these compartments, unless the piping system is made of steel or other equivalent material with melting point above 925 °C and with fully welded joints.

.5 Each urea storage tank is to be provided with temperature and level monitoring arrangements. High and low level alarms together with high and low temperature alarms are also to be provided.

.6 Where urea-based ammonia solution is stored in integral tanks, the following are to be considered during the design and construction:

1) These tanks may be designed and constructed as integral part of the hull, (e.g. double bottom, wing tanks).

2) These tanks are to be coated with appropriate anti-corrosion coating and cannot be located adjacent to any fuel oil and fresh water tank.

3) These tanks are to be designed and constructed as per the structural requirements applicable to hull and primary support members for a deep tank construction.

4) These tanks are to be fitted with but not limited to level gauge, temperature gauge, high temperature alarm, low level alarm, etc.

5) These tanks are to be included in the ship's stability calculation.

.7 The reductant piping and venting systems are to be independent of other ship service piping and/or systems. Reductant piping systems are not to be located in accommodation, service spaces, or control stations. The vent pipes of the storage tank are to terminate in a safe location on the weather deck and the tank venting system is to be arranged to prevent entrance of water into the urea tank.

.8 Reductant tanks are to be of steel or other equivalent material with a melting point above 925 °C. Pipes/piping systems are to be of steel or other equivalent material[2] with melting point above 925 °C, except 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; in such case, type approved

[2] Material requirement "to be of steel or other equivalent material" in the first paragraph with a melting point above 925°C is not applicable for integral tanks on FRP vessels such as those listed below, provided that the integral tanks are coated and/or insulated with a self-extinguishing material.

a) FRP vessels complying with Regulation 17 of SOLAS Chapter 11-2 based upon its associated IMO guidelines (MSC.1/Circ. 1574), and

b) FRP vessels exempted from the application of SOLAS e.g., yachts, fast patrol, navy vessels, etc., generally of less than 500 gross tonnage, subject to yacht codes or flag regulations.

plastic piping may be accepted even if it has not passed a fire endurance test. Reductant tanks and pipes/piping systems are to be made with a material compatible with reductant or coated with appropriate anti-corrosion coating.

.9 For the protection of crew members, the ship is to have on board suitable personnel protective equipment. Eyewash station is to be provided, the location and number of these eyewash stations are to be derived from the detailed installation arrangements.

.10 Urea storage tanks are to be arranged so that they can be emptied of urea, and ventilated by means of portable or permanent systems.

5.2 Reductant using aqueous ammonia (28% or less concentration of ammonia)

Aqueous ammonia is not to be used as a reductant in a SCR except where it can be demonstrated that it is not practicable to use a urea based reductant. Where an application is made to use aqueous ammonia as the reductant then the arrangements for its loading, carriage and use are to be derived from a risk based analysis.

5.3 Reductant using anhydrous ammonia (99.5% or greater concentration of ammonia by weight)

Anhydrous ammonia is not to be used as a reductant in a SCR except where it can be demonstrated that it is not practicable to use a urea based reductant and where the Flag Administration agrees to its use. Where it is not practicable to use a urea reductant then it is also to be demonstrated that it is not practicable to use aqueous ammonia. Where an application is made to use anhydrous ammonia as the reductant then the arrangements for its loading, carriage and use are to be derived from a risk based analysis.

5.4 Sodium hydroxide solution (NaOH) for wet scrubbers

Tanks may be of the integrated or independent type. They may be part of the ship's side shell.

Structural materials used for tank construction, together with associated piping, pumps, valves, vents and their jointing materials shall be of stainless steel or carbon steel with an adequate corrosion allowance. For temperatures above 50 °C the recommended construction material is stainless steel. No aluminium, zinc or galvanized steel parts may be used.

The tanks shall be provided with a heating system.

The tanks shall be provided with temperature and high level alarm (95 %) and a gauging device.

The outlet of the tank venting system shall lead to the open deck and the terminal shall be arranged in an area not usually accessible.

5.5 Ammonia slip

Where Selective Catalytic Reduction (SCR) type exhaust gas cleaning systems are applied excessive slip of ammonia has to be prevented.

5.6 Safety measures against chemical treatment fluids for exhaust gas cleaning systems

5.6.1 Objectives

.1 Some types of exhaust gas cleaning systems to be approved by the Administration as "alternative compliance method" consume chemicals which are typically carried on board in bulk quantities, the prescriptive requirements contained in this UR related safety measures against chemical treatment fluids apply to exhaust gas cleaning systems using such fluids. In this context, the term "chemical treatment fluid" means the aqueous solution of sodium hydroxide (NaOH) or calcium hydroxide ($Ca(OH)_2$) that has corrosive properties or are considered to represent a hazard to personnel.

.2 For exhaust gas cleaning systems using chemicals other than NaOH or $Ca(OH)_2$, safety measures are to be taken according to the result of a risk assessment to be conducted to analyze the risks, in order to eliminate or mitigate the hazards to personnel brought by the use of such exhaust gas cleaning systems, to an extent equivalent to systems complying with 5.6.2.

5.6.2 Requirements exhaust gas cleaning systems using aqueous solution of NaOH or $Ca(OH)_2$ for chemical treatment fluid

.1 The storage tank for chemical treatment fluids is to be arranged so that any leakage will be contained and prevented from making contact with heated surfaces. All pipes or other tank penetrations are to be provided with manual closing valves attached to the tank. In cases where such valves are provided below top of tank, they are to be arranged with quick acting shutoff valves which are to be capable of being remotely operated from a position accessible even in the event of chemical treatment fluid leakages. Tank and piping arrangements are to be approved.

.2 The storage tank is to be protected from excessively high or low temperatures applicable to the particular concentration chemical treatment fluids. Depending on the operational area of the ship, this may necessitate the fitting of heating and/or cooling systems.

.3 If a storage tank for chemical treatment fluids is installed in a closed compartment, the area is to be served by an effective mechanical ventilation system of extraction type providing not less than 6 air changes per hour which is independent from the ventilation system of other spaces. The ventilation system is to be capable of being controlled from outside the compartment. A warning notice requiring the use of such ventilation before entering the compartment shall be provided outside the compartment adjacent to each point of entry.

.4 The storage tank may be located within the engine room. In this case, the requirements of 5.6.2.3 shall be complied with, except that a separate ventilation system is not required when the general ventilation system for the space is arranged so as to provide an effective movement of air in the vicinity of the storage tank and is maintained in operation continuously except when the storage tank is empty and has been thoroughly ventilated.

.5 Each storage tank for chemical treatment fluids is to be provided with level monitoring arrangements and high/low level alarms. In cases where heating and/or cooling systems are provided, high and/or low temperature alarms or temperature monitoring are also to be provided accordingly.

.6 The storage tanks are to have sufficient strength to withstand a pressure corresponding to the maximum height of a fluid column in the overflow pipe, with a minimum of 2,4 m above the top plate taking into consideration the specific density of the treatment fluid.

.7 Where chemical treatment fluid is stored in integral tanks, the following are to be considered during the design and construction:

.7.1 These tanks may be designed and constructed as integral part of the hull, (e.g. double bottom, wing tanks).

.7.2 These tanks are to be coated with appropriate anti-corrosion coating and are to be segregated by cofferdams, void spaces, pump rooms, empty tanks or other similar spaces so as to not be located adjacent to accommodation, cargo spaces containing cargoes which react with chemical treatment fluids in a hazardous manner as well as any food stores, oil tanks and freshwater tanks.

.7.3 These tanks are to be designed and constructed as per the structural requirements applicable to hull and primary support members for a deep tank construction.

.7.4 These tanks are to be included in the ship's stability calculation.

.8 The requirements specified in 5.6.2.3 also apply to closed compartments normally entered by persons:

.8.1 when they are adjacent to the integral storage tank for chemical treatment fluids and there are possible leak points (e.g. manhole, fittings) from these tanks; or

.8.2 when the treatment fluid piping systems pass through these compartments, unless the piping system is made of steel or other equivalent material with melting point above 925 °C and with fully welded joints.

.9 The chemical treatment fluid piping and venting systems are to be independent of other ship service piping and/or systems. The chemical treatment fluid piping systems are not to be located in accommodation, service spaces, or control stations. The vent pipes of the storage tank are to terminate in a safe location on the weather deck and the tank venting system is to be arranged to prevent entrance of water into the tank for chemical treatment fluids.

.10 Storage tanks and pipes/piping systems and drip trays for chemical treatment fluids which transfer undiluted chemical treatment fluids are to be of steel or other equivalent material with a melting point above 925 °C.

.11 Storage tanks and pipes/piping systems for chemical treatment fluids are to be made with a material compatible with chemical treatment fluids or coated with appropriate anti-corrosion coating.

Note:

Several metals are incompatible with the chemical treatment fluids, e.g. NaOH is incompatible with zinc, aluminum, etc.

.12 Regardless of design pressure and temperature, piping systems containing chemical treatment fluids only are to comply with the requirements applicable to Class I piping systems. As far as practicable, e.g. except for the flange connections that connect to tank valves, the piping systems are to be joined by welding.

.13 The following connections are to be screened and fitted with drip trays to prevent the spread of any spillage where they are installed:

.13.1 Detachable connections between pipes (flanged connections and mechanical joints, etc.);

.13.2 Detachable connections between pipes and equipment such as pumps, strainers, heaters, valves; and

.13.3 Detachable connections between equipment mentioned in the above subparagraph. The drip trays are to be fitted with drain pipes which lead to appropriate tanks, such as residue tanks, which are fitted with high level alarm, or are to be fitted with alarms for leak detection. In cases where such tank is an integral tank, 5.6.2.7.1 and 5.6.2.7.2 are to be applied to the tank.

.14 For the protection of crew members, the ship is to have on board suitable personnel protective equipment. The number of personnel protective equipment carried onboard is to be appropriate for the number of personnel engaged in regular handling operations or that may be exposed in the event of a failure; but in no case is there to be less than two sets available onboard.

.15 Personnel protective equipment is to consist of protective clothing, boots, gloves and tight-fitting goggles.

Eyewash and safety showers are to be provided, the location and number of these eyewash stations and safety showers are to be derived from the detailed installation arrangements. As a minimum, the following stations are to be provided:

.15.1 In the vicinity of transfer or treatment pump locations. If there are multiple transfer or treatment pump locations on the same deck then one eyewash and safety shower station may be considered for acceptance provided that the station is easily accessible from all such pump locations on the same deck.

.15.2 An eyewash station and safety shower is to be provided in the vicinity of a chemical bunkering station on-deck. If the bunkering connections are located on both port and starboard sides, then consideration is to be given to providing two eyewash stations and safety showers, one for each side.

.15.3 An eyewash station and safety shower is to be provided in the vicinity of any part of the system where a spillage/drainage may occur and in the vicinity of system connections/components that require periodic maintenance.

.16 Storage tanks for chemical treatment fluids are to be arranged so that they can be emptied of the fluids and ventilated by means of portable or permanent systems.

5.6.3 Requirement for Exhaust Gas Cleaning Systems discharge water pipeline

.1 Overboard discharges from exhaust gas cleaning system (EGCS) are not to be interconnected to other systems.

.2 Due consideration is to be given to the location of overboard discharges with respect to vessel propulsion features, such as thrusters, propellers or to prevent any discharge water onto survival craft during abandonment.

.3 The piping material for the EGCS discharge water pipeline system is to be selected based on the corrosive nature of the liquid media.

.4 Special attention is to be paid to the corrosion resistivity of EGCS overboard discharge piping. Where applicable, adequate arrangements are to be provided to prevent galvanic corrosion due to the use of dissimilar metals.

.5 In case distance piece is fitted between the outboard discharge valve and the shell plating, it shall be made of corrosion resistant material steel or be coated with an anti-corrosive material suitable for the operating environment. The thickness of the distance piece shall be at least the minimum values specified in .1 and .2 as below; otherwise Sch.160 thickness specified in piping standards shall, as far as practicable, be used.

.1 12 mm in cases where complete pipe is made of corrosion resistant material steel.

.2 15 mm of mild steel in cases where the inside the pipe is treated with an anticorrosive coating or fitted with a sleeve of corrosion resistant material

5.6.4 Miscellaneous

Tanks for residues generated from the exhaust gas cleaning process are to satisfy the following requirements:

.1 The tanks are to be independent from other tanks, except in cases where these tanks are also used as the over flow tanks for chemical treatment fluids storage tank.

.2 Tank capacities are to be decided in consideration of the number and kinds of installed exhaust gas cleaning systems as well as the maximum number of days between ports where residue can be discharged ashore. In the absence of precise data, a figure of 30 days is to be used.

.3 Where residue tanks used in closed loop chemical treatment systems are also used as the overflow tanks for chemical treatment fluids storage tank, the requirements for storage tanks apply.

6. Washwater criteria

Where the exhaust gases are washed with water, discharged wash water has to comply with criteria as specified in IMO Resolution MEPC.184(59).

7. 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.

O. Gas-Fuelled Engines

1. Scope and application

1.1 This section addresses the requirements For marine reciprocating internal combustion engines supplied with natural gas as fuel.

1.2 The scope of this Section is intended for natural gas fuelled engines. It may also be referred for engines using similar fuels with main component methane such as bio-methane or synthetic methane.

1.3 Special design features will be considered on a case by case basis, taking into account the basic.

1.4 It shall be ensured by the gas supply system that the gas supplied to the engine is always in gaseous state. This Section does not cover requirements for liquid or cryogenic gas.

1.5 The engines can be either dual fuel engines (hereinafter referred to DF engine), gas fuel only engines (hereinafter referred to SF engine) or any variations thereof including fuel sharing capability.

1.6 DF engines and SF engines may not be permitted for emergency applications.

2. Further Rules and Guidelines

2.1 The basic gas-fuelled engine requirements defined in Guidelines for The Use of Gas as Fuel for Ships (Pt.1, Vol.1) are generally to be fulfilled independent of the source of gas (boil-off from cargo or gas fuel from storage tanks).

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 Guidelines for The Use of Gas as Fuel for Ships (Pt.1, Vol.1) apply for gas fuel supplied from gas fuel storage tanks

2.4 Rules for Ship Carrying Liquefied Gases in Bulk (Pt.1, Vol.IX), apply to gas fuel supplied from liquefied gas carrier cargo boil-off.

Note:

Use of gas as fuel for ships is currently not covered by international conventions (except boil-off from cargo covered by the IGC Code). Therefore, acceptance by the flag administration is necessary for each individual installation. Resolution MSC.285(86) 'Interim Guidelines on Safety for Natural Gas-Fuelled Engine Installations in Ships' gives guidance on safety requirements for these installations. An International Code of Safety for Gas fuelled Ships (IGF Code) is currently under development at IMO.

3. Definitions

3.1 Definitions addressing gas as fuel as given in Guidelines for The Use of Gas as Fuel for Ships (Pt.1, Vol.1) 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.

3.4 Hazardous areas

Definition of hazardous areas with risk of explosion as well as definition of zone 0, 1 and 2 see Rules for Electrical Installations (Pt.1, Vol.IV), Sec. 1, B.11.

3.5 Low Pressure Gas

Gas with maximum working pressure up to 10 bar.

3.6 Certified safe equipment

Equipment certified by an independent national test institution or competent body to be in accordance with a recognised standard for electrical apparatus in hazardous areas.

Note:

Refer to IEC 60079 series, Explosive atmospheres and IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features

3.7 Explosion relief device

means a device to protect personnel and component against a determined overpressure in the event of a gas explosion. The device may be a valve, a rupture disc or other, as applicable.

3.8 High pressure gas

Gas with a maximum working pressure greater than 10 bar gauge.

3.9 Low pressure gas

Gas with a maximum working pressure lower or equal up to 10 bar gauge.

3.10 Pre-mixed engine

An engine where gas is supplied in a mixture with air through a common manifold for all cylinders, e.g. mixed before or after the turbocharger.

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 gas fuelled 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 gasfuelled engines practicable for single engine main propulsion plants.

5. Documents to be submitted

Documents and drawings of DF and GF as listed in Table 2.11 in addition to those required in Table 2.1 shall be submitted for approval respectively reviews. To facilitate a smooth and efficient approval process they should be submitted in electronic format.

6. Risk Analysis

6.1 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 double block and bleed valves
- 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 sub section.

6.2 Form of the risk analysis

The risk analysis is to be carried out in accordance with international standard IEC 31010:2019: Risk management - Risk assessment techniques, or other recognized standards.

The Guidance for Risk Evaluation for the Classification of Marine Related Facilities (Pt.4, Vol.A) and the Guidance Notes on Risk Assessment for the Marine and Offshore Oil and Gas Industries (Pt.4, Vol.1) should also be observed.

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.

6.3 Procedure for the risk analysis

The risk analysis is to:

1) Identify all the possible failures in the concerned equipment and systems which could lead:
   a) to the presence of gas in components or locations not designed for such purpose, and/or
   b) to ignition, fire or explosion.
2) Evaluate the consequences (see also O.7.1.2)
3) Where necessary, identify the failure detection method
4) Where the risk cannot be eliminated, identi fy the corrective measures:
   a) in the system design, such as:
      - redundancies

  - safety devices, monitoring or alarm provisions which permit restricted operation of the system

b) in 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.

6.4 Equipment and systems to be analysed

The risk analysis required for engines is to cover at least the following aspects:

1) failure of the gas-related systems or components, in particular:
   - gas piping and its enclosure, where provided
   - gas admission 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 supply system , are not to be considered in the analysis.

2) failure of the ignition system (oil fuel pilot injection, sparking plugs, glow plugs)

3) failure of the air to fuel ratio control system (charge air by-pass, gas pressure control valve, etc.))

4) for engines where gas is supplied upstream of the turbocharger compressor, failure of a component likely to result in a source of ignition (hot spots))

5) failure of the gas combustion or abnormal combustion (misfiring, knocking))

6) 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.

7) presence of gas in engine components (e.g. air inlet manifold or scavenge space and exhaust manifold) and in the external systems connected to the engines (e.g. exhaust duct, cooling water system, hydraulic oil system, etc.).

8) changes of operating modes for DF engines)

9) hazard potential for crankcase fuel gas accumulation, trunk-piston engines, refer to the Guidelines for the Use of Gas as Fuel (Pt.1, Vol.1) Sec.10.3.1.2 (IGF Code 10.3.1.2) and 2.F.2 and 2.F.3

10) risk of crankcase explosion in connection with active crankcase ventilation which produces a flow of external air into the crankcase, (see 2.F.2 and 2.F.3).

7. General requirements

Requirements as specified in Guidelines for The Use of Gas as Fuel for Ships (Pt.1, Vol.1). shall be observed.

7.1 General Principles

7.1.1 The manufacturer is to declare the allowable gas composition limits for the engine and the minimum and (if applicable) maximum methane number.

7.1.2 Components containing or likely to contain gas are to be designed to:

1) minimise the risk of fire and explosion so as to demonstrate an appropriate level of safety commensurate with that of an oil-fuelled engine;

2) 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 explosion relief devices of an approved type.

The strength of the component(s) of arrangement of explosion relief devices shall be documented (e.g., as part of risk analysis) or otherwise demonstrated to be sufficient for a worst-case explosion.

Also refer to the Guidelines for The Use of Gas as Fuel for Ship (Pt.1, Vol.1) Sec.10.2 and 10.3 (IGF Code 10.2 and 10.3).

7.1.3 Discharge from explosion 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".

7.1.4 Explosion relief devices shall be fitted with a flame arrester

7.2 Gas supply concept

7.2.1 Gas-fuelled engines shall either be designed according to Emergency Shut-down concept (ESD) or Gas Safe Concept (definition and requirements see Guidelines for The Use of Gas as Fuel for Ships (Pt.1, Vol.1)).

7.2.2 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.

7.2.3 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.

7.3 Requirements for single gas fuel engines

7.3.1 In general, single gas fuel engines are only considered suitable for electric power generating plants.

7.3.2 The application of single gas fuel engines for mechanical propeller drives requires special evaluation and consideration.

7.3.3 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.

Table 2.11: Additional documents to be submitted for the approval of DF and SF engines

Item No.	Description
Documents and drawings to be submitted for the approval of DF and SF engines	
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 and exhaust gas system on the engine) 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 used as fuel specification (for information)
Documents and drawings to be submitted for the approval of DF engine	
1	Schematic layout or other equivalent documents of pilot fuel system
2	Shielding of high-pressure fuel pipes for pilot fuel system, assembly
3	High pressure parts for pilot fuel oil injection system[3)]
Documents and drawings to be submitted for the approval of SF engine	
1	Schematic layout or other equivalent documents of the ignition system
1) if required in Table 2.1, see also O.9.3.2	
2) see .O.6.	
3) The Documentation to contain specification of design pressures, working pressure, pipe dimensions and materials.	

7.4 Requirements for dual-fuel engines

7.4.1 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 composition and its quality or the engine design.

This maximum continuous power available in gas mode and the corresponding conditions shall be stated by the engine manufacturer .

7.4.2 Starting, changeover and stopping

7.4.2.1 Dual-fuel engines are to be started using either oil fuel or gas fuel with pilot oil fuel ignition and to be capable of immediate change-over to oil fuel only.

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.

7.4.2.2 Only oil fuel is to be used when starting the engine.

7.4.2.3 Only oil fuel is, in principle, to be used when the operation of an engine is unstable, and/or during manoeuvring and port operations.

7.4.2.4 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.

7.4.2.5 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 from and to gas operation with minimal fluctuations in engine power and speed. Manual interruption is to be possible in all cases.

7.4.2.6 The change-over process from gas mode to oil mode shall be possible at all situations and power levels.

7.4.2.7 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.

7.4.2.8 If the power level or other conditions do not allow safe and reliable gas operation, changeover to oil fuel mode shall be automatically performed.

7.4.3 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.

7.5 Pre-Mixed Engines

7.5.1 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 6).

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.

7.6 Two-stroke engines

7.6.1 Scavenge air system

The risk analysis required in 1.4 is to cover the possible gas accumulation in a scavenge space.

7.6.2 Crankcase

The risk analysis required in 1.4 is to cover the possible failure of a piston rod stuffing box.

8. Systems

Requirements as specified in Guidelines for The Use of Gas as Fuel for Ships (Pt.1, Vol.1). shall be observed.

8.1 Cooling water system

8.1.1 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.

8.1.2 Suitable gas detectors are to be provided.

8.1.3 Flame arrestors are to be provided at the vent pipes.

8.2 Lubrication oil system

8.2.1 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.

8.2.2 Suitable gas detectors are to be provided.

8.2.3 Flame arrestors are to be provided at the vent pipes.

8.3 Fuel oil system

8.3.1 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.

8.3.2 Suitable gas detectors are to be provided.

8.3.3 Flame arrestors are to be provided at the vent pipes.

8.4 External gas supply system

8.4.1 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.

8.4.2 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.

8.4.3 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.

8.5 Gas system on the engine

8.5.1 General requirements

8.5.1.1 Gas piping on an engine shall be designed and installed taking due account of vibrations and movements during engine operation.

8.5.1.2 In case of rupture of a gas pipe or excessive pressure loss, automatic shutdown of the gas supply shall be activated.

8.5.1.3 Component containing gas are to be designed to minimize the risk of fire and explosion.

8.5.1.4 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 IGF Code chapter 7, or IGC Code chapter 5.1 to 5.9 and 16 as applicable.

8.5.1.5 Other connections as mentioned in IGF Code 7.3.6.4.4 may be accepted subject to type approval in accordance with the requirements of UR P2.7 and P2.11.

8.5.1.6 All single walled or high-pressure gas pipes should be considered as Class I.

8.5.1.7 Low pressure double walled gas pipes should be considered as Class II.

8.5.1.8 All secondary enclosures for gas pipes should be considered as Class II.

8.5.1.9 Single walled gas vent pipes, if permitted, should be considered as Class I, except it is justified that the maximum built up pressure is less than 5 bar gauge, in which case it should be considered as Class II.

8.5.1.10 Gas vent pipes protected by a secondary enclosure should be considered as Class II.

8.5.1.11 Secondary enclosure for vent pipes should be considered as Class III.

8.5.1.12 Flexible bellows used in the fuel gas system on the engine shall be approved based on the requirements of IGF Code 16.7.2, and IGC Code 5.13.1.2, as applicable.

8.5.1.13 The number of cycles, pressure, temperature, axial movement, rotational movement and transverse movement which the bellow will encounter in actual service on the engine should be specified by the engine designer.

8.5.1.14 Endurance against high cycle fatigue due to vibration loads shall be verified by testing or alternatively be documented by the Expansion Joint Manufacturers Association, Inc. (EJMA) calculation or equivalent (i.e., more than 10^7 cycles).

Note:

The fatigue test due to ship deformations in IGF 16.7.2.4 is considered not relevant for bellows which are an integral part of the engine.

Table 2.12: Design pressure for gas pipes

Design pressure		
Pipe type	**IGF Code**	**IGC Code**
Gas pipe, low pressure	7.3.3.1	5.4.1
Gas pipe, high pressure	7.3.3.1	5.4.1
Outer pipe, low pressure	9.8.1	5.4.4
Outer pipe, high pressure	9.8.2	5.4.4
Open ended pipes	7.3.3.2	5.4.1

8.5.2 Low pressure gas supply

8.5.2.1 Flame arresters shall be provided in the gas supply system on the engine as determined by the system FMEA.

8.5.2.2 Gas admission valves shall be located directly at each cylinder inlet.

8.5.2.3 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.

8.5.3 High pressure gas supply

8.5.3.1 Flame arresters shall be provided at the inlet to the gas supply manifold of dual-fuel engines.

8.5.3.2 The high pressure gas is to be blown directly into the cylinders without prior mixing with combustion air.

8.5.3.3 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.

8.5.4 Arrangement of the gas piping system on the engine

Pipes and equipment containing fuel gas are defined as hazardous area Zone 0 (refer to Guidelines for The Use of Gas as Fuel (Pt.1, Vol.1) Sec.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 Guidelines for The Use of Gas as Fuel (Pt.1, Vol.1) Sec.12.5.1) (IGF Code 12.5.2.6).

8.5.4.1 Normal "double wall" Arrangement

The gas piping system on the engine shall be arranged according to the principles and requirements of the Guidelines for The Use of Gas as Fuel for Ship (Pt.1, Vol.1), Sec. 9.6. For gas carriers, Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1 Vol.IX), Sec.16.4.3 applies.

The design criteria for the double pipe or duct are given in the Guidelines for The Use of Gas as Fuel for Ship (Pt.1, Vol.1), Sec. 7.4.1.4 and Sec. 9.8.

In case of a ventilated double wall, the ventilation inlet is to be located in accordance with the provisions of Guidelines for The Use of Gas as Fuel for Ship (Pt.1, Vol.1) Sec.13.8.3. For gas carriers, Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1 Vol.IX), Sec.16.4.3.2 applies.

The pipe or duct is to be pressure tested at 1.5 x design pressure to ensure gas tight integrity and to show that it can withstand the expected maximum pressure at gas pipe rupture.

8.5.4.2 Alternative arrangement

Single walled gas piping is only acceptable:

a) for engines supplied with low pressure gas and installed in ESD protected machinery spaces, as defined in Guidelines for The Use of Gas as Fuel for Ship (Pt.1, Vol.1) Sec. 5.4.1.2 and in compliance with other relevant parts of the Guidelines for The Use of Gas as Fuel for Ship (Pt.1, Vol.1);

b) in the case as per footnote to Guidelines for The Use of Gas as Fuel for Ship (Pt.1, Vol.1) Sec.9.6.2.

For gas carriers, Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1 Vol.IX) 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.

The minimum power to be maintained is to be assessed on a case-by-case basis from the operational characteristics of the ship.

8.5.5 Charge air system and exhaust gas system on the engine

The charge air system and the exhaust gas system on the engine are to be designed in accordance with 7.1.2 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 explosion 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 rupture disk).

8.5.6 Gas admission valve

8.5.6.1 The gas admission valve shall be controlled by the engine control system according to the actual gas demand of the engine.

8.5.6.2 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.

8.5.6.3 Electrically operated gas admission valve shall be certified as follows:

a) The inside of the valve contains gas and shall therefore be certified for Zone 0.

b) When the valve is located within a pipe or duct in accordance with 8.5.4.1, the outside of the valve shall be certified for Zone 1.

c) When the valve is arranged without enclosure in accordance with the “ESD protected machinery space ”(see 8.5.4.2) 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 are to be based on IEC 60079-10-1:2015 or IEC 60092-502:1999.

Gas admission valves operated by hydraulic oil system are to be provided with sealing arrangement to prevent gas from entering the hydraulic oil system.

8.6 Ignition system

8.6.1 General requirements

Ignition systems commonly use either electrical spark plugs (single gas fuel engines) or pilot fuel oil injection (dual fuel engines).

Requirements of Guidelines for The Use of Gas as Fuel for Ship (Pt.1, Vol.1) Sec.10.3 (IGF Code 10.3) apply. For gas carriers, Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol.X) Sec.16.7 (IGC Code 16.7) applies.

8.6.1.1 The ignition system has to ensure proper ignition of the gas at all operating conditions and must be able to provide sufficient ignition energy.

8.6.1.2 Before starting the engine, the engine has to be ventilated without injection or supplying any fuel.

8.6.1.3 Before activating the gas admission to the engine, the ignition system has to be checked automatically to verify correct functioning.

8.6.1.4 Combustion of each cylinder is to be monitored. Misfiring and knocking combustion is to be detected.

8.6.1.5 Safe and reliable operation of the ignition system shall be demonstrated and documented by a system FMEA.

8.6.1.6 During stopping of the engine the fuel gas supply shall be shut off automatically before the ignition source.

8.6.2 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.

8.6.3 Ignition by pilot injection

8.6.3.1 Prior to admission of fuel gas the correct operation of the pilot oil injection system on each cylinder shall be verified.

8.6.3.2 An engine shall always be started using fuel oil only.

8.7 Electrical systems

8.7.1 Care shall be taken to prevent any possible sources of ignition caused by electrical equipment, electrical sensors, etc. installed in hazardous areas.

8.7.2 For electrical equipment and sensors in hazardous areas the explosion protection requirements in Rules for Electrical Installations (Pt.1, Vol.IV), Sec. 1 are to be observed.

8.7.3 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.

8.8 Engine control, monitoring, alarm, and safety systems

8.8.1 General requirements

8.8.1.1 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 Guidelines for The Use of Gas as Fuel for Ship (Pt.1, Vol.1) and Rules for Ship Carrying Liquid Gases in Bulk (Pt.1, Vol.IX) shall be observed.

8.8.1.2 Knocking combustion and misfiring is to be detected and combustion conditions are to be automatically controlled to prevent knocking and misfiring.

8.8.1.3 The engine operating mode shall always be clearly indicated to the operating personnel.

8.8.1.4 The engine control system is to be independent and separate from the safety system.

8.8.1.5 The gas admission valves are to be controlled by the engine control system or by the engine gas demand.

8.8.1.6 Combustion is to be monitored on an individual cylinder basis.

8.8.1.7 In the event that poor combustion is detected on an individual cylinder, gas operation may be allowed in the conditions specified in Guidelines for The Use of Gas as Fuel for Ship (Pt.1, Vol.1) Sec.10.3.1.6 (IGF Code 10.3.1.6).

8.8.1.8 If monitoring of combustion for each individual cylinder is not practicable due to engine size and design, common combustion monitoring may be accepted.

8.8.1.9 Unless the risk analysis required by 6 of this sub-section proves otherwise, the instrumentation for monitoring, alarm, and safety systems for DF and SF engines are to be provided in accordance with Table 2.13.

Note:

For DF engines, Table 2.13 applies only to the gas mode

8.8.2 Gas detection

8.8.2.1 A continuous gas detection system shall be provided see Guidelines for The Use of Gas as Fuel for Ship (Pt.1, Vol.1).

8.8.2.2 The gas detection system shall be in operation as long as fuel gas is supplied to the engine.

8.8.2.3 As guidance, the gas detection system shall cover the spaces of the engine as specified in Table 2.13. Depending on engine design, safety concept, and system FMEA deviations from Table 2.13 may be agreed.

8.8.2.4 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.

8.8.3 Speed control and load acceptance

8.8.3.1 In general, the requirements in F.1 shall be observed.

8.8.3.2 The basic requirements of F.1.2.3 regarding design of the ship's power management system apply.

8.8.3.3 Exemptions from minimum required step loading capability of engines driving electrical generators as shown in Fig. 2.4 can be agreed for gas fuelled engines of limited step loading capability.

8.9 Exhaust gas system and ventilation system

8.9.1 Exhaust gas pipes from gas-fuelled machinery are to be installed separately from each other, taking into account structural fire protection requirements.

8.9.2 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.

8.9.3 Control of the ventilation system shall be included in the automation system. Failures shall be alarmed.

8.9.4 Continuous relief of exhaust gas (through open rupture disc) into the engine room or other enclosed spaces is not acceptable.

Suitable explosion relief system for air inlet manifolds, scavenge spaces and exhaust system should be provided unless designed to accommodate the worst-case overpressure due to ignited gas leaks or justified by the safety concept of the engine. A detailed evaluation regarding the hazard potential of overpressure in air inlet manifolds, scavenge spaces and exhaust system should be carried out and reflected in the safety concept of the engine.

Explosion relief devices for air inlet and exhaust manifold shall be type approved according to 9.3.3.3.

The necessary total relief area and the arrangement of the explosion relief devices shall be determined taking into account:

- The worst-case explosion pressure depending on initial pressure and gas concentration
- the volume and geometry of the component, and
- the strength of the component.

The arrangement shall be determined in the risk analysis (see 6.4.7)) and reflected in the safety concept.

Table 2.13: Indicative scope of instrumentation for gas-fuelled engines

	Indicator, alarm, shutdown	Shut off of gas Supply to individual engine (double block and bleed valves)	Shut off of gas supply to machinery space (master gas valve)	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 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	
Crackcase				
Pressure	H [6)], S	X	X	
Temperature [4)]	H, S	X	X	
Oil mist concentration	H, S [7)]	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				
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			
Failure of crankcase ventilation system, if applicable	A	X [7)]	X [7)]	
Engine shutdown	A, S	X		Externally or manually activated

I : Indicator
A : Alarm
L : Alarm for lower limit
H : Alarm for upper limit
S : Shutdown
X : Activation

[1)] In general, shut off of 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 subject to a continued safe operation
[3)] Cross-Head type engines
[4)] Temperature of liners and bearings
[5)] Automatic safety actions to be activated as specified by the engine manufacturer, see F.2 and F.3
[6)] Only for trunk piston engines. This pressure sensor cannot replace or substitute a gas detector.
[7)] Only for trunk piston engines. For crosshead engines slow down shall apply (see Rules for Automations (Pt.1, Vol.VII) Sec.8 Table 8.2)

9. Safety equipment and safety systems

Basic requirements as specified in the Guidelines for The Use of Gas as Fuel for Ship (Pt.1, Vol.1) shall be observed.

9.1 Safety concept and system FMEA

9.1.1 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.

9.1.2 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 8.7.3
- 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

9.2 Crankcase safety equipment

9.2.1 Piston failure

Piston failure and abnormal piston blow-by shall be detected and alarmed.

9.2.2 Crankcase

9.2.2.1 Crankcase venting pipes are to be equipped with flame arrestors.

9.2.2.2 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 9.1).

9.2.3 Removal of fuel gas from crankcase and inert gas injection

9.2.3.1 Means shall be provided to measure the fuel gas concentration in the crankcase.

9.2.3.2 Suitable measures, such as inert gas injection, shall be provided to remove fuel gas – air mixtures from the crankcase at engine standstill.

9.2.3.3 Suitable means shall be available to purge inert gas from the crankcase before opening the crankcase for maintenance.

9.2.3.4 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*

9.2.3.5 Inerting

For maintenance purposes, a connection, or other means, are to be provided for crankcase inerting and ventilating and gas concentration measuring.

9.2.3.6 Crankcase ventilation

Ventilation of crankcase (either supply or extraction), if arranged, is to comply with F.2 and F.3. Relevant evidence is to be documented in Safety Concept.

The ventilation systems for crankcase, sump and other similar engine spaces are to be independent from the systems on the other engines.

9.3 Explosion relief valves

9.3.1 General requirements

9.3.1.1 Explosion relief devices shall close firmly after an explosion event.

9.3.1.2 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.

9.3.1.3 Warning plates shall be applied at suitable places adjacent to the explosion relief valves.

9.3.2 Crankcase explosion relief valves

9.3.2.1 For crankcase safety devices (e.g. explosion relief valves, oil mist detection, etc.) the requirements specified in F.4. are to be observed.

Crankcase explosion relief valves are to be installed in accordance with Section 2.F.4. Refer also to Guidelines for The Use of Gas as Fuel for Ship (Pt.1, Vol.1) Sec.10.3.1.2 (IGF Code 10.3.1.2).

9.3.2.2 Crankcase explosion relief valves are to be provided at each crank throw.

9.3.2.3 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.

9.3.2.4 For the type approval of crankcase explosion relief valves, Guidance for The Approval and Type Approval of Materials and Equipment for Marines Use (Pt.1, Vol.W) Sec.3.I apply.

9.3.2.5 For engines not covered by F.3, the detailed evaluation as required in 6.4.9) is to determine if crankcase explosion relief valves are necessary.

9.3.3 Other explosion relief valves

9.3.3.1 As far as required in the Guidelines for The Use of Gas as Fuel for Ships (Pt.1, Vol.1), explosion relief valves are to be provided for combustion air inlet manifolds and exhaust manifolds.

9.3.3.2 Explosion relief valve shall generally be approved byBKI for the application on inlet manifolds and exhaust manifolds of gas-fuelled engines.

9.3.3.3 For the approval of relief valves, Guidance for The Approval and Type Approval of Materials and Equipment for Marines Use (Pt.1, Vol.W) Sec.3.I.I.

10. Type Testing, Factory Acceptance Tests and Shipboard Trials

10.1 Type Testing

10.1.1 General

Type approval of DF and SF engines is to be carried out in accordance with E.4, taking into account the additional requirements below.

10.1.2 Type of engine

In addition to the criteria given in Guidance for The Approval and Type Approval of Materials and Equipment for Marines Use (Pt.1, Vol.W) Sec.3.H.1.4 the type of engine is defined by the following:

- gas admission method (cylinder injection after compression stroke, cylinder individual injection before compression stroke, or pre-mixed)
- gas admission valve operation (mechanical or electronically controlled)
- ignition system (pilot injection, spark ignition, glow plug or gas self-ignition)
- ignition system (mechanical or electronically controlled)

Note:

Cylinder-individual injection before compression stroke may be port injection into the air inlet channel before the cylinder inlet valve, injection into the cylinder before or during compression stroke, or similar arrangements.

10.1.3 Safety precautions

In addition to the safety precautions mentioned in Guidance for The Approval and Type Approval of Materials and Equipment for Marines Use (Pt.1, Vol.W) Sec.3.H.3.2, measures to verify that gas fuel piping on engine is gas tight are to be carried out prior to start-up of the engine.

10.1.4 Test programme

The type testing of the engine is to be carried out in accordance with Guidance for The Approval and Type Approval of Materials and Equipment for Marines Use (Pt.1, Vol.W) Sec.3.H.3.3., taking into account the additional requirements of this Section.

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.

10.1.5 Measurements and records

In addition to the measurements and records required in Guidance for The Approval and Type Approval of Materials and Equipment for Marines Use (Pt.1, Vol.W) Sec.3.H.3.7, 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
- Pilot fuel temperature and pressure (supply or common rail as appropriate)

Note:

The gas concentration in the crankcase should normally be measured inside the crankcase or at the crankcase outlet (crankcase vent pipe). Gas concentration measurements may be carried out as part of Stage A if the method and the results are properly documented.

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

10.1.6 Stage A – internal tests

In addition to tests required in Guidance for The Approval and Type Approval of Materials and Equipment for Marines Use (Pt.1, Vol.W) Sec.3.H.3.8 Table 3.10 (Stage A), the following conditions are to be tested:

- DF engines are to run the load points defined in Guidance for The Approval and Type Approval of Materials and Equipment for Marines Use (Pt.1, Vol.W) Sec.3.H.3.8 Table 3.10 (Stage A) 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.
- The influence of the methane number and LHV of the fuel gas on the engine's maximum continuous power available in gas mode is to be verified.

10.1.7 Stage B – witnessed tests

10.1.7.1 General

Gas engines are to undergo the different tests required in Guidance for The Approval and Type Approval of Materials and Equipment for Marines Use (Pt.1, Vol.W) Sec.3.H.3.8 Table 3.10 (Stage B).

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. The independent overspeed protection device has to be tested both in gas and diesel mode.
- For engines with variable liquid/gas ratio, selected load tests are to be carried out at different ratios between the minimum and the maximum allowable value. (most relevant and critical loads and ratios should be selected for the test)
- The maximum continuous power available in gas mode (see 7.4.1) is to be demonstrated.
- Overload testing is not required in gas mode for DF engines, provided that changeover to oil fuel mode is automatically performed in case of overload.
- The load tests are to be carried out in diesel mode and in gas mode at the different percentages of the engine's MCR.

10.1.7.2 Functional tests

In addition to the functional tests required in Guidance for The Approval and Type Approval of Materials and Equipment for Marines Use (Pt.1, Vol.W) Sec.3.H.3.8 Table 3.10 (Stage B point 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.
- For DF engines, verification of automatic changeover to diesel mode when the load demand exceeds the maximum continuous power available in gas mode (see 7.4.1 and 7.4.2)
- The efficiency of the ventilation arrangement of the double walled gas piping system is to be verified.

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 Section 2.F.1.2.3
- 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 7.1.2, 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 Section 2.F.1.2.3.*

10.1.7.3 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 BKI for selected cases based on the risk analysis required in 6, 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 gas admission valve
- Failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc.)
- Abnormal gas pressure
- Abnormal gas temperature

10.1.8 Stage C – Component inspection

Component inspection is to be carried out in accordance with the provisions of Guidance for Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W) Sec.3.H Table 3.10 (Stage C).

The components to be inspected after the test run are to include also:

- gas admission valve including pre-chamber as found applicable
- spark igniter (for SF engines)
- pilot fuel injection valve (for DF engines)

10.1.9 Engine type approval certificate

For DF engines, the maximum continuous power available in gas mode should be specified on the type approval certificate in addition to the maximum continuous rating in diesel mode if differing.

10.2 Factory Acceptance Test

10.2.1 General

Factory acceptance tests of DF and SF engines are to be carried out in accordance with Sub-section E.5, taking into account the additional requirements below.

For DF engines, the load tests referred to in E.5.3 are to be carried out in diesel mode and in gas mode at the different percentages of the engines's MCR

Maximum continuous power available in gas mode is to be demonstrated (see 7.4.1).

10.2.2 Safety precautions

In addition to the safety precautions mentioned in Guidance for Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W) Sec.3.H.3.2, measures to verify that gas fuel piping on engine is gas tight are to be carried out prior to start-up of the engine.

10.2.3 Records

In addition to the records required in E.5.2, the following engine data are to be recorded:

- Fuel index, both gas and diesel as applicable (or equivalent reading)
- Gas pressure and temperature
- Pilot fuel temperature and pressure (supply or common rail as appropriate)

10.2.4 Test loads

Test loads for various engine applications are given in E.5.3. 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.

10.2.5 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 BKI for selected cases based on the risk analysis required in 6 and shall at least include the following incidents:

- Failure of ignition (spark ignition or pilot injection systems), for one cylinder unit
- Failure of a gas admission 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 BKI.

10.3 Shipboard trials

A leak test is to be carried out for the gas piping system (IGF Code 16.7.3.3) after assembly on board.

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
- testing of start blocking

For DF engines, the test loads required in E.6 are to be carried out in all operating modes (gas mode, diesel mode, etc.) as applicable (see O.7.4.1).

The maximum continuous power available in gas mode is to be demonstrated.

Note:
If a test load is performed in all applicable operation modes without interruption (direct changeover at same power and speed), the duration as required in E.6.4 may be considered as the total duration demonstrated in all fuel modes. However, demonstration at each mode shall not be less than one hour.

The starting maneuvers required in E.6.2 are to be carried out in diesel mode and gas mode, if applicable.

For DF engines, automatic switching over to oil fuel mode is to be tested. Further, manual change over from diesel to gas mode and vice versa is to be tested.

The efficiency of the ventilation arrangement, or other approved principle, of the double walled gas piping system is to be verified.

11. Certification of Engine Components

The principals, definitions, and general requirements of D.2 apply.

In addition to those components specified in D.2, the engine components listed in Table 2.14 shall be documented as listed in the table.

Table 2.14: Required documentation for engine components

Part	Material Properties	NDE	Pressure testing	Visual Inspection of welds	Component certificate
Gas pipe Low-pressure double walled	W(C+M)	W 2),6)	W 4)	X	
Single walled Gas pipes	W(C+M)	W 1)	W 4)	X	SC
High-pressure gas pipes	W(C+M)	W 1)	W 4)	X	SC
Secondary enclosure for gas pipes	W(C+M)	W 2)	W 3)	X	
Gas pipe Low-pressure, Flanges *	W(C+M)	W 2),6)		X	
Gas pipe High-pressure, Flanges *	W(C+M)	W 1)		X	SC
Gas pipe Low-pressure, Fittings and other components	W(C+M)		W 4)	X	
Gas pipe High-pressure, Fittings and other components	W(C+M)		W 4)	X	SC
Gas pipe Low-pressure Bodies of valves, 7)	W(C+M)		W 4)		
Gas pipe High-pressure Bodies of valves	W(C+M)		W 4)		SC
Gas venting pipes and flanges*, build up pressure less than 5.0bar	TR(C+M)	W 2)	W 4)	X	
Gas venting pipes and flanges*, build up pressure at 5.0bar or more with secondary enclosure	TR(C+M)	W 2)	W 4)	X	
Gas venting pipes and flanges*, build up pressure at 5.0bar or more	W(C+M)	W 1)	W 4)	X	SC
Gas venting pipes Secondary enclosure			W 5)	X	

Footnotes:

1) 100% radiographic or ultrasonic inspection of all butt-welded joints (IGF Code 16.6.3.1)

2) 10% radiographic or ultrasonic inspection of butt-welded joints (IGF Code 16.6.3.4)

3) Pressure test at 1.5 x design pressure to ensure gas tight integrity, not less than the expected maximum pressure at gas pipe rupture (as per IGF 16.7.3.4, and 9.8.4)

4) Pressure test at 1.5 x design pressure

5) Leak test.

6) If inside diameter > 75 mm or wall thickness > 10 mm: 100% radiographic or ultrasonic inspection of all butt-welded joints (IGF Code 16.6.3.1)

7) If nominal diameter > 25 mm

(*) "Flanges" limited to the final connection to the engine.

12. Machinery spaces

12.1 Sufficient air exchange and air flow shall be ensured around the engine to prevent accumulation of explosive, flammable, or toxic gas concentrations.

12.2 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.

12.3 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.

12.4 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 behaviour in case of gas leaks and failure of machinery are to be provided at prominent positions in machinery spaces.

13. 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.

14. 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.

15. 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 BKI.

P. Astern Power for Main Propulsion

1. In order to maintain sufficient manoeuvrability and secure control of the ship in all normal circumstances, the main propulsion machinery is to be capable of reversing the direction of thrust so as to bring the ship to rest from the maximum service speed. The main propulsion machinery is to be capable of maintaining in free route astern at least 70% of the ahead revolutions [3)]

2. For the main propulsion systems with reversing gears, controllable pitch propellers or electric propeller drive, running astern should not lead to the overload of propulsion machinery.

3. Main propulsion systems are to undergo tests to demonstrate the astern response characteristics.

The tests are to be carried out at least over the manoeuvring range of the propulsion system and from all control positions. A test plan is to 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.

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

[3)] The ahead revolutions as mentioned above are understood as those corresponding to the maximum continuous ahead power for which the vessel is classed.

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Section 3 Steam Turbines, Gas Turbines and Exhaust Gas Turbocharges

I. Steam Turbines

A. General

1. Scope

The following Section apply to main and auxiliary steam turbines.

BKI reserves the right to authorize deviations from the requirements of this Section in the case of low-power turbines.

2. Documents for approval

The documents listed below are to be submitted for approval to BKI in electronic format.

— assembly and sectional drawings of the turbines,
— detail drawings of rotors, casings, guide blading, blades, valves, bed frames and main condenser (for gearing, see Section 5),
— details of operating characteristics and critical speeds,
— proof of a sufficient safety margin 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 100000 hours at service temperature,

— details of the welding conditions applicable to welded components and
— on request, calculations relating to blade vibration.

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. Heat flow diagrams for each turbine installation and a set of operating instructions for at least each turbine type are to be submitted.

B. Materials

1. Approved materials

1.1 Rotating components

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

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.

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.

Grey and nodular cast iron may be used up to a steam temperature of 300°C.

2. Testing of materials

2.1 The following parts are subject to testing in accordance Rules for Materials (Pt.1, Vol.V):

— rotating parts such as rotors, discs, shafts, shrink rings, blades, toothed couplings and other dynamically loaded components as well as valve spindles and cones.
— stationary parts such as casings, guide blading, nozzles and nozzle chests, guide vanes, turbine casing bolts, bed frames and bearing pedestals.
— condenser tubes and tube plates.

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.

C. Design and Construction Principles

1. Foundations

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.

For the design of foundation, Regulations for the Seating of Diesel Engine Installations (Pt.1, Vol.U) have to be considered.

2. Jointing of mating surfaces

The mating flanges of casings shall form a tight joint without the use of any interposed material.

3. Bearing lubrication

The lubrication of bearings are not to be impaired by adjacent hot parts or by steam.

For the lubricating oil system, see Section 11, H.

4. 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. Turning gear

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. 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.

8. Vibrations

The range of service speeds of turbine plant is not to give rise to unacceptable bending vibrations or to vibrations affecting the entire installation[1)].

D. Astern Running, Emergency Operation

1. Astern power for main propulsion

1.1 The main propulsion machinery is to 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[2)] for a period of at least 15 minutes. The astern trial is to be limited to 30 minutes or in accordance with manufacturer's recommendation to avoid overheating of the turbine due to the effects of "windage" and friction.

1.2 Requirements in Section 2.P.2 to 2.P.4 are to be applied.

2. Arrangements for emergency operation

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.

The necessary pipes and valves for the 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 BKI prior to the first sea trials.

[1)] The assessment may be based on ISO 10816-3 "Mechanical vibration - Evaluation of machine vibrations by measurements on non-rotating parts" or an equivalent standard.

[2)] The ahead revolutions as mentioned above are understood as those corresponding to the maximum continuous ahead power for which the vessel is classed.

The permissible operating conditions (power/speeds) when operating without one of the turbines (all combinations) are to be specified and accessibly documented on board.

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 BKI for appraisal.

E. Manoeuvring and Safety Equipment

1. Manoeuvring and control equipment

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.

1.2 Fluids for operating hydraulic manoeuvring equipment, quick-closing and control systems are to be suitable for all service temperatures and of low flammability.

1.3 Where the main turbine installation incorporates a reverse gear, electric transmission, controllable pitch propeller or other free-coupling arrangement, a separate speed governor in addition to the overspeed protective device is to be fitted and is to be capable of controlling the speed of the unloaded turbine without bringing the overspeed protective device into action.

1.4 Where exhaust steam from auxiliary systems is led to the main turbine it is to be cut off at activation of the overspeed protective device.

1.5 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 is to be separated by a sufficient margin from the trip speed.

2. Safety devices

2.1 Main propulsion turbines are to be equipped with quick-closing devices which automatically shut off the steam supply in case of:

a) over speed. Excess speeds of more than 15 % above the rated value are to be prevented. Where two or more turbines are coupled to the same gear wheel set, BKI may agree that only one overspeed protective device be provided for all the turbines.

b) unacceptable axial displacement of the rotor,

c) an unacceptable increase in the condenser pressure,

d) an unacceptable increase in the condenser water level and

e) an unacceptable drop in the lubricating oil pressure.

2.2 In cases a) and b) of 2.1, the quick-closing devices shall to be actuated by the turbine shafts.

2.3 It is to also be possible to trip the quick closing device manually at the turbine and from the control platform.

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.

2.5 It is recommended that an alarm system should be fitted which responds to excessive vibration velocities[1)].

2.6 An interlock is to be provided to ensure that the main turbine cannot be started up when the turning gear is engaged.

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.

2.8 Turbines driving auxiliary machines at least are to be equipped with quick-closing devices for contingencies 2.1 a) and 2.1 d). An excessive rise in the exhaust steam pressure as to actuate the quick-closing device.

2.9 It shall be possible to start up any turbine only when the quick-closing device is ready for operation.

2.10 Efficient steam strainers are to be provided close to the inlets to ahead and astern high pressure turbines or alternatively at the inlets to manoeuvring valves.

2.11 Main turbines are to be provided with a satisfactory emergency supply of lubricating oil which will come into use automatically when the pressure drops below a predetermined value.

The emergency supply may be obtained from a gravity tank containing sufficient oil to maintain adequate lubrication until the turbine is brought to rest or by equivalent means. If emergency pumps are used these are to be so arranged that their operation is not affected by failure of the power supply. Suitable arrangement for cooling the bearings after stopping may also be required.

2.12 To provide a warning to personnel in the vicinity of the exhaust end steam turbines of excessive pressure, a sentinel valve or equivalent is to be provided at the exhaust end of all turbines. The valve discharge outlets are to be visible and suitably guarded if necessary. When, for auxiliary turbines, the inlet steam pressure exceeds the pressure for which the exhaust casing and associated piping up to exhaust valve are designed, means to relieve the excess pressure are to be provided.

3. Other Requirements

Depending on the degree of automation involved, the extent and design of the equipment is also subject to the requirements in Rules for Automation (Pt.1, Vol.VII).

F. Control and Monitoring Equipment

1. Arrangement

The control and monitoring equipment for each main propulsion unit is to be located on the control platform.

2. Scope and design of equipment

Depending on the degree of automation involved, scope and design of the equipment is also subject to Rules for Automation (Pt.1, Vol.VII).

3. Control and indicating instruments

When the turning gear is engaged, this fact is to 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.

4. Equipment for auxiliary turbines

Turbines driving auxiliary machines are to be provided with the necessary equipment on the basis of E.

G. Condensers

1. Design

The condenser is to be so designed that the inlet steam speed does not result in prohibitive stressing of the condenser tubes. Excessive sagging of the tubes and vibration are to be avoided, e.g. by the incorporation of tube supporting plates.

The water chambers and steam space are to be provided with openings for inspection and cleaning. Anti-corrosion protection is to be provided on the water side.

In the case of single-plane turbine installations, suitable measures are to be taken to prevent condensate from flowing back into the low pressure turbine.

2. Cooling water supply

The supply of cooling water to the condenser is subject to the requirements contained in Section 11.I.

H. Tests

1. Testing of turbine rotors

1.1 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.

1.2 Balancing

Finished rotors, complete with blades and associated rotating parts and ready for assembly, are to be dynamically balanced in the presence of the Surveyor[3)]

1.3 Cold overspeed test

Turbine rotors are to be tested at a speed at least 15 % above the rated speed for not less than three minutes. BKI 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.

2. Pressure and tightness tests

2.1 All finished casing components are to be subjected to hydrostatic testing in the presence of the Surveyor.

The test pressure pp is calculated as follows:

$$p_p = 1{,}5 \cdot p_{e,perm}$$

where $p_{e,perm} \leq 80$ bar

$p_{e,perm}$ = maximum allowable working pressure [bar]

$$p_p = p_{e,perm} + 40 \text{ bar}$$

where $p_{e,perm} > 80$ bar

For the bodies of quick-closing, maneuvering 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)] The assessment may be based on ISO 1940-1 standard "Mechanical vibration - Balance quality requirements of rigid rotors" an equivalent standard.

2.2 Casing parts on the exhaust side of low pressure turbines subjected during operation to the condenser pressure are to be tested at p_p = 1,0 bar.

2.3 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 bar on the steam side

p_p = 1,5 $p_{e,perm}$ on the water side

I. 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
— uring 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 are not to reach 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.

II. Gas Turbine

A. General

1. Scope

The following Section apply to main and auxiliary gas turbines.

BKI reserves the right to authorize deviations from the requirements of this Section in the case of low-power turbines.

2. Documents for approval

The documents for approval of main and auxiliary gas turbines have to be submitted to BKI Head Office.

The approval will be performed in accordance with BKI Head Office.

B. Control and Safety of Gas Turbine for Marine Propulsion Use

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 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 BKI together with the failure mode and effect analysis (FMEA).

Unless the FMEA required by this Section proves otherwise, the shutdown functions for gas turbines are to be provided in accordance with Table 8.5 of the Rules for Automations (Pt.1, Vol.VII) Sec.8.D.

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:

- Overspeed
- 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

Although in principle alarming devices listed in Table 8.5 of the Rules for Automations (Pt.1, Vol.VII) Sec.8.D are to be provided, they can be added or omitted, taking into account the result of FMEA specified in item 2.1.

4. Other Requirements

Depending on the degree of automation involved, the extent and design of the equipment is also subject to the requirements in Rules for Automations (Pt.1, Vol.VII).

III. Exhaust Gas Turbochargers

A. General

1. Application

1.1 This Subsection are applicable for approval of turbochargers fitted on diesel engines and describe the required procedures for drawing approval, testing, and shop approval.

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. Type approval

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.

For approval of exhaust gas turbocharger, see Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1 Vol.W) Sec.3.K.

2.1 Documentation to be submitted

The documents in the following Table 3.1 - 3.3 are to be submitted by the manufacturer to BKI for approval or information:

Table 3.1: Documentation to be submitted on request for approval of Category A turbocharger

No.	Documents
1	Containment test report.
2	Cross sectional drawing with principal dimensions and names of components.
3	Test program.

Table 3.2: Documentation to be submitted for Category B and C turbochargers

No.	Documents	A/I
1	Cross sectional drawing with principal dimensions and materials of housing components for containment evaluation.	I
2	Documentation of containment in the event of disc fracture, see C.7.	A
3	Operational data and limitations as[1]: — 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	I
4	Arrangement of lubrication system, all variants within a range.	I
5	Type test reports.	A
6	Test program.	I

1 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%

Note:

A = Documents for approval

I = Documents for information

Table 3.3: Additional documentation to be submitted for Category C turbocharger

No.	Documents	A/I
1	Drawings of the housing and rotating parts including details of blade fixing.	A
2	Material specifications (chemical composition and mechanical properties) of all parts mentioned above.	I
3	Welding details and welding procedure of above mentioned parts, if applicable.	A
4	Documentation[1] of safe torque transmission when the disc is connected to the shaft by an interference fit, see B.6.	A
5	Information on expected lifespan, considering creep, low cycle fatigue and high cycle fatigue.	I
6	Operation and maintenance manuals[1]	I

1 Applicable to two sizes in a generic range of turbochargers

Note:

A = Documents for approval

I = Documents for information

B. Design and Installation

1. General

Turbocharger is to be designed to operate at least under the conditions given in Section 1, C.

2. Basic design considerations

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.

The turbocharger rotors 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 overspeed after compressor burst due to loss of energy absorption in compressors.

3. Air inlet

The air inlet of the turbocharger is to be fitted with a filter in order to minimize the entrance of dirt or water.

4. Hot surfaces

According to SOLAS Rules and Regulations, Chapter II-2, Part B-Prevention of fire and explosions, 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.

Pipe connections have to be located or shielded with collars in such a way that leakage oil either spraying or dripping may not come into contact with hot surfaces of more than 220 °C.

Hot components in range of passageways or within the working area of turbocharger shall be insulated or protected so that touching does not cause burns.

5. Bearing lubrication

Bearing lubrication shall not be impaired by exhaust gases or by adjacent hot components.

Leakage oil and oil vapours 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.

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.

A gas flow from turbocharger to adjacent components containing explosive gases, e.g. crankshaft casing shall be prevented by an adequate ventilating system.

6. Disc-shaft shrinkage fit

6.1 Applicable to Category CApplicable to Category C

6.2 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.

C. Test

1. Material Tests

1.1 General

Material testing is required for casings, shaft, compressor and turbine wheel, including the blades.

The material 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.

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 BKI. According to the decision of BKI, 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.

The turbochargers casing are to be from ductile materials (minimum 90 % ferritic structure) and properly heat-treated in order to achieve the required microstructure and ductility as well as to remove residual stresses. Deviations from the standard heat-treatment have to be approved separately by BKI.

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 Certificates. 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 BKI separately.

1.3 Chemical composition and mechanical properties

Materials and products have to be satisfy the requirements relating to chemical compositions and mechanical properties specified in Rules for Material (Pt.1, Vol.V) or, where applicable, in the relevant manufacturer's specifications approved for the type 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

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
- results of mechanical property tests carried out on material at ambient temperature

Depending on the produced component of turbocharger material test certificates are to be issued by the manufacture or BKI. The required Certificates are summarized in Table 3.4.

Table 3.4: Material certificates

Turbocharger components	Type of Certificates [1)]
Shaft	BKI Material Certificate
Rotors (compressor and turbine)	BKI Material Certificate
Blades	BKI Material Certificate
Casing	Manufacturer Test Report

[1)] Test Certificates are to be issued in accordance with Rules for Materials (Part 1, Vol.V) Section 1.

The materials are to conform to specifications approved in connection with the type approval in each case. Test Certificates are to be issued in accordance with Rules for Material (Pt.1, Vol.V) Sec.1.

2. Testing of components

The following tests as outlined in 3 to 5 may be carried out and certified by the manufacturer for all exhaust gas turbochargers. The identification of components subject to testing must be ensured. On request, the documentation of the test, including those of subcontractors' tests, are to be provided to the BKI Surveyor for examination.

The test as specified in 6 to 8 are to be performed in presence of a BKI Surveyor.

BKI reserve the right to review the proper performance and the results of the test at any time to the satisfaction of the Surveyor.

3. Pressure tests

Cooling water spaces as well as the emergency lubrication oil system for gas inlet and gas outlet casings are to be subjected to a hydrostatic pressure test of pp = 4 bar, but not less than pp = 1.5 x pc (pp : test pressure; pc : design pressure).

4. Overspeed test

All wheels (compressor and turbine) have to undergo an overspeed test for 3 minutes at 20% over the maximum operational speed at room temperature, or 10% over the maximum permissible speed at maximum permissible working temperature. If each wheel is individually checked by a BKI approved non-destructive testing method no overspeed test is required. Deviations are to be approved separately by BKI.

5. Dynamic balancing

Each shaft and bladed wheel as well as the complete rotating assembly has to be dynamically balanced individually in accordance with the approved quality control procedure. For assessment of the balancing conditions the DIN ISO 1940 or comparable regulations may be referred to.

6. Bench test

Each turbocharger has to pass a test run.

The test run is to be carried out during 20 minutes with an overload (110% of the rated diesel engine output) on the engine for which the turbocharger is intended.

This test run may be replaced by a separate test run of the turbocharger unit for 20 minutes at maximum operational speed and working temperature.

In case of sufficient verification of the turbocharger's performance during the test, a subsequent dismantling is required only in case of abnormalities such as high vibrations or excessive noise or other deviations of operational parameters such as temperatures, speed, pressures to the expected operational data.

On the other hand turbochargers shall be presented to the BKI Surveyor for inspection based upon an agreed spot check basis.

7. Containment test

7.1 The Turbochargers shall fulfil containment in the event of a rotor burst. This means that at a 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.

7.2 For category B and C, containment shall be documented by testing. Fulfilment of this requirement can be awarded to a generic range[4)] 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.

7.3 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)

7.4 The containment test has to be performed at a temperature which is not lower than the maximum allowable temperature of the turbocharger to be specified by the manufacturer.

7.5 Manufacturers are to determine whether cases more critical than those defined in 7.3. and 7.3 exist with respect to containment safety. Where such a case is identified, evidence of containment safety shall also be provided for that case.

7.6 The theoretical (design) natural burst speed of compressor and turbine has to be submitted for information.

7.7 A numerical prove of sufficient containment integrity of the casing based on calculations by means of a simulation model such as Finite Element Method (FEM) or other comparable methods may be accepted in lieu of the practical containment test, provided that:

- The numerical simulation model has been tested and its suitability/accuracy has been proven by direct comparison between calculation results and the practical containment test for a reference application (reference containment test). This test shall be performed at least once by the manufacturer for acceptance of the numerical simulation method in lieu of tests.
- the corresponding numerical simulation for the containment is performed for the same speeds, as specified for the containment test (see above)
- 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.
- the design of the turbocharger regarding the geometry and kinematics is to be similar to that of one turbocharger which has passed the containment test.
- the application of the simulation model may give hints that containtment speeds lower as above specified may be more critical for the casing's integrity, due to special design features and different kinematics behaviour. In such cases the integrity properties of containment for the casing shall be proven for the worst case.

[4)] A generic range means a series of turbocharger which are of the same design, but scaled to each other.

7.8 In cases where a totally new design [1] is adopted for a turbocharger for which an application for type approval certification has been requested, new reference containment tests are to be performed.

7.9 In general a BKI Surveyor or the Head Office has to be involved for the containment test. The documentation of the physical containment test as well as the report of the simulation results are to be submitted to BKI within the scope of the approval procedure.

8. Type testing

For the requirements of type testing, see Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1 Vol.W) Sec.3.K.

9. 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 BKI approved manufacturers according to the previously approved drawings and material specifications. The manufacturer is to be recognized by the holder of the original type approval.

D. Workshop Inspection and Testing

1. Category B and C turbochargers shall go to through following inspections and testings and associated certificates shall be produced as mentioned in Table 3.4

E. Certification [5]

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.

2. For category C, this shall be verified by means of periodic product audits of an Alternative Certification Scheme (ACS) by BKI

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.

[1] Totally new design means the principal differences between a new turbocharger and previous ones are related to geometry and kinematics. The turbochargers are to be regarded as having a totally new design if the structure and/or material of the turbocharger casings are changed, or any of, but not limited to, the following items is changed from the previous design.

- Maximum permissible exhaust gas temperature
- Number of bearings
- Number of turbine blades
- Number of turbine wheels and/or compressor wheels
- Direction of inlet air and/or exhaust gas (e.g., axial flow orientation, radial flow orientation)
- Type of the turbocharger drive (e.g., axial turbine type, radial turbine type, mixed flow turbine type)

[5] The date of application for certification is the date of whatever document the Classification Society requires/accepts as an application or request for certification of a new turbocharger type or of a turbocharger type that has undergone substantive modifications in respect of the one previously type approved, or for renewal of an expired type approval certificate.

- 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. Turbochargers shall be delivered with:

- For category C, BKI 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.

5. The same applies to replacement of rotating parts and casing.

6. Alternatively to the above periodic product audits, individual certification of a turbocharger and its parts may be made at the discretion of BKI. 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.

F. Alarms & Monitoring

1. For all turbochargers of Categories B and C, indications and alarms as listed in the Table 3.5 are required.

2. Indications may be provided at either local or remote locations.

Table 3.5: Alarm and indication for turbocharger categories B and C

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 each turbocharger outlet, temperature			High	X	If not forced system, oil temperature near bearings
4	Lub. oil at each turbocharger intlet, pressure	Low	X	Low	X	Only for forced lubricationsystems[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.

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Section 4 Main Shafting

A. General

1. Scope

The following Rules apply to standard and established types of shafting for main and auxiliary propulsion as well as for lateral thrusters. Deviating designs require BKI's special approval.

BKI reserve 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.

2. Documents for approval

General drawings of the entire shafting, from the main engine coupling flange to the propeller, and detail drawings of the shafts, couplings and other component parts transmitting the propelling engine torque, and in addition detail drawings and the arrangement of the stern tube seals and the cast resin mount for stern tube and shafts bearings are to be submitted for approval in electronic format

For the arrangement of the shaft bearings of the propulsion plant an alignment calculation, including alignment instructions, has to be submitted, see D.5.6. With consent of BKI for shafting with an intermediate shaft diameter < 200 mm the alignment calculation may be waived.

The documentation shall contain all the data necessary to enable the stresses to be evaluated.

B. Material

1. Approved materials

Propeller, intermediate and thrust shafts together with flange and clamp couplings are to be made of forged steel; where appropriate, couplings may be made of cast steel. Rolled round steel may be used for plain, flangeless shafts.

In general, the tensile strength of steels used for shafting (shafts, flange couplings, bolts/fitted bolts) shall be between 400 N/mm^2 and 800 N/mm^2. For dynamically loaded parts of the shafting, designed in accordance to the formulas as given under C. and D., and explicitly for the shafts themselves as well as for connecting/fitted bolts for flanged connections in general quenched and tempered steels shall be used with a tensile strength of more than 500 N/mm^2.

However, the value of R_m used for calculation of the material factor C_w in accordance with formula (2) shall not exceed

- 600 N/mm^2 for propeller shafts (exceptions need the special consent of BKI).
- 760 N/mm^2 for shafts made of carbon or carbon manganese steel except propeller shafts
- 800 N/mm^2 for shafts made of alloy steel except propeller shafts.

Where materials with higher specified or actual tensile strengths than the limitations given above are used, the shaft dimensions derived from formulae (1) and 2) are not to be reduced accordingly.

Where in special cases wrought copper alloys resistant to seawater are to be used for the shafting, consent of BKI shall be obtained.

2. Testing of materials

All component parts of the shafting which are participating in transmitting the torque from the ship's propulsion plant are subject to Rules for Materials (Pt.1, Vol.V), and Rules for Welding (Pt.1,Vol.VI), are to be tested. This requirement also covers metal propeller shaft liners. Where propeller shafts running in seawater are to be protected against seawater penetration not by a metal liner but by plastic coatings, the coating technique used is to be approved by BKI.

3. Special approval of alloy steel used for intermediate shaft material

3.1 Application

This appendix is applied to the approval of alloy steel which has a minimum specified tensile strength greater than 800 N/mm^2, but less than 950 N/mm^2 intended for use as intermediate shaft material.

3.2 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_1 given by the formulae in Section 16.C.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.

3.2.1 Test conditions

Test conditions are to be in accordance with Table 4.1. Mean surface roughness is to be <0,2µm Ra with the absence of localised machining marks verified by visual examination at low magnification (x20) as required by Section 8.4 of ISO 1352:2011.

Test procedures are to be in accordance with Section 10 of ISO 1352:2011.

Table 4.1: Test Condition

Loading type	Torsion
Stress ratio	R = -1
Load waveform	Constant-amplitude sinusoidal
Evaluation	S-N curve
Number of cycles for test termination	cycles

3.2.2 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 16.C.1
scf	=	stress concentration factor, see Section 16.C.1 Table 16.1 (For unnotched specimen, 1,0.)
c_D	=	size factor, see Section 16.C.1
R_m	=	specified minimum tensile strength in N/mm^2 of the shaft material

3.3 Cleanliness requirements

The steels are to have a degree of cleanliness as shown in Table 4.2 when tested according to ISO 4967:2013 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 Rules for Materials (Pt.1, Vol.V) Sec.6.B, Table 6.2b, 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 the Society.

Table 4.2: Cleanliness requirements

Inclusion group	Series	Limiting chart diagram index I
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

4. Inspection

The ultrasonic testing required by Rules for Material (Pt.1, Vol.V) Sec.6.H.6 is to be carried out prior to acceptance. The acceptance criteria are to be in accordance with IACS Recommendation No. 68 or a recognized national or international standard.

C. Shaft Dimensioning

1. General

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.

For shafts that are integral to equipment, such as for gear boxes (see Section 5), 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.

Explicitly it will be emphasized that the following applications are not covered by the requirements in this Section:

— additional strengthening for shafts in ships which are strengthened for navigation in ice (see Section 13)

- gear shafts (see Section 5)
- electric motor and generator rotor shafts
- turbine rotor shafts (see Section 3.I and, 3.II)
- crankshafts for internal combustion engines (see Section 2)

Additionally, all parts of the shafting are to be designed to comply with the requirements relating to torsional vibrations, set out in Section 16.

In general dimensioning of the shafting shall be based on the total rated installed power.

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 BKI.

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 < 104), 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 » 107), i.e torsional vibration stresses permitted for continuous operation as well as reverse bending stresses. The limits for torsional vibration stresses are given in Section 16. 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 barred speed ranges or other transient condition with stresses beyond the permitted limits for continuous operation is addressed by the criterion for transient stress in Section 16.

2. Minimum diameter

The minimum shaft diameter is to be determined by applying formula (1).

$$d_a \geq d \geq F \cdot k \cdot \sqrt[3]{\frac{P_W}{n \cdot \left[1 - \left(\frac{d_i}{d_a}\right)^4\right]} \cdot C_W} \qquad (1)$$

d	=	minimum required outer shaft diameter [mm]
d_a	=	actual outer shaft diameter [mm]
d_i	=	actual diameter of shaft bore. If the bore in the shaft is ≤ 0,4 · da, the expression [mm]
	=	$1-\left(\frac{d_i}{d_a}\right)^4$ may be taken as 1,0
P_W	=	rated power of propulsion motor, gear box and bearing losses are not to be subtracted [kW]
n	=	shaft speed at rated power [Rpm]

F = factor for type of propulsion installation
a) Propeller shafts
= 100 for all types of installations
b) Intermediate and thrust shafts
= 95 for turbine installations, diesel engine installations with hydraulic slip couplings, electric propulsion installations
= 100 for all other propulsion installations

C_w = material factor

$$\frac{560}{R_m + 160} \tag{2}$$

R_m = specified minimum tensile strength of the shaft material (see also .B.1.) [N/mm^2]

k = factor for the type of shaft
a) intermediate shafts
k = 1.0 for plain sections of intermediate shafts with integral forged coupling flanges or with shrink-fitted keyless coupling flanges. For shafts with high vibratory torques, the diameter in way of shrink fitted couplings should be slightly increased, e.g. by 1 to 2 %.
k = 1.10 for intermediate shafts where the coupling flanges are mounted on the ends of the shaft with the aid of keys. At a distance of at least 0.2 · d from the end of the keyway, such shafts can be reduced to a diameter calculated with
k = 1.0.
k = 1.10 for intermediate shafts with radial holes which diameter is not exceeding 0.3 · d. Intersections between radial and eccentric axial holes require a special strength consideration.
k = 1.15 for intermediate shafts designed as multi-splined shafts where d is the outside diameter of the splined shaft. Outside the splined section, the shafts can be reduced to a diameter calculated with k = 1.0.
k = 1.20 for intermediate shafts with longitudinal slots within the following limitations :
— slot length up to 0.8 · d_a
— inner diameter up to 0.8 · d_a
— slot width e up to 0.1 · d_a
— end rounding at least 0.5 · e
— 1 slot or 2 slots at 180° or 3 slots at 120°
Slots beyond these limitations require a special strength consideration.
b) Thrust shafts
k = 1.10 for thrust shafts external to engines near the plain bearings on both sides of the thrust collar, or near the axial bearings where a roller bearing is used.
c) Propeller shafts
k = 1.22 for propeller shafts with flange mounted or keyless taper fitted propellers, applicable to the shaft part 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 · d.
In case of keyless taper fitting, the method of connection has to be approved by BKI.
k = 1.26 for propeller shafts in the area specified for k= 1.22, if the propeller is keyed to the tapered propeller shaft.
k = 1.40 for propeller shafts in the area specified for k = 1.22, if the shaft inside the stern tube is lubricated with grease.
k = 1.15 for propeller shafts between forward end of aftmost bearing and forward end of fore stern tube seal. The portion of the propeller shaft located forward of the stern tube seal can gradually be reduced to the size of the intermediate shaft

D. Design

1. General

Changes in diameter are to be effected by tapering or ample radiusing. Radius are to 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. Fillets are to have a smooth finish and should not be recessed in way of nuts and bolt heads.

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 0.08 times the actual shaft diameter.

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

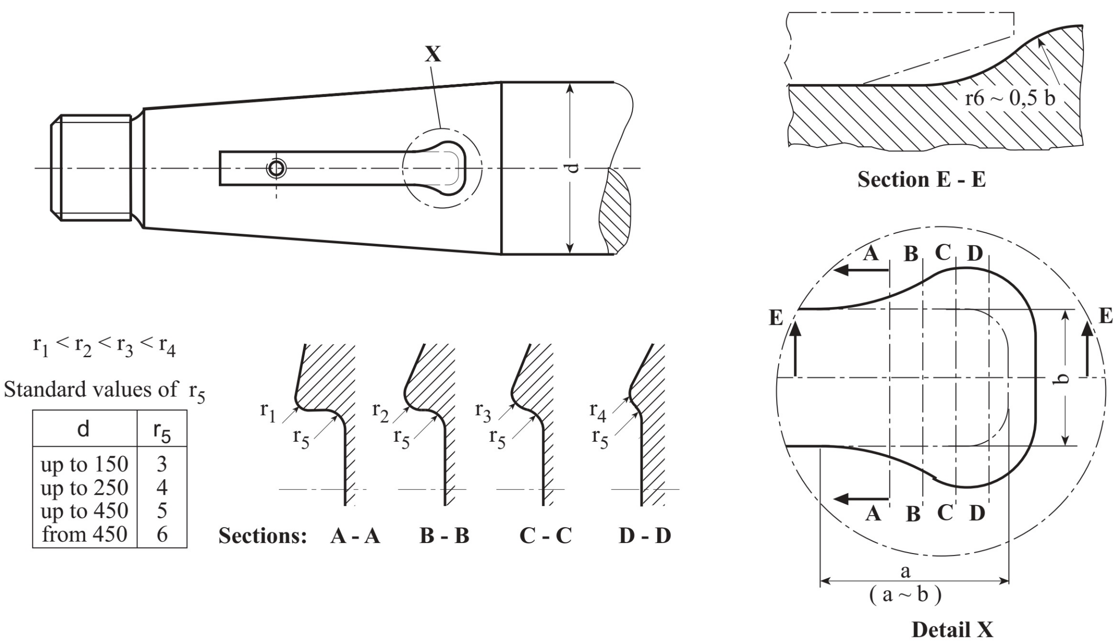
2. Shaft tapers and nut threads

Keyways are in general not to be used in installations with a barred speed range.

Keyways in the shaft taper for the propeller are to be designed in a way that the forward end of the groove makes a gradual transition to the full shaft section. In addition, the forward end of the keyway shall be spoon-shaped. The edges of the keyway at the surface of the shaft taper for the propeller are not be sharp. The forward end of the rounded keyway has to lie well within the seating of the propeller boss. Threaded holes for securing screws for propeller keys shall be located only in the aft half of the keyway, see Fig. 4.1.

In general, tapers for securing flange couplings which are jointed with keys shall have a conicity of between 1: 12 and 1: 20. See Section 6 for details of propeller shaft tapers on the propeller side.

The outside diameter of the threaded end for the propeller retaining nut shall not be less than 60% of the calculated big taper diameter.



d	r_5
up to 150	3
up to 250	4
up to 450	5
from 450	6

Figure 4.1: Design of keyway in propeller shaft

3. Propeller shaft protection

3.1 Sealing

At the stern tube ends propeller shafts with oil or grease lubrication are to be fitted with seals of proven efficiency and approved by BKI, see also the requirements applicable to the external sealing of the stern tube in the context with the propeller shaft survey prescribed in Rules for Classification and Survey (Pt.1, Vol.I), Sec. 3.

The securing at stern tube, shaft line or propeller (e.g. chrome steel liner) shall guarantee a permanent tightness. BKI reserves the right to demand corresponding verifications.

For protection of the sealing a rope guard shall be provided. The propeller boss seating is to be effectively protected against the ingress of seawater. This seal can be dispensed with if the propeller shaft is made of corrosion-resistant material.

In the case of Class Notation **IW**, the seal is to be fitted with a device by means of which the bearing clearance can be measured when the vessel is afloat.

3.2 Shaft liners

3.2.1 Propeller shafts which are not made of corrosion-resistant material and which run in seawater are to be protected against ingress of seawater by seawater-resistant metal liners or other liners approved by BKI and by proven seals at the propeller.

3.2.2 Metal liners in accordance with 3.2.1 which run in seawater, are to be made in a single piece. With the expressed consent of BKI 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 BKI to guarantee water-tightness. Such possibilities are special coatings. Such joints will be subject to special test to prove their effectiveness.

3.2.3 Minimum wall thickness of shaft liners

The minimum wall thickness s [mm] of metal shaft liners in accordance with 3.2.1 is to be determined as follows:

$$s = 0,03 \cdot d + 7.5 \quad (3)$$

where:

d = shaft diameter under the liner [mm]

In the case of continuous liners, the wall thickness between the bearings may be reduced to 0,75 · s.

4. Coupling connections

4.1 For intermediate shafts, thrust shafts and inboard end of propeller shafts the flange is to have a minimum thickness of 0,20 times the Rule diameter d of the intermediate shaft or the thickness of the coupling bolt diameter calculated for the material having the same tensile strength as the corresponding shaft, whichever is greater.

Where propellers are attached to a forged flange on the propeller shaft, the flange has to have a thickness of at least 25% of the calculated minimum diameter of a solid shaft at the relevant location.

Special consideration will be given by BKI for flanges having non-parallel faces, but in no case is the thickness of the flange to be less than the coupling bolt diameter.

In the formula (4), (5), (6), and (7), the following symbols are used:

A	=	effective area of shrink-fit seating [mm^2]
C_A	=	coefficient for shrink-fitted joints, depending on the kind of driving unit
	=	1,0 for geared diesel engine and turbine drives
	=	1,2 for direct coupled diesel engine drives
C	=	conicity of shaft ends
	=	difference in cone diameters/length of cone
d	=	shaft diameter in area of clamp type coupling [mm]
d_s	=	diameters of fitted bolts [mm]
d_k	=	inner throat diameter for necked down bolts [mm]
D	=	diameter of pitch circle of bolts [mm]
f	=	coefficient for shrink-fitted joints
Q	=	peripheral force at the mean joint diameter of a shrink fit [N]
n	=	shaft speed [Rpm]
p	=	contact pressure of shrink fits [N/mm^2]
P_w	=	rated power of the driving motor [kW]
S_{f1}	=	flange thickness in area of bolt pitch circle [mm]
S	=	safety factor against slipping of shrink fits in the shafting
	=	between motor and gear 3,0
	=	for all other applications 2,5
T	=	propeller thrust respectively axial force [N]
z	=	number of fitted or necked-down bolts
R_m	=	tensile strength of fitted or necked-down bolt material [N/mm^2]
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

4.2 The bolts used to connect flange couplings are normally to be designed as fitted bolts. The minimum diameter ds of fitted bolts at the coupling flange faces is to be determined by applying the formula:

$$d_s = 16 \cdot \sqrt{\frac{10^6 \cdot P_w}{n \cdot D \cdot z \cdot R_m}} \text{ [mm]} \quad (4)$$

4.3 Where, in special circumstances, the use of fitted bolls is not feasible, BKI may agree to the use of an equivalent frictional transmission.

4.4 The minimum thread root diameter dk of the connecting bolts used for clamp-type couplings is to be determined using the formula:

$$d_k = 12 \cdot \sqrt{\frac{10^6 \cdot P_w}{n \cdot d \cdot z \cdot R_m}} \text{ [mm]} \quad (5)$$

4.5 The shaft of necked-down bolts shall not be less than 0,9 times the thread root diameter. If, besides the torque, the bolted connection has to transmit considerable additional forces, the bolts shall be reinforced accordingly.

4.6 Nuts for fitted coupling bolts and shaft nuts for coupling flanges shall be properly secured against unintentional loosening. Shaft nuts for keyless fitted couplings shall be secured to the shaft.

4.7 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 diameter for the bore and the shafts according to the manufacturing drawings. The contact pressure p [N/mm^2] in the shrunk-on joint to achieve the required safety margin may be determined by applying formula (6) and (7).

$$p = \frac{\sqrt{\Theta^2 \cdot T^2 + f \cdot \left(c_a^2 \cdot Q^2 + T^2\right)} - \Theta \cdot T}{A \cdot f} \left[N/mm^2\right] \tag{6}$$

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.

$$f = \left(\frac{\mu_o}{s}\right)^2 - \Theta^2 \tag{7}$$

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 = 1,8 (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.

5. Shafting bearings

5.1 Arrangement of shaft bearings

Drawings showing all shaft bearings, like stern tube bearings, intermediate bearings and thrust bearings, shall be submitted for approval separately, if the design details are not visible on the shafting arrangement drawings. The permissible bearing loads are to 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 each bearing is subjected to positive reaction forces irrespective of the ship's loading condition when the plant is at operating state temperature.

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 operating state 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 significantly 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 formulae (8)

$$\ell_{max} = K_1 \cdot \sqrt{d}\,[mm] \tag{8}$$

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 rpm it is recommended that the maximum bearing spacing is determined in accordance with formulae (9) in order to avoid excessive loads due to bending vibrations. In limiting cases a bending vibration analysis for the shafting system is recommended.

$$\ell_{max} = K_2 \cdot \frac{d}{n} \, [mm] \tag{9}$$

n = shaft speed [Rpm]

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 formulae (8) or (9) respectively.

5.2 Stern tube bearings

5.2.1 Inside the stern tube the propeller shaft shall 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.

5.2.2 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 stern tube bearings shall be approximately $2{,}0 \cdot d_a$ 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 less 0,6 MPa in the case of bearings made of synthetic materials. Synthetic materials are to be Type Approved.

5.2.3 Where the propeller shafts inside the stern tube runs in bearings made of lignum vitae, rubber or plastic approved for use in water-lubricated stern tube bearings, the length of the after stern tube bearing shall be approximately $4 \cdot d_a$ and of the forward stern tube bearing approximately $1{,}5 \cdot d_a$

A reduction of the bearing length may be approved if the bearing is shown by means of bench tests to have sufficient load-bearing capacity.

For water lubricated bearings of synthetic material design substantiated by experiments to the satisfaction of BKI 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.

5.2.4 Where the propeller shaft runs in grease-lubricated, grey cast iron bushes the lengths of the after and forward stern tube bearings are to be approximately $2{,}5 \cdot d_a$ and $1{,}0 \cdot d_a$ respectively.

The peripheral speed of propeller shafts is to not exceed:

— 2,5 to a maximum of 3,0 m/s for grey cast iron bearings with grease lubrication
— 6,0 m/s for rubber bearings
— 3,0 to a maximum of 4,0 m/s for lignum vitae bearings with water lubrication

5.2.5 If roller bearings are provided, the requirements of 5.3.2 have to be considered.

5.3 Intermediate bearings

5.3.1 Plain bearings

For intermediate bearings shorter bearing lengths or higher specific loads as defined in 5.2 may be agreed with BKI.

5.3.2 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.

5.4 Bearing lubrication

5.4.1 Lubrication and matching of materials of the plain and roller bearings for the shafting have to meet the operational demands of seagoing ships. Sufficient lubrication and cooling must also be ensured at slow shaft rotation and slow ship speed.

5.4.2 Lubricating oil or grease is to 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 bearing.

With grease lubrication, the forward and after bearings are each to be provided with a grease connection. Wherever possible, a grease gun driven by the shaft is to be used to secure a continuous supply of grease. Biodegradable grease should be preferred.

Where the shaft runs in oil inside the stern tube, a header tank is to be fitted at a sufficient height above the ship's load line. It shall be possible to check the filling of the tank at any time.

The temperature of the after stern tube bearing (in general near the lower aft edge of the 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.

5.4.3 In the case of ships with automated machinery, Rules for Automations (Pt.1,Vol.VII), is to be complied with.

5.5 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 instead of the filling connection. If required, this flushing line shall also act as forced water lubrication.

5.6 Condition monitoring of propeller shaft at stern tube

5.6.1 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 5.4.2
- 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 BKI specifically for the plant.

5.6.2 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 Rules for Classification and Surveys (Pt.1,Vol.I), Sec. 3, B.1.3.8.

5.6.3 If the requirements according to 5.6.1 and 5.6.2 are fulfilled, the Class Notation **CM-PS** may be assigned.

5.7 Cast resin mounting

The mounting of stern tubes and stern tube bearings made of cast resin and also the seating of intermediate shafts bearings on cast resin parts is to be carried out by BKI approved companies in the presence of a BKI Surveyor.

Only BKI approved cast resins may be used for seating's.

The installation instructions issued by the manufacturer of the cast resin have to be observed.

For further details see Guidelines for the Seating of Diesel Engines Installations (Pt.1, Vol.U).

5.8 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 propulsion plant. At this all essential static, dynamic and thermal effects have to be taken into account.

The calculation reports to be submitted are to include the complete scope of used input data and have to disclose the resulting shaft deflection, bending stress and bearing loads and have to document the compliance with the specific requirements of the component manufacturer.

For the execution of the alignment on board an instruction has to be created which lists the permissible gap and sag values for open flange connections respectively the "Jack-up" loads for measuring the bearing loads. Before the installation of the propeller shaft the correct alignment of the stern tube bearings is to be checked.

Before the installation of the propeller shaft the correct alignment of the stern tube bearings is to be checked.

The final alignment on board has to be checked by suitable methods in a float condition in presence of the BKI Surveyor.

5.9 Shaft locking devices

A locking device according to Section 1, D.8.3 has to be provided at each shaft line of multiple-shaft systems.

The locking device is at least to be designed to prevent the locked shaft from rotating while the ship is operating with the remaining shafts at reduced power. This reduced power has to ensure a ship speed that maintains the maneuvering capability of the ship in full scope, in general not less than 8,0 kn.

If the locking device is not designed for the full power/speed of the remaining shafts, this operational restriction has to be recognizable for the operator by adequate signs.

5.10 Shaft earthing

Shaft earthing has to be provided according to Section 2, E.6.6.

E. Pressure Tests

1. Shaft liners

Prior to fitting, shaft liners are to be subjected to a hydraulic tightness test at 2,0 bar pressure in the finish machined condition.

2. Stern tubes

Prior to fitting, cast stern tube and cast stern tube parts are to be subjected to a hydraulic tightness test at 2,0 bar pressure in the finished-machined condition. 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 test applied to the hull spaces passed by the stern tube.

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Section 5 Gear, Couplings

A. General

1. Scope

1.1 These requirements apply to spur, planetary and bevel gears and to all types of couplings for incorporation in the main propulsion plant or essential auxiliary machinery as specified in Section 1, H. The design requirements laid down here may also be applied to the gears and couplings of auxiliary machinery other than that mentioned in Section 1, H.

1.2 Application of these requirements to the auxiliary machinery couplings mentioned in 1.1 may normally be limited to a general approval of the particular coupling type by BKI. Regarding the design of elastic couplings for use in generator sets, reference is made to G.2.4.6.

1.3 For the dimensional design of gears and couplings for ships with ice class, see Section 13.

2. Documents for approval

Assembly and sectional drawings together with the necessary detail drawings and parts lists are to be submitted to BKI in electronic format. They shall contain all the data necessary to enable the load calculations to be checked.

B. Materials

1. Approved materials

1.1 Shafts, pinions, wheels and wheel rims of gears in the main propulsion plant are preferably to 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)], nodular cast iron or may be fabricated from welded steel plates with steel or cast steel hubs. For the material of the gearings the requirements according to ISO 6336, part 5 are to be considered.

1.2 Couplings in the main propulsion plant are to 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 the 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 gears intended for auxiliary machinery other than that mentioned in Section 1, H, other materials may also be permitted.

[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.

1.4 Flexible coupling bodies for essential 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 shall 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 couplings are well able to withstand the shock torques occasioned by short circuits. BKI reserve the right to impose similar requirements on the couplings of particular auxiliary drive units.

2. Testing of materials

All gear and coupling components which are involved in the transmission of torque and which will be installed in the main propulsion plant have to be tested in accordance with Rules for Materials (Pt.1, Vol.V), The same applies to the materials used for gear components with major torque transmission function of gears and couplings in generator drives.

Suitable proof is to be submitted for the materials used for the major components of the couplings and gears of all other functionally essential auxiliary machines in accordance with Section 1. This proof may take place by a Manufacturer Inspection Certificate of the steelmaker.

C. Calculation of the Load-Bearing Capacity of Cylindrical and Bevel Gearing

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 ISO 6336, ISO 9083 or DIN 3990 for spur gear respectively ISO 10300 or DIN 3991 for bevel gears while maintaining the safety margins stated in Table 5.1 for flank and root stresses.

Table 5.1: Minimum safety margins for flank and root stress

Case	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 8000 Nm	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 BKI, 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 BKI*

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 Ff for peripheral speeds at the pitch circle up to 25 m/s shall 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 $f_{H\beta}$ shall conform at least to quality 5 to DIN 3962, while the parallelism of axis shall 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 shall generally not exceed 10 μm. In the case 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 ao on the tool reference profile is to be at least 0,25 · m_n.

BKI reserve 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. 5.2.

2. Symbols, terms and summary of input data

2.1 Indices

1	=	pinion
2	=	wheel
m	=	in the mid of face width
n	=	normal plane
t	=	transverse plane
o	=	tool

2.2 Parameters

a	=	centre distance [mm]
b	=	face width [mm]
b_{eff}	=	effective face width (bevel gears) [mm]
B_{z0}	=	measure for shift of datum line [mm]
d	=	standard pitch diameter [mm]
d_a	=	tip diameter [mm]
d_f	=	root diameter [mm]
F_t	=	circular force at reference circle [N]
$F_{\beta x}$	=	initial equivalent misalignment [μm]
f'_{pe}	=	normal pitch error [μm]
f'_f	=	profile form error [μm]
$h_{a0}{}^*$	=	addendum coefficient of tool
$h_{f0}{}^*$	=	dedendum coefficient of tool
$h_{F\,fp0}{}^*$	=	utilized dedendum coefficient of tool
K_A	=	application factor
$K_{F\alpha}$	=	transverse load distribution factor (root stress)
$K_{F\beta}$	=	face load distribution factor (root stress)
$K_{H\alpha}$	=	transverse load distribution factor (contact stress)
$K_{H\beta}$	=	face load distribution factor (contact stress)
$K_{H\beta-be}$	=	bearing factor (bevel gears)
K_v	=	dynamic factor

Table 5.2: List of input data for evaluating load bearing capacity

Yard /Newbuild No.						Reg. No.			
Manufacturer					Type				
Application					Cylindrical gear ☐		Bevelgear[1] ☐		
Nominal rated power	P			kW	Ice class				-
No. of revolutions	n_1			Rpm	No. of planets				-
Application factor	K_A			-	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	$K_{H\alpha}$			-
	$K_{F\beta}$			-		$K_{F\alpha}$			-
Geometrical data		Pinion	Wheel	-	**Tool data**		Pinion	Wheel	-
Number of teeth	z			-	Addendum modification coeff.	X/X_{hm}[1]			-
Normal modul	m_n/m_{nm}[1]			mm	Thickness modification coeff	X_{sm}[1]			-
Normal press. Angle	α_n			°	Coefficient of tool tip radius	ρ_{a0}^*			-
Centre distance	a			mm	Addendum coefficient of tool	h_{a0}^*			-
Shaft angle	Σ[1]			°	Dedendum coefficient of tool	h_{f0}^*			-
Relative effective facewidth	b_{eh}/b[1]			-	Utilized dedendum coefficient of tool	h_{Ffp0}^*			-
Helix angle	β/β_m[1]			°	Protuberance	pr			mm
					Protuberance angle	α_{pr}			°
Facewidth	b			mm	Machining allowance	q			mm
Tip diameter	d_a			mm	Measure at tool	B_{Z_0}			mm
Root diameter	d_{fe}			mm	Backlash allowance /tolerance				–
Lubrication data					**Quality**				
kin. viscosity 40°C	ν_{40}			mm^2/s	Quality acc. 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 class				-	Initial equivalent misalignment	$F\beta_x$			µm
Material data					Normal pitch error	f'_{pe}			µm
Material type					Profile form error	f'_f			µm
Endurance limit for contact stress	$\sigma_{H\,lim}$			N/mm^2	Date:				
Endurance limit for bending stress	$\sigma_{F\,lim}$			N/mm^2					
Surface hardness				HV	Signature:				
Core hardness				HV					
Heat treatment method				-					
[1] Declaration for bevel gear									

K_Y	=	load distribution factor
m_n	=	normal modul [mm]
m_{nm}	=	mean normal modul (bevel gears) [mm]
n	=	number of revolutions [Rpm]
N_L	=	number of load cycles [Rpm]
P	=	transmitted power [kW]
pr	=	protuberance at tool [mm]
Q	=	toothing quality, acc. to DIN
q	=	machining allowance [mm]
R_a	=	arithmetic mean roughness [μm]
R_{zF}	=	mean peak to valley roughness of root [μm]
R_{zH}	=	mean peak to valley roughness of flank [μm]
S_F	=	safety factor against tooth breakage
S_H	=	safety factor against pittings
T	=	torque [Nm]
U	=	gear ratio
x	=	addendum modification coefficient
X_{hm}	=	mean addendum modification coefficient (bevel gears)
X_{sm}	=	thickness modification coefficient (bevel gears)
Y_F	=	tooth form factor (root)
Y_{NT}	=	live factor (root)
$Y_{\delta\ rel\ T}$	=	relative notch sensitivity factor
$Y_{R\ rel\ T}$	=	relative surface condition factor
Y_S	=	stress correction factor
Y_{ST}	=	stress correction factor for reference test gears
Y_X	=	size factor for tooth root stress
Y_{β}	=	helix angle factor for tooth root stress [°]
z	=	number of teeth
Z_E	=	elasticity factor
Z_H	=	zone factor (contact stress)
Z_L	=	lubricant factor
Z_{NT}	=	live factor (contact stress)
Z_V	=	speed factor
Z_R	=	roughness factor
Z_W	=	work-hardening factor
Z_X	=	size factor (contact stress)
Z_{β}	=	helix angle factor (contact stress)
Z_{ε}	=	contact ratio factor (contact stress)
α_n	=	normal pressure angle [°]
α_{pr}	=	protuberance angle [°]
β	=	helix angle [°]
β_m	=	mean helix angle (bevel gears) [°]
ϑ oil	=	oil temperature [°C]
40	=	kinematic viscosity of the oil at 40 °C [mm^2/s]
100	=	kinematic viscosity of the oil at 100 °C [mm^2/s]
$\rho_{a0}{}^*$	=	coefficient of tip radius of tool
Σ	=	shaft angle (bevel gears) [°]
σ_F	=	root bending stress [N/mm^2]
σ_{FE}	=	root stress [N/mm^2]
σ_{FG}	=	root stress limit [N/mm^2]
σ_{F0}	=	nominal root stress [N/mm^2]

$\sigma_{F\ lim}$	=	endurance limit for bending stress [N/mm^2]
σ_{FP}	=	permissible root stress [N/mm^2]
σ_H	=	calculated contact stress [N/mm^2]
σ_{HG}	=	modified contact stress limit [N/mm^2]
$\sigma_{H\ lim}$	=	endurance limit for contact stress [N/mm^2]
σ_{HP}	=	permissible contact stress [N/mm^2]
σ_{H0}	=	nominal contact stress [N/mm^2]

3. Influence factors for load calculations

3.1 Application factor, K_A

The application factor K_A takes into account the increase in rated torque caused by superimposed dynamical or impact loads. K_A is determined for main and auxiliary systems in accordance with Table 5.3.

Table 5.3: Application factors

System type	KA
Main system:	
Turbines and electric drive system	1,1
Diesel engine drive systems with fluid clutch between engine and gears	1,1
Diesel engine drive systems with highly flexible coupling between engine and gears	1,3
Diesel engine drive system with no flexible coupling between engine and gears	1,5
Generator drives	1,5
Auxiliary system:	
Thruster with electric drive	1,1 (20000 h) [1)]
Thruster drives with diesel engines	1,3 (20000 h) [1)]
Windlasses	0,6 (300 h) [1)]
	2,0 (20 h) [2)]
Combined anchor and mooring winches	0,6 (1000 h) [1)]
	2,0 (20 h) [2)]
[1)] Assumed operating hours [2)] Assumed maximum load for windlasses For other type of system K_A is to be stipulated separately.	

3.2 Load distribution factor K_γ

The load distribution factor K_γ takes into account deviations in load distribution e.g. in gears with dual or multiple load distribution or planetary gearing with more than three planet wheels.

The following values apply for planetary gearing:

Gear with:

- up to 3 planet wheels $K_\gamma = 1{,}0$
- 4 planet wheels $K_\gamma = 1{,}2$
- 5 planet wheels $K_\gamma = 1{,}3$
- 6 planet wheels $K_\gamma = 1{,}6$

In gears which have no load distribution $K_\gamma = 1{,}0$ is applied.

For all other cases K_γ is to be agreed with BKI.

3.3 Face load distribution factors $K_{H\beta}$ and $K_{F\beta}$

The face load distribution factors take into account the effects of uneven load distribution over the tooth flank on the contact stress ($K_{H\beta}$) and on the root stress ($K_{F\beta}$). In the 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.

3.4 Transverse load distribution factors $K_{H\alpha}$ and $K_{F\alpha}$

The transverse load distribution factors $K_{H\alpha}$ and $K_{F\alpha}$ take into account the effects of an uneven distribution of force of several tooth pairs engaging at the same time.

In the case of gears in main propulsion systems with a toothing 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.

4. Contact stress

4.1 The calculated contact stress σ_H shall not exceed the permitted contact stress σ_{HP} (Hertzian contact stress).

$$\sigma_H = \sigma_{HO} \cdot \sqrt{K_A\, K_\gamma\, K_V\, K_{H\beta}\, K_{H\alpha}} \le \sigma_{HP}$$

with $\sigma_{HO} = Z_H \cdot Z_E \cdot Z_\varepsilon \cdot Z_\beta \cdot \sqrt{\dfrac{F_t}{d_1 \cdot b} \cdot \dfrac{u+1}{u}}$

4.2 The permissible contact stress σ_{HP} shall include a safety margin S_H as given in Table 5.1 against the contact stress limit σ_{HG} which is determined from the material-dependent endurance

limit $\sigma_{F\ lim}$ as shown in Table 5.4[1] allowing for the influence factors Z_{NT}, Z_L, Z_V, Z_R, Z_W, Z_X. $\sigma_{HP} = \dfrac{\sigma_{HG}}{S_H}$

with $\sigma_{HP} = \sigma_{H\ lim} \cdot Z_{NT} \cdot Z_L \cdot Z_V \cdot Z_R \cdot Z_W \cdot Z_X$

Table 5.4: Endurance limits [3] for contact stress

Material	$\sigma_{H\ lim}$ [N/mm^2]
Case-hardening steel, case-hardened	1500
Nitriding steels, gas nitrided	1250
Alloyed heat treatable steels, bath or gas nitrided	850 - 1000
Alloyed heat treatable steels, induction hardened	0,7 HV10 + 800
Alloyed heat treatable steels	1,3 HV10 + 350
Unalloyed heat treatable steels	0,9 HV10 + 370
Structural steel	1,0 HB + 200
Cast steel, cast iron with nodular cast graphite	1,0 HB + 150

[1] With consent of BKI for case hardened steel with proven quality higher endurance limits may be accepted.

Table 5.5: Endurance limits[2)] for tooth root bending stress

$\sigma_{FE} = \sigma_{F\,lim} \cdot Y_{ST}$ with $Y_{ST} = 2$

Material	$\sigma_{FE} = \sigma_{F\,lim} \cdot Y_{ST}$ with Y_{ST} [N/mm^2]
Case hardening steel, case hardened	860 - 920
Nitriding steels, gas nitride	850
Alloyed heat treatable steels, bath or gas nitride	740
Alloyed heat treatable steels, induction hardened	700
Alloyed heat treatable steels	0,8 HV10 + 400
Unalloyed heat treatable steels	0,6 HV10 + 320
Structural steel	0,8 HB + 180
Cast steel, cast iron with nodular cast graphite	0,8 HB + 140
Note: For alternating stressed toothing only 70% of these values are permissible.	

5. Tooth root bending stress

5.1 The calculated maximum root bending stress σ_F of the teeth shall not exceed the permissible root stress σ_{FP} of the teeth.

Tooth root stress is to be calculated separately for pinion and wheel.

$$\sigma_F = \sigma_{FO} \cdot K_A \cdot K_v \cdot K_\gamma \cdot K_{F\beta} \cdot K_{F\alpha} \leq \sigma_{FP}$$

with $\sigma_{FO} = \frac{F_t}{b \cdot m_n} \cdot Y_F \cdot Y_S \cdot Y_\beta$

5.2 The permissible root bending stress σ_{FP} shall have a safety margin S_F as indicated in Table 5.1 against the root stress limit σ_{FG} which is determined from the material-dependent fatique strength σ_{FE} or $\sigma_{F\,lim}$ in accordance with Table 5.5 [2)], allowing for the stress correction factors Y_{ST}, Y_{NT}, $Y_{\delta relT}$, $Y_{R\,relT}$, Y_X

$$\sigma_{FP} = \frac{\sigma_{FG}}{S_F}$$

with $\sigma_{FG} = \sigma_{F\,lim} \cdot Y_{ST} \cdot Y_{NT} \cdot Y_{\delta relT} \cdot Y_{R\,relT} \cdot Y_X$

For alternating stressed toothing the values given in Table 5.5 shall be reduced to:

- 70 % in case of stress reversal at each rotation (examples: reversing wheels, idler wheels, planetary gear wheels),
- 85 % in case of stress reversal after numerous rotations (example: lateral thruster with fixed pitch propeller).

No reduction is required where one direction of rotation is the usual one and reverse operation occurs rather infrequently, with less operating hours and at reduced power (example: output stage of reverse gearbox for common ships' main propulsion).

Regarding vibratory stresses, also at partial load and no-load conditions, Section 16 is to be observed.

[2)] With consent of BKI for case hardened steel with proven quality higher endurance limits may be accepted.

D. Gear Shafts

1. Minimum diameter

The dimensions of shafts of reversing and reduction gears are to be calculated by applying the following formula:

$$d \geq F \cdot k \cdot \sqrt[3]{\frac{P}{n \cdot \left[1 - \left(\frac{d_i}{d_a}\right)^4\right]}} \cdot C_W$$

if = $\frac{d_i}{d_a} \leq 0,4$; therefore, the expression

$\left[1 - \left(\frac{d_i}{d_a}\right)^4\right]$ maybe set to 1,0

Where:

d	=	required outside diameter of shaft [mm]
d_i	=	diameter of shaft bore for hollow shafts [mm]
d_a	=	actual shaft diameter [mm]
P	=	driving power of shaft [kW]
n	=	shaft speed [Rpm]
F	=	factor for the type of drive
	=	95 for turbine plants, electrical drives and internal combustion engines with slip couplings
	=	100 for all other types of drive. BKI reserves the right to specify higher F values if this appears necessary in view of the loading of the plant.
C_W	=	material factor in accordance with Section 4, formula (2). However, for wheel shafts the value applied for Rm 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	=	1,10 for gear shafts
	=	1,15 for gear shafts in the area of the pinion or wheel body if this is keyed to the shaft and for multiple spline shafts. Higher values of k may be specified by BKI where increased bending stresses in the shaft are liable to occur because of the bearing arrangement, the casing design, the tooth forces, etc.

2. Shrink fits

For the design of shrink fits, Section 4 is to be applied analogously. Axial tooth forces have to be considered

E. Equipment

1. Oil level indicator

For monitoring the lubricating oil level in main and auxiliary gears, equipment shall 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 the oil enters the gears. Plain journal bearings arc 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 BKI.

Where ships are equipped with automated machinery, the requirements of Rules for Automations (Pt.1, Vol.VII), 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 assigned, see Section 11, H.3.

4. Gear casings

The casings of gears belonging to the main propulsion plant and to essential auxiliaries are to be fitted with removable inspection covers to enable the toothing to be inspected, 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 chocks is to conform to Guidance for the Seating of Diesel Engine Installations (Pt.1, Vol.U).

In the case of cast resin seatings, the thrust has to be absorbed by means of stoppers. The same applies to cast resin seatings of separate thrust bearings

F. Balancing and Testing

1. Balancing

1.1 Gear wheels, pinions, shafts, couplings and, where applicable, high-speed flexible couplings are to 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:

$$U = \frac{9,6 \cdot Q \cdot G}{z \cdot n} [\text{kgmm}]$$

Where:

G	=	mass of body to be balanced [kg]
n	=	operating speed of component to be balanced [Rpm]
z	=	numbering 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 gear 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 essential auxiliaries in accordance with Section 1, are to be presented to BKI for final inspection and operational testing in the manufacturer's works. For the inspection of welded gear casing, see Rules for Welding (Pt.1, Vol.VI).

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 the toothing are to be checked. In the case of a trial at full-load, any necessary running-in of the gears shall 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 BKI.

2.2 Tests during sea trials

2.2.1 Prior to the start of sea trials, the teeth of the gears belonging to the main propulsion plant are to be coloured with suitable dye to enable the check of the contact pattern. During the sea trials, the gears are to be checked at all forward and reverse speeds for their operational efficiency and smooth running as well as the bearing temperatures and the pureness of the lubricating oil. At the latest 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 5.6 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 BKI, be reduced.

Table 5.6: Percentage area of contact

Material / manufacturing of toothing	Working tooth depth (without tip relief)	Width of tooth (without end relief)
Heat treated, milled, Shaped	Average 33%	70%
Surface hardened, grinded, scarped	Average 40%	80%

2.2.3 For checking the gears of rudder propellers as main propulsion, see Section 14.B.

2.2.4 Further requirements for the sea trials are contained in Guidance for Sea Trials of Motor Vessels (Pt.1, Vol.B).

G. Design and Construction of Couplings

1. Tooth couplings

1.1 For a sufficient load bearing capacity of the tooth flanks of straight-flanked tooth couplings is valid:

$$p = \frac{2,55 \cdot 10^7 \cdot P \cdot K_A}{b \cdot h \cdot d \cdot z \cdot n} \leq p_{perm}$$

p	=	actual contact pressure of the tooth flanks [N/mm^2]
P	=	driving power at coupling [kW]
K_A	=	application factor in accordance with C.3.1
z	=	number of teeth
n	=	speed in rev/min [Rpm]
h	=	working depth of toothing [mm]
b	=	load-bearing tooth width [mm]
d	=	standard pitch diameter [mm]
P_{perm}	=	0,7 · R_{eH} for ductile steels [N/mm^2]
P_{perm}	=	0,7 · R_m for brittle steels [N/mm^2]
σ_{HP}	=	permissible contact stress according to C.4.2 [N/mm^2]

Where methods of calculation recognized by BKI are used for determining the Hertzian stress on the flanks of tooth couplings with convex tooth flanks, the permissible Hertzian stresses are equal to 75% of the value of σ_{HP} shown in C.4.2 with influence factors Z_{NT} to Z_X set to 1,0:

P_{perm} = 400 - 600 N/mm^2
for toothing made of quenched and tempered steel. Higher values apply for high tensile steels with superior tooth manufacturing and surface finish quality.

P_{perm} = 800 - 1000 N/mm^2
for toothing of hardened steel (case or nitrogen). Higher values apply for superior tooth manufacturing and surface finish quality.

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, if

$$d \cdot n^2 < 6 \cdot 10^9 \,[\text{mm/min}^2] \quad (8)$$

For higher values of $d \cdot n^2$, couplings in main propulsion plants are to be provided with a forced lubrication oil system.

1.3 For the dimensional design of the coupling sleeves, flanges and bolts of tooth couplings the formulae given in Section 4 are to be applied.

1.4 Magnetic particle or dye penetrant inspection shall be applied for crack detection at surface hardened zones with increased stress level as well as at shrinkage surfaces. The manufacturer shall issue a Manufacturer Inspection Certificate.

Couplings for ship propulsion plants, for generator sets and transverse thrusters are to be presented to BKI for final inspection. Regarding couplings for transverse thrusters, this applies only to power ratings of 100 kW and more.

2. Flexible couplings

2.1 Scope

Flexible couplings shall be approved for the loads specified by the manufacturer and for use in main propulsion plants and essential auxiliary machinery. In general, flexible couplings shall be type approved.

Detailed requirements for type approvals of flexible couplings are defined in Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1 Vol.W).

2.2 Documentation

The documentation to be submitted shall include:

1) assembly drawings
2) detailed drawings including material characteristics
3) definition of main parameters:
   - rubber Shore hardness
   - nominal torque T_{KN}
   - permissible torque T_{Kmax1} for normal transient conditions like starts/stops, passing through resonances, electrical or mechanical engagements, ice impacts, etc.
   - permissible torque T_{Kmax2} for abnormal impact loads like short circuit, emergency stops, etc.
   - permissible vibratory torque + T_{KW} for continuous operation
   - permissible power loss P_{KV} due to heat dissipation
   - permissible rotational speed nmax
   - dynamic torsional stiffness C_{Tdvn}, radial C_{rdvn}
   - relative damping Ψ respectively damping characteristics
   - permissible axial, radial and angular displacement
   - permissible permanent twist
4) design calculations
5) test reports

2.3 Tests

The specifications mentioned in 2.2 are to be proven and documented by adequate measurements at test establishments. The test requirements are included in Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1 Vol.W) For single approvals the scope of tests may be reduced by agreement with BKI.

2.4 Design

2.4.1 With regards to casings, flanges and bolts the requirements specified in Section 4, D. are to be complied with.

2.4.2 The flexible element of rubber coupling 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/mm^2.

2.4.3 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 5.7.

Higher values can be accepted if appropriate strengths of rubber materials have been documented by means of relevant test and calculations.

Table 5.7: Limits of shear stress

Shore hardness	Limit 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.

2.4.4 Flexible couplings in the main propulsion plant and in power-generating plants shall be so dimensioned that they are able to withstand for a reasonable time operation with any one engine cylinder out of service, see Section 16, C.4.2. Additional dynamic loads for ships with ice class are to be taken into account according to Section 13, C.

2.4.5 If a flexible coupling is so designed that It exerts an axial thrust on the coupled members of the driving mechanism, provision shall be made for the absorption of this thrust.

If torsional limit devices are applicable, the functionality shall be verified.

2.4.6 Flexible couplings for diesel generator sets shall be capable of absorbing impact moments due to electrical short circuits up to a value of 6 times the nominal torque of the plant.

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 4 are to be complied with.

4. Clutches

4.1 General

4.1.1 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.

4.1.2 Documentation

For all new types of clutches a complete documentation shall be submitted in form of electronic format. This documentation has to include e.g.:

- assembly drawings
- detail drawings of torque transmitting components including material properties
- documentation of the related system for engaging/disengaging
- definition of the following main technical parameters
    - maximum and minimum working pressure for hydraulic or pneumatic system [bar]
    - static and dynamic friction torque [kNm]
    - time diagram for clutching procedure
    - operating manual with definition of the permissible switching frequency
- for special cases calculation of heat balance, if requested by BKI.

4.2 Materials

The mechanical characteristics of materials used for the elements of the clutch shall conform to the Rules for Materials (Pt.1, Vol.V).

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 4 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 reinforcement defined in Section 13,C.4.2 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 a single propulsion plants an emergency operation shall be possible. This may be done by a redundant power system for engagement/disengagement or in 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.

4.3.6 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 Rules for Automation (Pt.1, Vol.VII), have to be provided.

4.4 Test

4.4.1 Tests at the manufacturer's work

Magnetic particle or dye penetrant inspection shall be applied for crack detection at surface hardened zones with increased stress level as well as at shrinkage surfaces. The manufacturer shall issue a Manufacturer Inspection Certificate.

Clutches for ship propulsion plants, for generator sets and transverse thrusters are to be presented to BKI for final inspection and, where appropriate, for the performance of functional and tightness tests.

The requirements for a type approval, if requested, will be defined case by case by BKI Head Office.

4.4.2 Tests on board

As part of the sea trials the installed clutches will be tested for correct functioning on board in presence of a BKI Surveyor, see also Guidance for Sea Trials of Motor Vessels (Pt.1, Vol.B).

H. Load Capacity of Involute Parallel Axis Spur and Helical Gears

1. Basic principles - introduction and general influence factors

1.1 Introduction

The following definitions are mainly based on the ISO 6336 series standard (hereinafter called "reference standard") for the calculation of load capacity of spur and helical gears.

1.2 Scope

These requirements apply to enclosed gears, both intended for main propulsion and for essential auxiliary services, 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

These requirements, however, may be applied to the enclosed gears, whose gear set is intended to transmit a maximum continuous power less than those specified above at the request of the individual society.

The following definitions deal with the determination of load capacity of external and internal involute spur and helical gears, having parallel axis, with regard to surface durability (pitting) and tooth root bending strength and to this purpose the relevant basic equations are provided in Section H.2 and H.3.

The influence factors common to said equations are described in the present Section H.1.

The others, introduced in connection with each basic equation , are described in the following Section H.2 and H.3.

All influence factors are defined regarding their physical interpretation. Some of the influence factors are determined by the gear geometry or have been established by conventions. These factors are to be calculated in accordance with the equations provided. Other factors, which are approximations, can be calculated according to methods acceptable to BKI.

1.3 Symbols and units

The main symbols used are listed below.

Other symbols introduced in connection with the definition of influence factors are described in the appropriate sections.

SI units have been adopted.

a	=	centre distance [mm]
b	=	common face width [mm]
$b_{1,2}$	=	face width of pinion, wheel [mm]
d	=	reference diameter [mm]
$d_{1,2}$	=	reference diameter of pinion, wheel [mm]
$d_{a1,2}$	=	tip diameter of pinion, wheel [mm]
$d_{b1,2}$	=	base diameter of pinion, wheel [mm]
$d_{f1,2}$	=	root diameter of pinion, wheel [mm]
$d_{w1,2}$	=	working diameter of pinion, wheel [mm]
F_t	=	nominal tangential load [N]
F_{bt}	=	nominal tangential load on base cylinder in the transverse section [N]
h	=	tooth depth [mm]

m_n	=	normal module [mm]
m_t	=	transverse module [mm]
$n_{1,2}$	=	rotational speed of pinion, wheel revs/min (rpm)
P	=	maximum continuous power transmitted by the gear set [kW]
$T_{1,2}$	=	torque in way of pinion, wheel [Nm]
u	=	gear ratio
v	=	linear velocity at pitch diameter [m/s]
$x_{1,2}$	=	addendum modification coefficient of pinion, wheel
z	=	number of teeth
$z_{1,2}$	=	number of teeth of pinion, wheel
z_n	=	virtual number of teeth
α_n	=	normal pressure angle at reference cylinder [°]
α_t	=	transverse pressure angle at ref. cylinder [°]
α_{tw}	=	transverse pressure angle at working pitch cylinder [°]
β	=	helix angle at reference cylinder [°]
β_b	=	helix angle at base cylinder [°]
ε_α	=	transverse contact ratio
ε_β	=	overlap ratio
ε_γ	=	total contact ratio

1.4 Geometrical definitions

For internal gearing z_2, a, d_2, d_{a2}, d_{b2} and d_{w2} are negative. 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:

$$U = z_2/z_1 \qquad = d_{w2}/d_{w1} \qquad = d_2/d_1$$

For external gears u is positive, for internal gears u is negative.

In the equation of surface durability b is the common face width on the pitch diameter. In the equation of tooth root bending stress b_1 or b_2 are the face widths 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 module (m_n) on either side.

The common face width b may be used also in the equation of teeth root bending stress if significant crowning or end relief have been adopted.

$$\tan\alpha_t = \frac{\tan\alpha_n}{\cos\beta}$$

$$\tan\beta_b = \tan\beta \cdot \cos\alpha_t$$

$$d_{1,2} = \frac{Z_{1,2}\, m_n}{\cos\beta}$$

$$\left.\begin{aligned} d_{wl} &= \frac{2a}{u+1} \\ d_{w2} &= \frac{2au}{u+1} \end{aligned}\right\} \text{where } a = 0,5(d_{dwl} + d_{w2})$$

$$z_{n1,2} = \frac{z_{1,2}}{\cos^2\beta_b \cdot \cos\beta}$$

$$m_t = \frac{m_n}{\cos\beta} \mid$$

$$\text{inv}\alpha = \text{inv}\alpha - \frac{\pi\alpha}{180}; \quad \alpha[°]$$

$$\text{inv}\alpha_{tw} = \text{inv}\,\alpha_t + 2\tan\alpha_n \mid \frac{x_1 + X_2}{z_1 + z_2} \text{ or } \cos\alpha_{tw} = \frac{M_t(z_1 + z_2)}{2a}\cos\alpha_t$$

$$\varepsilon_\beta = \frac{0,5\sqrt{d_{a1}^2 - d_{b1}^2} \pm 0,5\sqrt{d_{a2}^2 - d_{b2}^2} - a \cdot \sin\alpha_{tw}}{\pi \cdot m_t \cdot \cos\alpha_t}$$

the positive sign is 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

$$\varepsilon_\gamma = \varepsilon_\alpha + \varepsilon_\beta$$

$$V = \pi \cdot d_{1,2} n_{1,2}/60 \cdot 10^3$$

1.5 Nominal tangential load, F_t

The nominal tangential load, Ft, 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:

$$T_{1,2} = \frac{30 \cdot 10^3 P}{\pi \cdot n_{1,2}}$$

$$F_t = 2000 \cdot T_{1,2}/d_{1,2}$$

1.6 General influence factors

1.6.1 Application factor, K_A [3)]

The application factor, K_A, accounts for dynamic overloads from sources external to the gearing.

K_A, for gears designed for infinite life is defined as the ratio between the maximum repetitive cyclic torque applied to the gear set and the nominal rated torque.

The nominal rated torque is defined by the rated power and speed and is the torque used in the rating calculations.

The factor mainly depends on:

- characteristics of driving and driven machines;
- ratio of masses;
- type of couplings;
- operating conditions (overspeeds, changes in propeller load conditions, etc.).

When operating near a critical speed of the drive system, a careful analysis of conditions must be made.

The application factor, K_A, should be determined by measurements or by system analysis acceptable to the BKI. Where a value determined in such a way cannot be supplied, the following values can be considered.

[3)] 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 Section 13 when applicable.

1) Main propulsion

- diesel engine with hydraulic or electromagnetic slip coupling : 1,00
- diesel engine with high elasticity coupling : 1,30
- diesel engine with other couplings : 1,50

2) Auxiliary gears

- electric motor, diesel engine with hydraulic or
- electromagnetic slip coupling : 1,00
- diesel engine with high elasticity coupling : 1,20
- diesel engine with other couplings : 1,40

1.6.2 Load sharing factor, K_γ

The load sharing factor, K_γ accounts for the maldistribution of load in multiple path transmissions (dual tandem, epicyclic, double helix, etc.)

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.

The load sharing factor, K_γ, should be determined by measurements or by system analysis. Where a value determined in such a way cannot be supplied, the following values can be considered for epicyclic gears:

- up to 3 planetary gears : 1,00
- 4 planetary gears : 1,20
- 5 planetary gears : 1,30
- 6 planetary gears and over : 1,40

1.6.3 Internal dynamic factor, K_V

The internal dynamic factor, K_V, accounts for internally generated dynamic loads due to vibrations of pinion and wheel against each other.

K_V is defined as the ratio between the maximum load which dynamically acts on the tooth flanks and the maximum externally applied load ($F_t K_A K_\gamma$).

The factor mainly depends on:

- transmission errors (depending on pitch and profile errors);
- 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 stiffnesses;
- damping characteristics of the gear system.

The dynamic factor, K_V, is to be calculated 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.:

$$\frac{v_{z_1}}{100}\sqrt{\frac{u^2}{1+u^2}} < 10 m/s$$

— spur gears (β = 0 °) and helical gears with $\beta \leq 30$ °

— 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

$$\frac{vz_1}{100}\sqrt{\frac{u^2}{1+u^2}} < 3 \text{ m/s}$$

as well as to helical gears where $\beta > 30°$.

For gears other than the above, reference is to be made to **Method B** outlined in the reference standard ISO 6336-1:2019.

A) For spur gears and for helical gears with overlap ratio $\varepsilon_\beta \geq 1$

$$K_v = 1 + \left(\frac{K_1}{K_A\frac{F_t}{b}}K_2\right)\cdot\frac{vz_1}{100}K_3\sqrt{\frac{u^2}{1+u^2}}$$

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 5.8[3)]

Table 5.8: Values of the factor K_1 for the calculation of K_v

K_1 ISO accuracy grades [3)]						
No.	**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

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:

$$\text{If}\ \frac{v_{z_1}}{100}\sqrt{\frac{u^2}{1+u^2}} \leq 0,2 \quad \text{then} \quad K_3 = 2,0$$

$$\text{If}\ \frac{v_{z_1}}{100}\sqrt{\frac{u^2}{1+u^2}} > 0,2 \quad \text{then} \quad K_3 = 2,071 - 0,357\cdot\frac{v_{z_1}}{100}\sqrt{\frac{u^2}{1+u^2}}$$

B) 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:

[3)] ISO accuracy grades according to ISO 1328-2:2020. In case of mating gears with different accuracy grades, the grade corresponding to the lower accuracy should be used.

$K_v = K_{v\alpha} - \varepsilon_\beta(K_{v\alpha} - K_{v\beta})$

Where:

$K_{v\alpha}$ is the Kv value for spur gears, in accordance with A);

$K_{v\beta}$ is the Kv value for helical gears, in accordance with A).

1.6.4 Face load distribution factors, $K_{H\beta}$ and $K_{F\beta}$

The face load distribution factors, $K_{H\beta}$ for contact stress, $K_{F\beta}$ for tooth root bending stress, account for the effects of the non-uniform distribution of load across the face width.

$K_{H\beta}$ is defined as follows:

$$K_{H\beta} = \frac{\text{maximum load per unit face width}}{\text{mean load per unit face width}}$$

$K_{F\beta}$ is defined as follows:

$$K_{H\beta} = \frac{\text{maximum bending stress at tooth root per unit face width}}{\text{mean bending stress at tooth root per unit face width}}$$

The mean bending stress at tooth root relates to the considered face width b_1 resp. b_2. $K_{F\beta}$ can be expressed as a function of the factor $K_{H\beta}$. The factors $K_{H\beta}$ and $K_{F\beta}$ 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.).

The face load distribution factors, $K_{H\beta}$ for contact stress, and $K_{F\beta}$ for tooth root bending stress, are to be determined according to the **Method C** outlined in the reference standard ISO 6336-1.

Alternative methods acceptable to BKI may be applied.

— In case the hardest contact is at the end of the face width $K_{F\beta}$ is given by the following equations:

$$K_{F\beta} = K_{H\beta}^{N}$$

$$N = \frac{(b/h)^2}{1 + (b/h) + (b/h))^2}$$

(b/h) = face width/tooth height ratio, the minimum of b_1/h_1 or b_2/h_2.

For double helical gears, the face width of only one helix is to be used.

When b/h < 3 the value b/h = 3 is to be used.

— In case of gears where the ends of the face width are lightly loaded or unloaded (end relief or crowning):

$$K_{F\beta} = K_{H\beta}$$

1.6.5 Transverse load distribution 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.

The factors $K_{H\alpha}$ and $K_{F\alpha}$ mainly depend on:

- total mesh stiffness;
- total tangential load F_t, F_A, F_γ, F_v, $F_{H\beta}$;
- base pitch error;
- tip relief;
- running-in allowances.

The transverse load distribution factors, $K_{H\alpha}$ for contact stress and $K_{F\alpha}$ for tooth root bending stress, are to be determined according to **Method B** outlined in the reference standard ISO 6336-1:2019.

2. Surface durability (pitting)

2.1 Scope and general remarks

The criterion for surface durability is based on the Hertz pressure on the operating pitch point or at the inner point of single pair contact. The contact stress σ_H must be equal to or less than the permissible contact stress σ_{HP}.

2.2 Basic equations

2.2.1 Contact stress

$$\sigma_H = \sigma_{HO}\sqrt{K_A \cdot K_\gamma \cdot K_v \cdot K_{H\alpha} \cdot K_{H\beta}} \leq \sigma_{HP}$$

where:

σ_H = basic value of contact stress for pinion and wheel

$$\sigma_{HO} = Z_B \cdot Z_H \cdot Z_E \cdot Z_\varepsilon \cdot Z_\beta \sqrt{\frac{F_t}{d_1 \cdot b}\frac{(u+1)}{u}} \quad \text{for pinion}$$

$$\sigma_{HO} = Z_D \cdot Z_H \cdot Z_E \cdot Z_\varepsilon \cdot Z_\beta \sqrt{\frac{F_t}{d_1 \cdot b}\frac{(u+1)}{u}} \quad \text{for wheel}$$

where:

Z_B	=	single pair tooth contact factor for pinion	(see H.2.3)
Z_D	=	single pair tooth contact factor for wheel	(see H.2.3)
Z_H	=	zone factor	(see H.2.4)
Z_E	=	elasticity factor	(see H.2.5)
Z_ε	=	contact ratio factor	(see H.2.6)
Z_β	=	helix angle factor	(see H.2.7)
F_t	=	nominal tangential load at reference cylinder in the transverse section	(see H.1.5)
b	=	common face width	
d_1	=	reference diameter of pinion	
u	=	gear ratio (for external gears u is positive, for internal gears u is negative)	

Regarding factors K_A, K_γ, K_v, $K_{H\alpha}$ and $K_{H\beta}$, see H.1.

2.2.2 Permissible contact stress

The permissible contact stress σ_{HP} is to be evaluated separately for pinion and wheel:

$$\sigma_{HP} = \frac{\sigma_{H\,lim} \cdot Z_N}{S_H} \cdot Z_L \cdot Z_v \cdot Z_R \cdot Z_W \cdot Z_X$$

where,

$\sigma_{H\,lim}$	=	endurance limit for contact stress	(see H.2.8)
Z_N	=	life factor for contact stress	(see H.2.9)
Z_L	=	lubrication factor	(see H.2.10)
Z_v	=	velocity factor	(see H.2.10)
Z_R	=	roughness factor	(see H.2.10)
Z_W	=	hardness ratio factor	(see H.2.11)
Z_X	=	size factor for contact stress	(see (see H.2.12)
S_H	=	safety factor for contact stress	(see (see H.2.13)

2.3 Single pair tooth contact factors, Z_B and Z_D

The single pair tooth contact factors, Z_B for pinion and Z_D for wheel, account for the influence of the tooth flank curvature on 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 factors, Z_B for pinions and Z_D for wheels, are to be determined as follows:

For spur gears, ε_β = 0

Z_B = M_1 or 1 whichever is the larger value

Z_D = M_2 or 1 whichever is the larger value

$$M_1 = \frac{\tan \alpha_{tw}}{\sqrt{\left(\sqrt{\frac{d_{a1}^2}{d_{b1}^2}} - 1 - \frac{2\pi}{z_1}\right)\left(\sqrt{\frac{d_{a2}^2}{d_{b2}^2}} - 1 - (\varepsilon_\alpha - 1) - \frac{2\pi}{z_2}\right)}}$$

$$M_1 = \frac{\tan \alpha_{tw}}{\sqrt{\left(\sqrt{\frac{d_{a2}^2}{d_{b2}^2}} - 1 - \frac{2\pi}{z_2}\right)\left(\sqrt{\frac{d_{a1}^2}{d_{b1}^2}} - 1 - (\varepsilon_\alpha - 1) - \frac{2\pi}{z_1}\right)}}$$

For helical gears when $\varepsilon_\beta \geq 1$

Z_B = 1

Z_D = 1

For helical gears when ε_β < 1 the values of Z_B and D are determined by linear interpolation between Z_B and Z_D for spur gears and Z_B and Z_D for helical gears having ε_β ≥ 1.

Thus:

$Z_B = M_1 - \varepsilon_\beta (M_1 - 1)$ and $Z_B > 1$

$Z_D = M_2 - \varepsilon_\beta (M_2 - 1)$ and $Z_D > 1$

For internal gears, ZD shall be taken as equal to 1.

2.4 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 load at the pitch cylinder.

The zone factor, Z_H, is to be calculated as follows:

$$Z_H = \sqrt{\frac{2\cos\beta b}{\cos^2\alpha_t \tan\alpha_{tw}}}$$

2.5 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 elasticity factor, Z_E, for steel gears (E= 206000 N/mm^2, ν= 0,3) is equal to:

$$Z_E = 189,8\sqrt{\text{N/mm}^2}$$

In other cases, reference is to be made to the reference standard ISO 6336-2:2019.

2.6 Contact ratio factor, 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:

Spur gears:

$$Z_\varepsilon = \sqrt{\frac{4-\varepsilon_\alpha}{3}}$$

Helical gears:

— for ε_β <1

$$Z_\varepsilon = \sqrt{\frac{4-\varepsilon_\alpha}{3}(1-\varepsilon_\beta) + \frac{\varepsilon_\beta}{\varepsilon_\alpha}}$$

— for $\varepsilon_\beta \geq 1$

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}}$$

2.7 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:

$$Z_\beta = \sqrt{\frac{1}{\cos\beta}}$$

Where β is the reference helix angle.

2.8 Endurance limit for contact stress, $\sigma_{H\ lim}$

For a given material, $\sigma_{H\ lim}$ is the limit of repeated contact stress which can be permanently endured. The value of $\sigma_{H\ lim}$ can be regarded as the level of contact stress which the material will endure without pitting for at least $5x10^7$ load cycles.

For this purpose, pitting is defined by:

- 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.

The $\sigma_{H\ lim}$ values are to correspond to a failure probability of 1% or less.

The endurance limit mainly depends on:

- material composition, cleanliness and defects;
- mechanical properties;
- residual stresses;
- hardening process, depth of hardened zone, hardness gradient;
- material structure (forged, rolled bar, cast).

The endurance limit for contact stress $\sigma_{H\ lim}$, is to be determined, in general, making reference to values indicated in the standard ISO 6336-5, for material quality MQ.

2.9 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 reference standard ISO 6336-2:2019.

2.10 Influence factors of lubrication film on contact stress, 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 velocity factor, Z_V, and the roughness factor Z_R are to be calculated as follows:

a) Lubricant factor, Z_L
The factor, Z_L, is to be calculated from the following equation:

$$Z_L = C_{ZL} + \frac{4(1 - C_{ZL})}{\left(1,2 + \frac{134}{v_{40}}\right)^2}$$

In the range 850 N/mm^2 ≤ $\sigma_{H\ lim}$ ≤ 1200 N/mm^2, C_{ZL} is to be calculated as follows:

$$C_{ZL} = \left(0,08 \frac{\sigma_{H\ lim} - 850}{350}\right) + 0,83$$

If $\sigma_{H\ lim}$ < 850 N/mm^2, take C_{ZL} = 0,83

If $\sigma_{H\ lim}$ > 1200 N/mm^2, take C_{ZL} = 0,91

Where:

v_{40} = nominal kinematic viscosity of the oil at 40°C, mm^2/s

b) Velocity factor, Z_v

The velocity factor, Z_v, is to be calculated from the following equations:

$$Z_v = C_{ZL} + \frac{2(1 - C_{zv})}{\sqrt{0,8 + \frac{32}{v}}}$$

In the range 850 N/mm^2 $\leq \varsigma_{H\ lim} \leq$1200 N/mm^2, C_{ZV} is to be calculated as follows:

$$C_{ZV} = C_{ZL} + 0,02$$

c) Roughness factor, Z_R

The roughness factor, Z_R, is to be calculated from the following equations:

$$Z_R = \left(\frac{3}{R_{Z_{10}}}\right)^{C_{ZR}}$$

Where:

$$R_Z = \frac{R_{Z1} + R_{Z2}}{2}$$

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 reference standard ISO 6336-2:2019).

$$R_{Z10} = R_Z \sqrt[3]{\frac{10}{\rho_{red}}}$$

relative radius of curvature:

$$\rho_{red} = \frac{\rho_1 \cdot \rho_2}{\rho_1 + \rho_2}$$

Where in:

$\rho_{1,2} = 0,5 \cdot d_{b1,2} \cdot \tan \alpha_{tw}$

(also for internal gears, d_b negative sign)

If the roughness stated is an arithmetic mean roughness, i.e. R_a value (=CLA value) (=AA value) the following approximate

R_a = CLA = AA= R_Z / 6

In the range 850 N/mm^2 ≤ σ_H lim ≤1200 N/mm^2, C_{ZR} is to be calculated as follows:

$C_{ZR} = 0,32 – 0,0002 \cdot \sigma_{H\ lim}$

If σ_H lim < 850N/mm^2, take $C_{ZR} = 0,150$

If σ_H lim > 1200N/mm^2, take $C_{ZR} = 0,080$

2.11 Hardness ratio factor, Z_W

The hardness ratio factor, Z_W, accounts for the increase of surface durability of a soft steel gear meshing with a significantly harder gear with a smooth surface in the following cases:

— Surface-hardened pinion with through-hardened wheel

If HB < 130 $\quad Z_W = 1,2 \cdot \left(\frac{3}{R_{zH}}\right)^{0,15}$

If $130 \le$ HB ≤ 470 $\quad Z_W = \left(1,2 - \frac{HB - 130}{1700}\right) \cdot \left(\frac{3}{R_{zH}}\right)^{0,15}$

If HB > 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

R_{zH} = equivalent roughness, μm

$$R_{zH} = \frac{R_{z1} \cdot (10/\rho_{red})^{0,33} \cdot (R_{z1}/R_{z2})^{0,66}}{V \cdot V_{40}/1500)^{0,33}}$$

ρ_{red}= relative radius of curvature (see 2.10 c)

— 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.

If HB_1/HB_2 < $1,2$ $\quad Z_W = 1$

If $1,2 \le HB_1/HB_2 \le 1,7$ $\quad Z_W = 1 + \left(0,00898 \frac{HB_1}{HB_2} - 0,00829\right) \cdot (u - 1)$

If $HB_1/HB_2 > 1,7$ $\qquad Z_W = 1 + 0,00698 \cdot (u - 1)$

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.

2.12 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 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 adequate casedepth relative to tooth size and radius of relative curvature $Z_X = 1$. When the casedepth is relatively shallow then a smaller value of Z_X should be chosen.

2.13 Safety factor for contact stress, S_H

The safety factor for contact stress, S_H, can be assumed by BKI taking into account the type of application.

The following guidance values can be adopted:

- Main propulsion gears: 1,20 to 1,40
- Auxiliary gears: 1,15 to 1,20

For gearing of duplicated independent propulsion or auxiliary machinery, duplicated beyond that required for class, a reduced value can be assumed at the discretion of BKI.

3. Tooth root bending strength

3.1 Scope and general remarks

The criterion for tooth root bending strength is the permissible limit of local tensile strength in the root fillet. The root stress σ_F and the permissible root stress σ_{FP} shall be calculated separately for the pinion and the wheel.

σ_F must not exceed σ_{FP}.

The following formulae and definitions apply to gears having rim thickness greater than 3,5 m_n.

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°.

For larger pressure angles and large helix angles, the calculated results should be confirmed by experience as by **Method A** of the reference standard ISO 6336-3:2019.

3.2 Basic equations

3.2.1 Tooth root bending stress for pinion and wheel

$$\sigma_F = \frac{F_t}{b m_n} Y_F Y_S Y_\beta Y_{Y_B} Y_{DT} Y_A Y_\gamma Y_v Y_{F\alpha} Y_{F\beta} \leq \sigma_{FP}$$

where:

Y_F	=	tooth form factor	(see H.3.3)
Y_S	=	stress correction factor	(see H.3.4)
Y_β	=	helix angle factor	(see H.3.5)
Y_B	=	rim thickness factor	(see H.3.6)
Y_{DT}	=	deep tooth factor	(see H.3.7)
F_t, K_A, K_γ, K_v, $K_{F\alpha}$, $K_{F\beta}$			(see H.1)
b			(see H.1.4)
m_n			(see H.1.3)

3.2.2 Permissible tooth root bending stress for pinion and wheel

$$\sigma_{FP} = \frac{\sigma_{FE} Y_d Y_N}{S_F} Y_{\delta relT} Y_{RrelT} Y_x$$

where:

σ_{FE}	=	bending endurance limit
Y_d	=	design factor
Y_N	=	life factor
$Y_{\delta relT}$	=	relative notch sensitivity factor
Y_{RrelT}	=	relative surface factor
Y_x	=	size factor
S_F	=	safety factor for tooth root bending stress

3.3 Tooth form factor, Y_F

The tooth form factor, Y_F, represents the influence on nominal bending stress of the tooth form with load applied at the outer point of single pair tooth contact. Y_F shall be determined separately for the pinion and the wheel. In the case of helical gears, the form factors for gearing shall 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:

Where:

h_F	=	bending moment arm for tooth root bending stress for application of load at the outer point of single tooth pair contact	[mm]
s_{Fn}	=	tooth root normal chord in the critical section	[mm]
α_{Fen}	=	pressure angle at the outer point of single tooth pair contact in the normal section	[°]

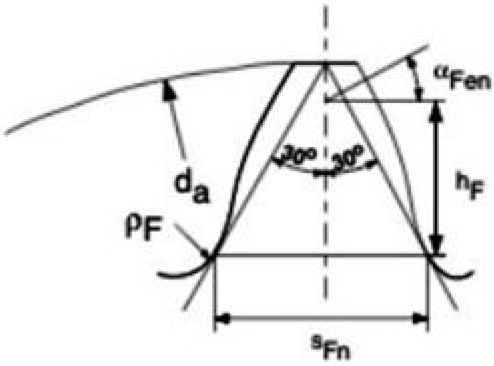


Figure 5.1: Dimensions of h_F, S_{Fn} and α_{Fen} for external gear

For the calculation of h_F, S_{Fn} and α_{Fen}, the procedure outlined in the reference standard ISO 6336-3:2019 (**Method B**) is to be used.

3.4 Stress correction factor, Y_S

The stress correction factor Y_S, 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 range of validity: $1 \leq q_S \leq 8$):

$$Y_S = (1,2 + 0,13L) q_S^{\left(\frac{1}{1,21 + 2,3/L}\right)}$$

Where:

$$q_S = \frac{S_{Fn}}{2\rho_F}$$

q_S	=	notch parameter,
ρ_F	=	root fillet radius in the critical section [mm]
L	=	s_{Fn}/h_F

For h_F and s_{Fn} see section 3.I

For the calculation of ρ_F the procedure outlined in the reference standard ISO 6336-3:2019 is to be used.

3.5 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.

The helix angle factor, Y_β is to be calculated as follows:

$$Y_\beta = 1 - \varepsilon_\beta \frac{\beta}{120}$$

where:

β = reference helix angle in degrees.

The value 1,0 is substituted for ε_β when ε_β > 1,0, and 30° is substituted for β > 30°.

3.6 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 YB is to be determined as follows:

— for external gears:

if $S_R/h \geq 1,2$ $\quad Y_B = 1$

if $0,5 < S_R/h < 1,2$ $\quad Y_B = 1,6 \cdot \ln\left(2,242\frac{h}{S_R}\right)$

where:

S_R	=	rim thickness of external gears [mm]
h	=	tooth height [mm]

The case s_R / h $\leq$ 0,5 is to be avoided.

— for internal gears:

if $S_R/m_n \geq 3,5$ $\quad Y_B$=1

if $1,75 < S_R/m_n$ $\quad Y_B = 1,15 \cdot \ln\left(8,324\frac{m_n}{S_R}\right)$

where:

S_R	=	rim thickness of internal gears [mm]

The case $S_R/m_n \leq$ 1,75 is to be avoided.

3.7 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 $\varepsilon_{\alpha n}$ > 2,5	$Y_{DT} = 0,7$
if ISO accuracy grade $\leq$ 4 and $2,05 < \varepsilon_{\alpha n} \leq 2,5$	$Y_{DT} = 2,366 - 0,666 \cdot \varepsilon_{\alpha n}$
in all other cases	Y_{DT} = 1.0

3.8 Bending endurance limit, σ_{FE}

For a given material, σ_{FE} is the local tooth root stress which can be permanently endured. According to the reference standard ISO 6336-5:2016 the number of 3x10^6 cycles is regarded as the beginning of 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 alternating stress or prestressing etc. are covered by the design factor Y_d.

The σ_{FE} values are to correspond to a failure probability 1% or less.

The endurance limit mainly depends on:

- material composition, cleanliness and defects;
- mechanical properties;
- residual stresses;
- hardening process, depth of hardened zone, hardness gradient;
- material structure (forged, rolled bar, cast).

The bending endurance limit, σ_{FE} is to be determined, in general, making reference to values indicated in the reference standard ISO 6336-5:2016, for material quality MQ.

3.9 Design factor, Y_d

The design factor, Y_d, takes into account the influence of load reversing and shrinkfit prestressing 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 in general;

Y_d = 0.9 for gears with occasional part load in reversed direction, such as main wheel in reversing gearboxes;

Y_d = 0.7 for idler gears

3.10 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 factor mainly depends on:

- material and heat treatment;
- number of load cycles (service life);
- influence factors ($Y_{\delta relT}$, Y_{RrelT}, Y_X).

The life factor, Y_N, is to be determined according to Method B outlined in the reference standard ISO 6336-3:2019.

3.11 Relative notch sensitivity factor, $Y_{\delta relT}$

The relative notch sensitivity factor, $Y_{\delta relT}$, 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, $Y_{\delta relT}$, is to be determined as follows:

$$Y_{\delta relT} = \frac{1 + \sqrt{0,2\rho'(1 + 2q_s)}}{1 + \sqrt{1,2\rho'}}$$

where:

q_s = notch parameter (see 3.4)
ρ' = slip-layer thickness [mm], from the following Table 5.9

Table 5.9: Slip layer thickness

Material		ρ' [mm]
case hardened steels, flame or induction hardened steels		0,0030
through-hardened steels[1], yield point Re =	500 N/mm^2	0,0281
	600 N/mm²	0,0194
	800 N/mm²	0,0064
	1000 N/mm²	0,0014
nitrided steels		0,1005
1) The given values of ρ' can be interpolated for values of Re not stated above		

3.12 Relative surface factor, Y_{RrelT}

The relative surface factor, Y_{RrelT}, 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_{RrelT} is to be determined as follows Table 5.10:

Table 5.10: Relative surface factor

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 (σ_B > 800 N/mm^2)
1,070	5,306 – 4,203 $(R_z + 1)^{0,01}$	normalised steels (σ_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 [μm]
σ_B = tensile strength [N/mm^2]

The method applied here is only valid when scratches or similar defects deeper than $2R_z$ are not present.

If the roughness stated is an arithmetic mean roughness, i.e. R_a value (=CLA value) (=AA value) the following approximate relationship can be applied:

R_a = CLA = AA = R_z / 6

3.13 Size factor, Y_X

The size factor, Y_X, takes into account the decrease of the strength with increasing size.

The 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 be determined as follows Table 5.11:

Table 5.11: Size Factor Y_X

$Y_X = 1,00$	for $m_n \leq 5$	generally
$Y_X = 1,03 - 0,06\ m_n$	for $5 < m_n < 30$	normalised and through-hardened steels
$Y_X = 0,85$	for $m_n \geq 30$	
$Y_X = 1,05 - 0,010\ m_n$	for $5 < m_n < 25$	surface hardened steels
$Y_X = 0,80$	for $m_n \geq 25$	

3.14 Safety factor for tooth root bending stress, S_F

The safety factor for tooth root bending stress, S_F, can be assumed by BKI taking into account the type of application.

The following guidance values can be adopted:

— Main propulsion gears: 1,55 to 2,00

— Auxiliary gears: 1,40 to 1,45

For gearing of duplicated independent propulsion or auxiliary machinery, duplicated beyond that required for class, a reduced value can be assumed at the discretion of BKI.

Section 6 Propeller

A. General

1. Scope

These Rules apply to screw-propellers (controllable and fixed pitch). Refer to Section 13 for dimensioning and materials of propellers for vessels with ice class.

2. Documents for approval

2.1 Design drawings of propeller in main propulsion plant shaving an engine output in excess of 300 kW and in transverse thrust units of over 500 kW, as well as a general arrangement drawing are to be submitted to the BKI for approval. The drawings have to include all the details necessary to carry out an examination in accordance with the following Rules. The drawings could be submitted in electronic format.

2.2 In the case of controllable pitch propeller systems, general and sectional drawings of the complete controllable pitch propeller system are to be submitted in form of electronic format in addition to the design drawings for blade, boss and pitch control mechanisms. Control and hydraulic diagrams are to be submitted with a functional description manual. In the case of new designs or controllable pitch propeller system which are being installed for the first time on a vessel with the BKI Class, a description of the controllable pitch propeller system is also to be submitted.

B. Material

1. Propellers and propeller hubs

Propellers are to be made of seawater-resistant cast copper alloys or cast steel alloys with a minimum tensile strength of 440 N/mm^2, according to Rules for Materials (Pt.1, Vol.V). 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 10^8 load cycles amounting to about 20% of the minimum tensile strength and carried out in a 3% Na Cl solution, and provided 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% Na Cl solution. Sufficient fatigue strength under alternating bending stresses has to be proven by a method recognized by BKI.

2. Components for controllable pitch and assembled fixed pitch propellers

The materials of the major components of the pitch control mechanism and also the blade and boss retaining bolts have to comply with the BKI Rules for Materials (Pt.1, Vol.V).

The blade retaining bolts of assembled fixed pitch propellers or controllable pitch propellers are to be made of seawater-resistant materials, so far 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 BKI.

4. Material testing

The material of propellers, propeller bosses and all essential components involved in the transmission of torque is to be tested in accordance with Rules for Materials (Pt.1, Vol.V). This also applies to components which are used to control the pitch of the blades and also to propellers in main propulsion systems 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 [mm^2]
B	=	developed blade width of cylindrical sections at radii 0,25 R, 0,35 R and 0,6 R in an expanded view [mm]
c_A	=	coefficient for shrink joints
	=	1,0 for geared diesel engine and turbine plants as well as for electric motor drives
	=	1,2 for direct diesel engine drives
C_G	=	size factor in accordance with formula (2)
C_{Dyn}	=	dynamic factor in accordance with formula (3)
C_w	=	characteristic material value for propeller material as shown in Table 6.1, corresponds to the minimum tensile strength R_m of the propeller material where sufficient fatigue strength under alternating bending stresses in according to B.1 is proven.

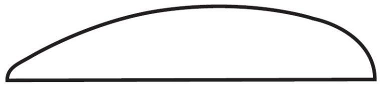
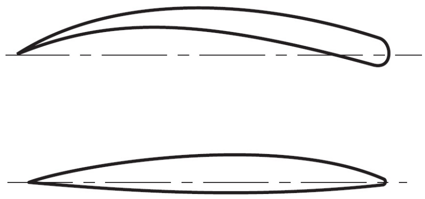
Table 6.1: Characteristic material values C_w

Material	Description[1]	Cw
Cu 1	Cast manganese brass	440
Cu 2	Cast manganese nickel brass	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 cast chrome 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 Rules for Material (Pt.I, Vol.V), and Rules for welding (Pt.I, Vol.VI)

C	=	conicity of shaft ends
	=	$\dfrac{\text{difference in taper diameter}}{\text{length of taper}}$
d	=	pitch circle diameter of blade or propeller-fastening bolts [mm]
d_i	=	inner diameter of shaft [mm]
d_k	=	root diameter of blade or propeller-fastening bolts [mm]
D	=	diameter of propeller [mm]
	=	$2 \cdot R$
d_m	=	mean taper diameter [mm]
D_N	=	mean outer diameter of propeller hub [mm]
e	=	blade rake to aft according to Fig. 6.1 [mm]
	=	$R \cdot \tan \varepsilon$
E_T	=	thrust stimulating factor in accordance with formula (5)
E_N	=	Modulus of elasticity for hub material [N/mm^2]
E_W	=	Modulus of elasticity for shaft material [N/mm^2]
$f, f_1, f_2,$	=	factors in formulae (2), (4) and (10)
H	=	pressure side pitch of propeller blade at radii 0,25 R, 0,35 R and 0,6 R [mm]
H_m	=	mean effective pressure side pitch for pitch varying with the radius [mm]
	=	$\dfrac{\Sigma(R \cdot B \cdot H)}{\Sigma(R \cdot B)}$ R, B and H are the corresponding measures of the various sections.
k	=	coefficient for various profile shapes in accordance with Table 6.2
K_N	=	diameter ratio of hub = $\dfrac{d_m}{D_N}$
K_W	=	diameter ratio of shaft = $\dfrac{d_i}{d_m}$
L_M	=	2/3 of the leading-edge part of the blade width at 0,9 R, but at least 1/4 of the tot blade width at 0,9 R for propellers with high skew blades [mm]
	=	pull-up length propeller on cone [mm]
L_{act}	=	chosen pull-up distance [mm]
L_{mech}	=	pull-up length at t = 35 °C [mm]
L_{temp}	=	temperature-related portion of pull-up length at t <35 °C [mm]
n_2	=	propeller speed [Rpm]
P_W	=	nominal power of driving engines [kW]
p	=	surface pressure in shrink joint between propeller and shaft [N/mm^2]
p_{act}	=	surface pressure in the shrink joint at L_{act} [N/mm^2]
Q	=	peripheral force at mean taper diameter [N]

Table 6.2: Values of k for various profile shapes

Profile shape		**Values of k**		
		0,25 R	**0,35 R**	**0,60 R**
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

$R_{p\,0,2}$ = 0,2 % proof stress [N/mm^2]

R_{eH} = yield strengths [N/mm^2]

R_m = tensile strengths [N/mm^2]

S = safety margin against propeller slipping on cone

= 2,8

t = maximum blade thickness of developed cylindrical section at radii 0,25R($t_{0,25}$), 0,35R($t_{0,35}$), 0,6R ($t_{0,6}$) and 1,0R ($t_{1,0}$) [mm]

T = propeller thrust [N]

T_M = impact moment [Nm]

V_s = speed of ship [kn]

w = wake fraction

$W_{0,35R}$ = section modulus of cylindrical blade's section at radius 0,35R [mm^3]

$W_{0,6R}$ = section modulus of cylindrical blade's section at radius 0,6R [mm^3]

Z = total number of bolts used to retain one blade or propeller

z = number of blades

α = pitch angle of profile at radii 0,2R, 0,35R and 0,6R [°]

$$\alpha_{0,25} = \text{arc tan}\,\frac{1,27 \cdot H}{D}$$

$$\alpha_{0,35} = \text{arc tan}\,\frac{0,91 \cdot H}{D}$$

$$\alpha_{0,6} = \text{arc tan}\,\frac{0,53 \cdot H}{D}$$

α_N = coefficient of linear thermal expansion of hub material [1/°C]

α_W = coefficient of linear thermal expansion of shaft material [1/°C]

ε = angle between lines of face generatrix and normal

Θ = half-conicity $\frac{C}{2}$

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

ν_N = Poisson's ratio of hub material

ν_W = Poisson's ratio of shaft material

Ψ = skew angle according to Fig. 6.1 [°]

$\frac{\sigma_{max}}{\sigma_m}$ = ratio of maximum to mean stress at pressure side of blades

σ_v = von Mises' equivalent stress [N/mm^2]

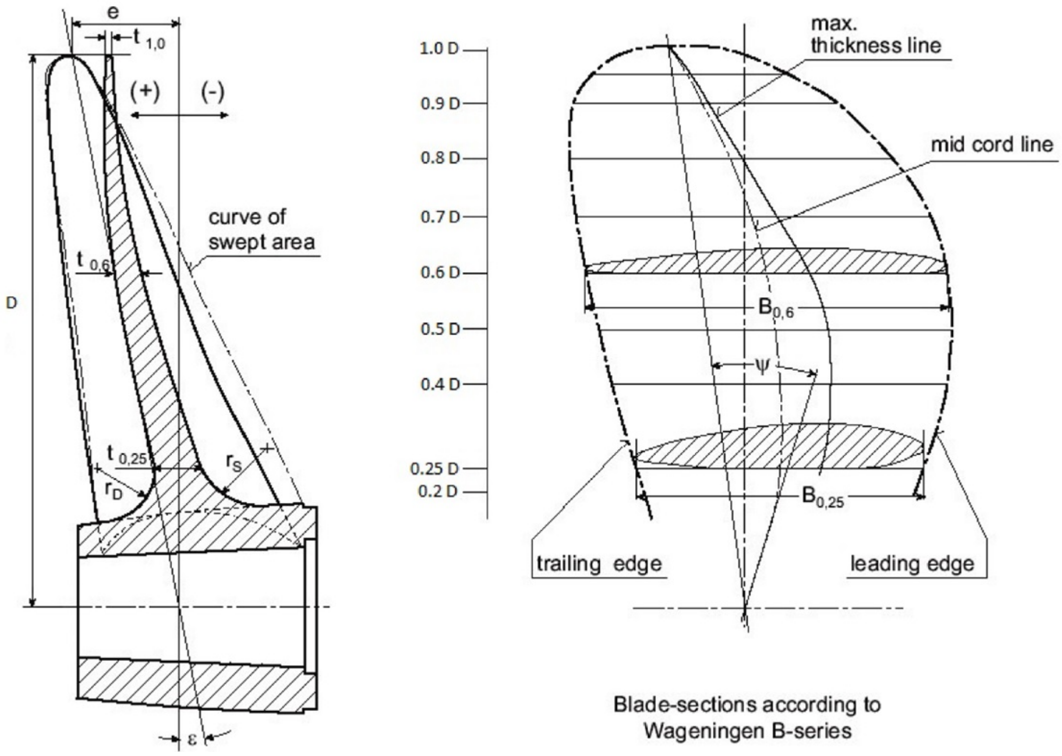


Figure 6.1: Blade Sections

2. Calculation of blade thickness

2.1 At radii 0,25 R($t_{0,25}$) and 0,6 R($t_{0,6}$) the maximum blade thicknesses of solid propellers have at least to comply with formula (1).

$$t \geq K_o\ k\ K_l\ C_G\ C_{dyn} \quad (1)$$

K_o = $1 + \frac{e \cdot \cos\alpha}{H} + \frac{n_2}{15000}$, k as in Table 6.2

K_1 = $\sqrt{\frac{P_{w \cdot 10^5} \cdot \left(2 \cdot \frac{D}{H_m} \cdot \cos\alpha + \sin\alpha\right)}{n_2 \cdot B \cdot z \cdot C_w \cdot \cos^2\varepsilon}}$

C_G = size factor

= $\sqrt{\frac{f_1 + \frac{D}{1000}}{12,2}}$

CG has to full fill the following condition

$$1,1 \geq CG \geq 0,85 \quad (2)$$

f_1 = 7,2 for solid propellers

= 6,2 for separately cast blades of variable-pitch or built up propellers

C_{dyn} = dynamic factor

= $\sqrt{\frac{(\sigma_{max}/\sigma_m - 0,8)}{0,7}} \geq 1,0$ for $\frac{\sigma_{max}}{\sigma_m} > 1,5$, otherwise C_{dyn} = 1,0 (3)

σ_{max}/σ_m is generally to be taken from the detailed calculation according to C.2.5. If, in exceptional cases, no such calculation exists, the stress ratio may be calculated approximately according to formula (4)

$$\frac{\sigma_{max}}{\sigma_m} = f_2 \cdot E_T + 1 \quad (4)$$

$$E_T = 4,3 \cdot 10^{-9} \frac{V_s \cdot n_2 \cdot (1 - w) \cdot D^3}{T} \quad (5)$$

f_2 = 0,4 - 0,6 for single-screw ships, the lower value has to be chosen for stern shapes with a big propeller tip clearance and no rudder heel, the larger value to sterns with small clearance and with rudder heel. Intermediate values are to be selected accordingly.

= 0,2 for twin-screw ships

2.2 The blade thicknesses 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 profiles, the diameter/pitch ratio D/H_m for the maximum bollard pull has 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 = Maximum Continuous Rating) can be used in formula (1).

2.3 The blade thicknesses calculated by applying formula (1) represent the lowest acceptable values for the finish-machined propellers.

2.4 The fillet radii at the transition from the pressure and suction side of the blades to the propeller boss shall correspond for three and four-bladed propellers to about 3,5% of the propeller diameter. For propellers with a larger number of blades the maximum possible fillet radii shall be aimed at, but these shall not be chosen less than 40% of the blade root thickness.

Variable fillet radii which are aiming at a uniform stress distribution, may be applied if an adequate proof of stress 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 C.2.4.

2.5 For special designs such as propellers with skew angle $\Psi \geq 25°$, tip fin propellers, special profiles etc. a special strength calculation is to be submitted to BKI.

For calculation of the blade stress of these special propeller designs a blade geometry data file and details on the measured wake field are to be submitted to BKI together with the design documentation. This file should be sent in plain text format. Supplementary information on the Classification of special designs can be requested from BKI.

2.6 If the propeller is subjected to an essential wear e.g. by abrasion in tidal flats or dredgers, a wear addition has to be provided to the thickness determined under C.2.1 to achieve an equivalent lifetime. If the actual thickness in service drops below 50% at the blade tip or 90% at other radii of the rule thickness obtained from C.2.1, effective counter measures have to be taken. For unconventional blade geometries as defined in C.2.5, the design thickness as shown on the approved drawing replaces the thickness requested according to C.2.1.

3. Design of the propeller

The propeller has to be protected against electrochemical corrosion according to Rules for Hull (Pt 1, Vol.II), Sec. 38.

D. Controllable Pitch Propellers

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 to control the blade pitch and being able to move the blades from the ahead to the astern position in an sufficiently short time for safe manoeuvring.

The selection and arrangement of filters has to 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, before the pump, should be provided.

Section 11, 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 to be furnished that the individual components when subjected to impact loads still have a safety factor of 1,5 against the yield strength of the materials used. The impact moment T_M has to be calculated according to formula (6) and the resulting equivalent stresses at the different components are to be compared with their yield strength.

$$T_M = 1,5 \cdot \frac{R_{PO,2} \cdot W_{0,6R}}{\sqrt{\left(\frac{0,15 \cdot D}{L_M}\right)^2 + 0,75}} \cdot 10^{-3} \qquad (6)$$

$W_{0,6R}$ can be calculated by applying formula (7)

$$W_{0,6R} = 0,11 \cdot (Bt^2)_{0,6R} \qquad (7)$$

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 even of plastic deformation at 0,35R caused by a force acting on the blade at 0,9R. At this occasion the bolt material shall have a safety margin of 1,5 against the yield strength.

The thread core diameter of the blade retaining bolts shall not be less than:

$$d_k = 2,6 \cdot \sqrt{\frac{M_{0,35R} \cdot \sigma_A}{d \cdot Z \cdot R_{eH}}} \qquad (8a)$$

$W_{0,35R}$ may be calculated analogously to formula (7) or (8b)

For nearly elliptically sections at the root area of the blade the following formula may be used instead:

$$M_{0,35R} = W_{0,35R} \cdot R_{p\ 0,2} \qquad (8b)$$

3.2 The blade retaining bolts are to be tightened in a controlled way so 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 a minimum diameter of 0,9 times the root diameter of the threaded part.

3.3 Blade retaining bolts are to be secured against unintentional loosening.

4. Indicators

4.1 Controllable pitch propeller systems are to be provided with a direct acting indicator inside the engine room showing the actual setting of the blades. Further blade position indicators are to be mounted on the bridge, see also Rules for Automations (Pt 1,Vol.VII), and Rules for Electrical Installation (Pt 1,Vol.IV) Sec. 9.

4.2 Hydraulic pitch control systems are to be provided with means to monitor the oil level. A pressure gauge for the pitch control oil pressure is to be fitted. 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 Rules for Automations (Pt 1,Vol.VII), are to be complied with.

5. Failure of control system

Suitable devices have to prevent that an alteration of the blade pitch setting can lead to an overload or stall of the propulsion engine. It has to be ensured 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 plants are to be equipped with means for emergency control to maintain the function of the controllable pitch propeller in case of failure 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. Cone connection

1.1 Where the cone connection between shaft and 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.

1.2 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 L on the tapered shaft is to be determined according to formula (9). Where appropriate, allowance is also to be made for surface smoothing when calculating L.

$$L = L_{mech} + L_{temp} \tag{9}$$

L_{mech} is determined according to the formulae of elasticity theory applied to shrink joints for a specific surface pressure p [N/mm] at the mean taper diameter found by applying formula (10) and for a water temperature of 35°C.

$$p = \frac{\sqrt{\Theta^2 \cdot T^2 + f \cdot (C_A^2 \cdot Q^2 + T^2)} - \Theta \cdot T}{A \cdot f} \tag{10}$$

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 absorbed 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.

$$f = \left(\frac{\mu_o}{S}\right)^2 - \Theta^2 \tag{10a}$$

$$L_{temp} = \frac{d_m}{C}(\alpha_N - \alpha_W) \cdot (35 - t) \tag{11}$$

t = temperature at which the propeller is mounted [°C]

Values for α_N and α_W can be taken from Table 6.3. At least the temperature range between 0 °C and 35 °C has to be considered.

Table 6.3: Material values according to IACS UR K3

Material	Modulus of elasticity E [N/mm^2]	Poisson's ratio ν	Coefficient of linear thermal expansion α[1/°C]
Steel	205000	0,29	$12{,}0 \times 10^{-6}$
Copper based alloys Cu1 and Cu2	105000	0,33	$17{,}5 \times 10^{-6}$
Copper based alloys Cu3 and Cu4	115000	0,33	$17{,}5 \times 10^{-6}$
Note: for austenitic stainless steel see manufacturer's specification.			

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 = 1,8, the coefficient c_A may be set to 1,0. For this additional proof the respective influence of the thrust may be disregarded.

1.3 For keyless propeller fittings without intermediate sleeve, the required pull-up distance and related stresses in the propeller hub and shaft can be calculated as follows.

Joint stiffness factor:

$$K_{el} = \frac{d_m}{C} \cdot \left[\frac{1}{E_N} \cdot \left(\frac{1 + K_N{}^2}{1 - K_N{}^2} + V_N\right) + \frac{1}{E_W} \cdot \left(\frac{1 + K_W{}^2}{1 - K_W{}^2} + V_W\right)\right] \tag{12}$$

Value for E_N, E_W, ν_N and ν_W can be taken from Table 6.3

Minimum required pull-up distance at mounting temperature 35 °C:

$$L_{mech} = p \cdot K_{el} \tag{13}$$

Minimum required pull-up distance at mounting temperature t [°C]:

$$L = L_{mech} + L_{temp} \tag{14}$$

Surface pressure at the mean taper diameter at chosen pull-up distance L_{act} [mm]:

$$P_{act} = \frac{L_{act}}{K_{el}} \tag{15}$$

Related von Mises' equivalent stresses: (16)

$$\sigma_V = \frac{P_{act}}{1 - K_N{}^2} \cdot \sqrt{3 + K_N{}^4} \quad \text{(hub)} \tag{16a}$$

$$\sigma_V = P_{act} \quad \text{(solid shaft)} \tag{16b}$$

$$\sigma_V = \frac{P_{act} \cdot 2}{1 - K_W{}^2} \quad \text{(hollow shaft)} \tag{16c}$$

1.4 The von Mises' equivalent stress resulting from the maximum surface pressure p and the tangential stress in the bore of the propeller hub shall not exceed 75% of the 0,2% proof stress or yield strength of the propeller material in the installed condition and 90% during mounting and dismounting.

1.5 The cones of propellers which are mounted on the propeller shaft by means of the hydraulic oil technique shall not be steeper than 1 : 15 and not be less than 1 : 25. For keyed connections the cone shall not be steeper than 1 : 10.

1.6 The propeller nut shall be strongly secured to the propeller shaft.

2. Flange connections

2.1 Flanged propellers and the hubs of controllable pitch propellers are to be connected by means of fitted pins and retaining bolts (preferably necked down bolts).

2.2 The diameter of the fitted pins is to be calculated by applying formula (4) given in Section 4.D.4.2.

2.3 The propeller retaining bolts are to be designed in accordance to D.3, however the thread core diameter shall not be less than

$$d_K = 4,4 \frac{M_{0,35R} \cdot \alpha_A}{d \cdot Z \cdot R_{eH}} \tag{17}$$

2.4 The propeller retaining bolts have to be secured against unintentional loosening.

F. Balancing and Testing

1. Balancing

Monobloc propellers ready for mounting as well as the blades of controllable and built up fixed pitch propellers are required to undergo static balancing. Thereby the mass difference between blades of controllable or built up fixed pitch propeller has to be not more than 1,5%.

2. Testing

2.1 Fixed pitch propellers, controllable pitch propellers and controllable pitch propeller systems are to be presented to BKI for final inspection and verification of the dimensions.

BKI reserve the right to require non-destructive tests for detecting surface cracks or casting defects.

In addition, controllable pitch propeller systems shall undergo pressure, tightness and functional tests.

2.2 Casted propeller boss caps, which also serve as corrosion protection, have to be tested for tightness at the manufacturer's workshop. BKI reserve 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 Surveyor. The blue print pattern shall not show any larger areas without contact, especially not at the forward cone end. The proof 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.

3. Testing of the control system of controllable pitch propellers intended for main propulsion

3.1 Purpose

The purpose of the tests required by this UR is to ascertain that the pitch control system of CP propellers for main propulsion is working correctly.

3.2 Application

The requirements in this UR apply to all new buildings and to all replacements, modifications, repairs, or re-adjustments that may affect the pitch control or response characteristics for main propulsion.

3.3 Scope of the tests

3.3.1 Pitch response test

A full range of tests is to be carried out to get the pitch response and verify that it coincides with the combinator curve of the propeller[1]. The tests are to be carried out for at least three positions of the control lever in ahead and astern directions (e.g., dead slow ahead / astern, half ahead / astern, full ahead / astern).

The tests are to be carried out in normal and emergency operating conditions.

Tests that are not affected by the control position may be carried out from one control position only.

[1] The combinator curve is the relationship between the propeller pitch setting and the propeller speed.

3.3.2 Test of the fail-to-safe characteristics

A test of the fail-to-safe characteristics of the propeller pitch control system is to be carried out to demonstrate that failures in the pitch command and control or feedback signals are alarmed and do not cause any change of thrust. Such failures are to be clearly identified and included in the test procedure.

3.3.3 Test procedure

Test procedure is to be prepared and proposed by the pitch control system manufacturer or integrator and agreed with BKI.

3.4 Parameters to be recorded

The list of the parameters to be recorded during the pitch response test within this UR is to be established by the pitch control system manufacturer or integrator and agreed with the BKI. This should include at least the following parameters:

— Position of the control handle,

— Actual pitch indication (local indication, remote indications),

— Rotational speed of the propeller,

— Response time between the pitch change order (modification of the lever position) and the instant when the pitch and propeller speed have reached their final position,

— Propelling thrust variation during the transfer of the control from one location to another one.

3.5 Tests results

Tests are to demonstrate:

— that the propelling thrust is not significantly altered when transferring control from one location to another and in case of failures in the pitch command and control or feedback signals.

— that the pitch response times measured during the test do not exceed the maximum value to be defined by the pitch control system manufacturer or integrator.

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Section 7 Steam Boilers and Thermal Oil Systems

I. Steam Boilers

A. General

1. Scope

1.1 For the purpose of these requirements, the term ”steam boiler” includes all closed vessels and piping systems used for:

— generating steam with a pressure above atmospheric (steam generators). The generated steam is to be used in a system outside of the steam generators

— raising the temperature of water above the boiling point corresponding to atmospheric pressure (hot water generators, discharge temperature > 120 °C). The generated hot water is to be used in a system outside of the hot water generators

The term ”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.

1.2 Steam generators as defined in 1.1 are subject to the requirements set out in I.B. to I.F. For hot water generators the requirements set out in I.G. apply additionally.

Flue gas economizers are subject to the requirements set out in I.H. In respect of materials, manufacture and design, the requirements specified in I.B, I.C and I.D apply as appropriate.

1.3 For warm water generators with an allowable discharge temperature of not more than 120 °C and steam or hot water generators which are heated solely by steam or hot liquids Section 8 applies.

2. Other Rules

2.1 Other applicable Rules

In addition the BKI Rules and Guidelines defined in the following have to be applied, in similar way:

— Section 9.	for oil burner and oil firing systems.
— Section 11, A to F.	for pipes valves and pumps
— Rules for Electrical Installations (Pt.1, Vol.IV).	for electrical equipment items
— Rules for Automations (Pt.1, Vol.VII)	for automated machinery systems [**OT**]
— Rules for Material (Pt.1, Vol.V), and Rules for Welding (Pt.1, Vol.VI)	for the manufacturing of steam boiler
— Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W)	for type approved components Component requirering type approval

2.2 Constructions, equipment and operation of steam boiler plants are also required to comply with the applicable national regulations.

3. Documents for approval

3.1 The following documents are to be submitted for approval to BKI in electronic format:

- Drawings of all boiler parts subject to pressure, such as shell, drums, headers, tube arrangements, manholes and inspection covers, etc.
- Drawings of the expansion vessel and other pressure vessels for hot water generating plants
- Equipment and functional diagrams with description of the steam boiler plant
- Circuit diagrams of the electrical control system, respectively monitoring and safety devices with limiting values

3.2 These drawings shall contain all the data necessary for strength calculations and design assessment, such as maximum allowable working pressures, heating surfaces, lowest water level, permissible steam capacity, steam conditions, superheated steam temperatures, as well as materials to be used and full details of welds.

3.3 Further on document shall contain information concerning the equipment of the steam boiler as well as description of the boiler plant with the essential boiler data, information about the installation location in relation to the longitudinal axis of the ship and data about feeding and oil firing equipment.

4. Definitions

4.1 Steam boiler walls are the walls of the steam and water spaces located between the boiler isolating devices. The bodies of these isolating devices belong to the boiler walls.

4.2 The maximum allowable working pressure PB is the approved steam pressure in bar (gauge pressure) in the saturated steam space prior to entry into the super heater. In once-through forced flow boilers, the maximum allowable working pressure is the pressure at the super heater outlet or, in the case of continuous flow boilers without a super heater, the steam pressure at the steam generator outlet.

4.3 The heating surface is that part of the boiler walls through which heat is supplied to the system, i.e.:

- the area [m^2] measured on the side exposed to fire or heating gas, or
- in the case of electrical heating, the equivalent heating surface:

  $H = \frac{P \cdot 860}{18000}$ [m^2], where P is the electric power in kW.

4.4 The allowable steam output is the maximum hourly steam quantity which can be produced continuously by the steam generator operating under the design steam conditions.

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 [m^3]

D = allowable steam output [kg/h]

V' = specific volume of water at saturation temperature [m^3/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
- super heaters
- 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.

6. Manual operation

6.1 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.

6.2 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.

6.3 Exhaust gas boilers with temperatures of the exhaust gas < 400 °C may be operated without water level limiters.

6.4 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 shutdown of the feeding pumps during manual operation.

6.5 The safety equipment not required for manual operation may only be deactivated by means of a key-operated switch. The actuation of the key-operated switch is to be indicated.

6.6 For detailed requirements in respect of manual operation of the oil firing system, see Section 9.

6.7 Manual operation demands constant and direct supervision of the system steam boiler plant

7. Power of steam propulsion plants

On ships propelled by steam, the plant is to be designed that, should one main boiler fail, sufficient propulsive capacity will remain to maintain adequate maneuverability and to supply the auxiliary machinery.

8. Hot water generators

8.1 Once-through hot water generators are generators where the allowable working temperature can be exceeded when the circulating pumps of the system are stopped.

8.2 Circulating hot water generators guarantee the water flow through the generator by using a separate circulating pump or by natural flow.

B. Materials

1. General requirements

With respect to their workability during manufacture and their characteristics in subsequent operation, materials used for the manufacture of steam boilers have to satisfy the technical requirements, particularly those relating to high-temperature strength and weldability.

2. Approved materials

The requirements specified in 1. are recognized as having been complied with if the materials shown in Table 7.1 are used.

Materials not specified in the Rules for Materials (Pt.1, Vol.V), may be used provided that proof is supplied of their suitability and material properties.

3. Material testing

3.1 The materials of boiler parts subject to pressure, including flue gas economizer tubes, are to be tested under supervision of BKI in accordance with Rules for Materials (Pt.1, Vol.V) and Rules for Welding (Pt.1, Vol.VI) (see. Table 7.1). For these materials an A-Type Certificate [1)] is to be issued.

3.2 Material testing under supervision of BKI may be waived in the case of

1) Small boiler parts made of unalloyed steels, such as stay bolts, stays of ≤100 mm diameter, reinforcing plates, hand hole and manhole covers, forged flanges up to DN 150 and nozzles up to DN 150 and

2) Smoke tubes (tubes subject to external pressure).

For the parts mentioned in 1) and 2), the properties of the materials are to be attested by Manufacturer Inspection Certificates[1)].

3.3 If the design temperature is 450 °C or higher or the design pressure is 32 bar or higher pipes shall be non-destructive tested in accordance with the Rules for Materials (Pt.1, Vol.V), Sec. 5.C.4.7.

3.4 Special agreements may be made regarding the testing of unalloyed steels to recognized standards.

3.5 The materials of valves and fittings are to be tested under supervision of BKI in accordance with the data specified in Table 7.2. For these materials an A-Type Certificate[1)] need to be issued.

3.6 Parts not subject to material testing, such as external supports, lifting brackets, pedestals, etc. are to be designed for the intended purpose and shall be made of suitable materials.

C. Principles Applicable to Manufacture

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 accordance with regulations.

Steam boiler parts whose microstructure has been adversely affected by hot or cold forming are to be subjected to heat treatment and testing in accordance with the Rules for Materials (Pt.1, Vol.V), Sec. 9.A.

2. Welding

2.1 Steam boiler are to be manufactured by welding.

2.2 All manufacturers who want to perform welding duties for steam boilers have to be approved by BKI. The approval has to be applied for by the work with information and documentation according to the Rules for Welding (Pt.1, Vol.VI), General requirements, proof of qualification, approval, in due time before start of the welding activities.

2.3 Valid are the Rules for Welding (Pt.1, Vol.VI). Especially Welding in the Various Fields of Application, Section 2.

3. Tube expansion

Tube holes are to 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.

[1)] See Rules for Materials, (Pt.1, Vol.V) Sec.1

4. Stays, stay tubes and stay bolts

4.1 Stays, stay tubes and stay bolts are to be arranged that they are not subjected to undue bending or shear forces.

Stress concentrations at changes in cross-section, in threads and at welds are to be minimized by suitable component geometry.

4.2 Stays bars and stay bolts are to be welded by full penetration preferably. Any vibrational stresses are to be considered for longitudinal stays.

4.3 Stays bars and stay bolts 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 shall be drilled to a distance of at least 25 mm (see Fig. 7.22)

4.4 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 penetration welds. In fire tube boilers, gusset stays are to be located at least 200 mm from the fire tube.

4.5 Where flat surfaces exposed to flames are stiffened by stay bolts, the distance between centers of the stay bolts shall not exceed 200 mm.

Table 7.1: Approved materials

Material and product form	Limits of application	Materials grades in accordance with Rules for Material (Pt.1, Vol.V)
Steel plates and steel strips	—	Plates and strips of high-temperature steel, Section 4, E
Steel pipes	—	Seamless and welded pipes of ferritic steels, Section 5, B and C
Forgings and formed parts: a) drums, headers and similar hollow components without longitudinal seam b) covers, flanges, nozzles, end plates	-	Forging for boilers, vessels and pipeline Section 6, E Formed and pressed parts to Section 9, A. and B.
Nuts and bolts	—	Fasteners, Section 9, C High-temperature bolts to DIN 17240
	$\leq$ 300 °C $\leq$ 40 bar $\leq$ M30	DIN 267 Parts 3 and 4 or equivalent standards
Steel castings	—	Cast steel for boilers, pressure vessels and pipelines to Section 7, D.
	$\leq$ 300 °C	Also, GS 38 and GS 45 to DIN 1681 and GS 16 Mn5 and GS 20 Mn5 to DIN 17182
Nodular cast iron	$\leq$ 300 °C $\leq$ 40 bar $\leq$ DN 175 for valves and fittings	Nodular cast iron to Section 8, B
Lamellar (grey) cast iron : a) Boiler parts (only for unheated surfaces and not for heaters in thermal oil systems) b) Valves and fittings (except valves subject to dynamic stresses) c) Exhaust gas economizer	$\leq$ 200 °C $\leq$ 10 bar $\leq$ 200 mm diameter $\leq$ 200 °C $\leq$ 10 bar $\leq$ DN 175 $\leq$ 52 bar smoke gas temperature $\leq$ 600 °C water outlet temperature $\leq$ 245 °C	Grey cast iron to Section 8, C
	$\leq$ 100 bar smoke gas temperature $\leq$ 700 °C water outlet temperature $\leq$ 260 °C	Grey cast iron of at least GG-25 grade to Section 8, C
Valves and fittings of cast copper alloys	$\leq$ 225 °C $\leq$ 25 bar	Cast copper alloys to Section 5, B

Table 7.2: Testing of materials for valves and fittings

Type of material [1]	Service temperature °[C]	Testing required for: PB [bar] DN [mm]
Steel, cast steel	> 300	DN > 50
Steel, cast steel, nodular cast iron	$\leq$ 300	PB x DN > 2.500 [2] or DN > 250
Copper alloys	$\leq$ 225	PB x DN > 1.500 [2]

[1] No test is required for grey cast iron.

[2] Testing may be dispensed with if DN is $\leq$ 50 mm.

5. Stiffeners, straps and lifting eyes

5.1 Where flat end surfaces are stiffened by profile sections or ribs, the latter shall transmit their load directly (i.e. without welded-on straps) to the boiler shell.

5.2 Doubling plates may not be fitted at 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.

6. 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 wall thickness ratio sB/sM shall not be greater than 1,8. The end is to be welded to the shell with a full penetration weld.

7. Nozzles and flanges

Nozzles and flanges are to be of rugged design and properly, preferably by full penetration to the shell. The wall thickness of nozzles has to be sufficiently large to safely 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 are to be made of forged material with favourable grain orientation.

8. Cleaning and inspection opening, cut outs and covers.

8.1 Steam boilers are to be provided with openings through which the space inside can be cleaned and inspected. Especially critical and high-stressed welds, parts subjected to flame radiation and areas of varying water level shall be sufficiently accessible to inspection. 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 shall not obstruct inner inspection or are to be capable of being removed.

8.2 Inspection and access openings are required to have the following minimum dimensions:

Manholes	300 x 400 mm or 400 mm diameter, where the annular height is >150 mm the opening measure shall be 320 x 420 mm.
Head holes	220 x 320 mm or 320 mm diameter
Hand holes	90 x 120 mm
Sight holes	are required to have a diameter of at least 50 mm; they shall, however, be provided only when the design of the equipment makes a hand hole impracticable.

8.3 The edges of manholes and other openings, e.g. for domes, are to be effectively reinforced if the plate has been unacceptably weakened by the cut outs. The edges of openings closed with covers are to be reinforced by welded on edge-stiffeners.

8.4 Cover plates, manhole frames and crossbars are to 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 are to 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 maximum allowable working pressure PB of less than 32 bar, or 1 mm where the pressure is 32 bar or over. The height of the rim or spigot is to be at least 5 mm greater than the thickness of the packing.

8.5 Only continuous rings may be used as packing. The materials used shall be suitable for the given operating conditions.

9. Boiler drums, shell sections, headers and fire tubes

See the Rules for Welding (Pt.1, Vol.VI), Welding in the Various Fields of Application, Section 2.

D. 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. Special allowance shall be made for additional forces and moments of significant magnitude, e.g. those resulting from connected piping or from the movement of the ship at sea. These shall be specified in the documentation.

1.1.2 The wall thicknesses arrived at by applying the formulae are the minimal required. The undersize tolerances permitted by the Rules for Materials (Pt.1, Vol.V), are to be added to the calculated values.

1.2 Design pressure p_c

1.2.1 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 0,5 bar.

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 which safety valves 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. attemporators 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 17 bar. The design is also required to take account of the loads imposed during the hydrostatic pressure test.

Table 7.3: Design temperatures

Reference temperature	Allowance to be added		
	Unheated parts	Heated parts, heated mainly by	
		contact	radiation
Saturation temperature at MAWP	0 °C	25 °C	50 °C
Superheated steam temperature	15 °C [1]	35 °C	50 °C

[1] The temperature allowance may be reduced to 7 °C provided that special measures are taken to ensure that the design temperature cannot be exceeded

1.3 Design temperature t

Strength calculations are based on the temperature at the center of the wall thickness of the component in question. The design temperature is made up of the reference temperature and a temperature allowance in accordance with Table 7.3. The minimum value is to be taken as 250 °C.

1.4 Allowable stress

The design of structural components is to be based on the allowable stress σ_{perm} [N/mm^2]. 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

$\frac{R_{eH,t}}{1,6}$ where $R_{eH,t}$ = guaranteed yield point or minimum 0,2% proof at design temperature t [N/mm^2]

$\frac{R_{m,20°}}{2,7}$ where $R_{m,20°}$ = guaranteed minimum tensile strength at room temperature [N/mm^2]

For design temperature over 350 °C

$\frac{R_{m,100000,t}}{1,5}$ where $R_{m,100000,t}$ = Mean 100000 hour creep strength at design temperature t [N/mm^2]

$\frac{R_{eH,t}}{1,6}$ where $R_{eH,t}$ = guaranteed yield point or minimum 0,2% proof at design temperature t [N/mm^2]

1.4.2 Cast material

1) Cast steel : $\frac{R_{m,20°}}{3,2};\ \frac{R_{eH,t}}{2,0};\ \frac{R_{m,100000,t}}{20}$

2) Nodular cast iron : $\frac{R_{m,20°}}{4,8};\ \frac{R_{eH,t}}{3,0}$

3) Grey cast iron : $\frac{R_{m,20°}}{11}$

1.4.3 Special arrangements may be agreed for high-ductility austenitic steels.

1.4.4 In the case of cylinder shells with cut outs and in contact with water, a nominal stress of 170 N/mm^2 shall not be exceeded in view of the protective magnetite layer.

1.4.5 Mechanical characteristics are to be taken from the Rules for Materials (Pt.1, Vol.V), or from the Standards specified therein.

1.5 Allowance for corrosion and wear

The allowance for corrosion and wear is to be c = 1,0 mm. For plate thicknesses of 30 mm and over and 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, the dimensions are to be designed following a Standard recognized by BKI, e.g. EN 12952, EN 12953 or equivalent. In individual cases, the dimensions 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 $\leq$ 1,7. Diameter ratios of up to $D_a/D_i \leq 2$ may be permitted provided that the wall thickness is $\leq$ 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 cut out [mm] hole diameter for expanded tubes and for expanded and seal-welded tubes (see Fig. 7. 1 a and Fig. 7. 1 b) inside tube diameter for welded-in pipe nipples and sockets (Fig. 7. 1 c)
t, t_ℓ,t_u	=	pitch of tube holes (measured at center of wall thickness for circumferential seams) [mm]
v	=	weakening factor (see. Table 7.4) for welds: weld factor for holes drilled in the shell: the ratio of the weakened to the un weakened plate section
σ_{perm}	=	allowable stress (see 1.4) [N/mm^2]
S_A	=	necessary wall thickness at edge of opening or cut out [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 [mm^2]
A_σ	=	supporting cross-sectional area [mm^2]

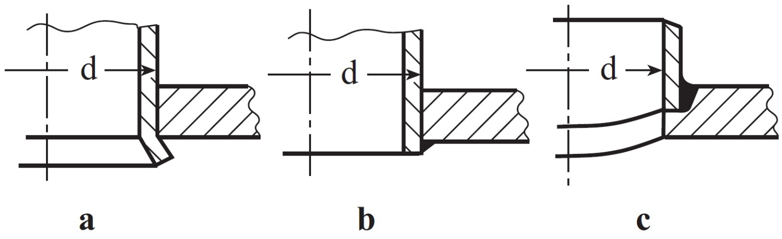


Figure 7.1: Hole diameters and inside tube diameter

2.3 Calculations

2.3.1 The necessary wall thickness is given by the expression:

$$s = \frac{D_a \cdot p_c}{20 \cdot \sigma_{perm} \cdot V + p_c} + c \quad (1)$$

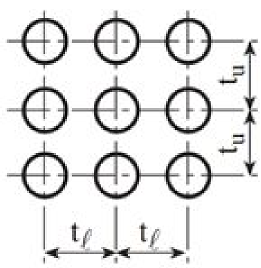
2.3.2 In the case of heated drums and headers with a maximum allowable working pressure of more than 25 bar, special attention is to be given to thermal stresses. For heated drums not located in the first pass (gas temperature up to 1000 °C max.), special certification proof in respect of thermal stresses may be waived subject to the following provision: 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 7.4.

Table 7.4: Weakening factor v

Construction	Weakening factor v	
Seamless shell rings and drums	1,0	
Shell rings and drums with longitudinal weld	Weld factor, see Rules for Welding (Pt.1, Vol.VI)	
Rows of holes[1] in :		
longitudinal direction	$\frac{t_\ell - d}{t_\ell}$	
circumferential direction	$2 \cdot \frac{t_u - d}{t_u}$	

[1] The value of v for rows of holes may not be made greater than 1,0 in the calculation. For staggered pitches, Fig. 7.27. Refer also to Fig 7.1 under paragraph 2.2

2.3.4 Weakening effects due to cut outs or individual branch pipes are to be taken into account by area compensation in accordance with the expression:

$$\frac{p_c}{10} \cdot \left\{ \frac{A_p}{A_\sigma} + \frac{1}{2} \right\} \leq \sigma_{perm} \quad (2)$$

The area under pressure Ap and the supporting cross-sectional area A_σ are defined in Figure I.7.2.

The values of the supporting lengths may not exceed:

for the parent component $b = \sqrt{(D_i + S_A - c) \cdot (S_A - c)}$

for the branch pipe $l_s = 1,25\sqrt{(D + S_S - c) \cdot (S_S - c)}$

Where a branch projects into the interior, the value introduced into the calculation as having a supporting function may not exceed $l_s' \leq 0,5 \cdot l_s$

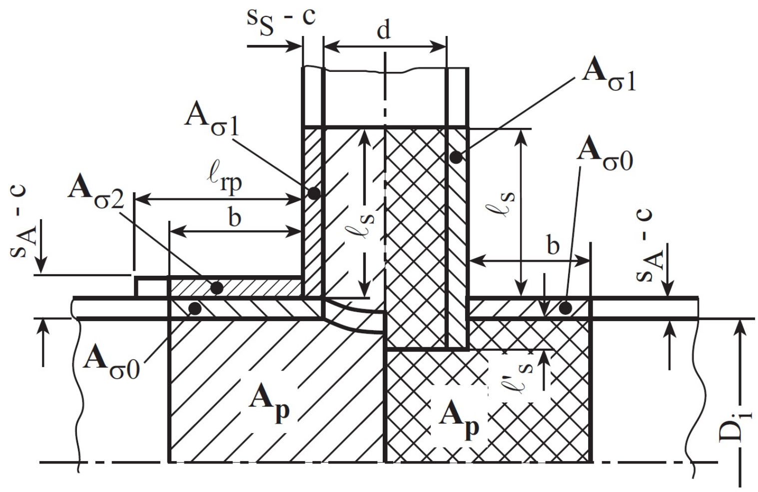


Figure 7.2: Opening in cylindrical shell

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.

Disc-shaped reinforcements are to be fitted on the outside and should not be thicker than the actual parent component thickness. This thickness is the maximum which may be allowed for the calculation and the width of the reinforcement shall be more than three times the actual wall thickness.

The wall thickness of the branch pipe shall not be more than twice the required wall thickness at the edge of the cut out.

Cut outs exert a mutual effect if the ligament is

$$1 \leq 2\sqrt{(D_i + S_A - c) \cdot (S_A - c)}$$

The area compensation is then as shown in Figure I.7.3.

For cut outs r which exert a mutual effect the reinforcement by internal branch pipe projections or reinforcement plates has also to be taken into account

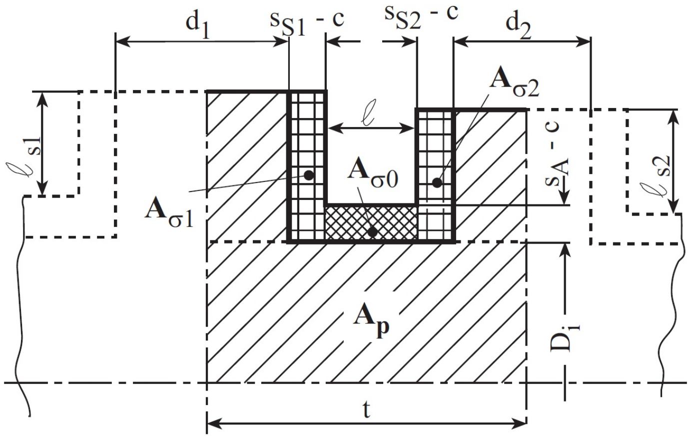


Figure 7.3: Mutual effect on openings

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 cylinder diameters up to 200 mm, smaller wall thicknesses may be permitted. The wall thicknesses of drums into which tubes are 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 of 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 fire tube [mm]
ℓ	=	length of tube or distance between two effective stiffeners [mm]
h	=	height of stiffening ring [mm]
b	=	thickness of stiffening ring [mm]
u		out-of-roundness of tube [%]
a	=	greatest deviation from cylindrical shape (see Fig. 7.5) [mm]
σ_{perm}	=	allowable stress [N/mm^2]
E_t		modulus of elasticity at design temperature [N/mm^2]
S_K	=	safety factor against elastic buckling
v	=	transverse elongation factor (0,3 for steel)
c	=	allowance for corrosion and wear [mm]

3.3 Calculation

3.3.1 Cylindrical shells and plain fire tubes

Calculation of resistance to plastic deformation:

$$p_c \leq 10 \cdot \sigma_{perm} \cdot \frac{2 \cdot (s - c)}{d} \cdot \frac{1 + 01 \cdot \frac{d}{\ell}}{1 + 0,03 \cdot \frac{d}{s - c} \cdot \frac{u}{1 + 5 \cdot \frac{d}{\ell}}} \tag{3}$$

Calculation of resistance to elastic buckling:

$$p_c \leq 20 \cdot \frac{E_t}{S_k} \left\{ \frac{\frac{s - c}{d_a}}{(n^2 - 1) \cdot \left[1 + \left(\frac{n}{Z}\right)^2\right]} + \frac{\left(\frac{(s - c)}{d_a}\right)^3}{3 \cdot (1 - v^2)} \left[n^2 - 1 + \frac{2 \cdot n^2 - 1 - v}{1 + \left(\frac{n}{Z}\right)^2}\right] \right\} \tag{4}$$

Where $Z = \frac{\pi \cdot d_a}{2 \cdot \ell}$

and $n \geq 2$

$n > Z$

n (integer) is to be chosen as to reduce pc to its minimum value. n represents the number of buckled folds occurring round the periphery in the event of failure. n can be estimated by applying the following approximation formula:

$$n = 1,63 \cdot \sqrt[4]{\left\{\frac{d_a}{\ell}\right\}^2 \cdot \frac{d_a}{s - c}}$$

3.3.2 In the case of corrugated tubes of Fox or Morrison types, the required wall thickness s is given by the expression:

$$s = \frac{p_c}{20} \cdot \frac{d_i}{\sigma_{perm}} + 1,0 [mm] \tag{5}$$

3.4 Allowable stress

Contrary to 1.4, the values for the allowable stress of fire tubes used in the calculations are to be as follows:

Plain fire tubes, horizontal	$\frac{R_{eH,t}}{2,5}$
Plain fire tubes, vertical	$\frac{R_{eH,t}}{2,0}$
Corrugated fire tubes	$\frac{R_{eH,t}}{2,8}$
Tubes heated by exhaust gases with a temperature >400 °C	$\frac{R_{eH,t}}{2,0}$

3.5 Design temperature

Contrary to 1.3, the design temperature to be used for fire tubes and heated tubes is shown in Table 7.5.

Table 7.5: Design temperatures for heated components under external pressure

For tubes exposed to fire (fire tubes) : plain tubes t [°C] = saturation temperature $+ 4 \cdot s + 30$ °C Corrugated tubes t [°C] = saturation temperature $+ 3 \cdot s + 30$ °C	but at least 250°C
For tubes heated by exhaust gases t [°C] = saturation temperature $+ 2 \cdot s + 15$ °C	

3.6 Stiffening

3.6.1 Apart from the fire tubes and firebox end-plates, the types of structure shown in Fig 7.4 can also be regarded as providing effective stiffening.

3.6.2 For fire tubes which consists of a plain tube and a corrugated tube for the calculation of the plain tube 1,5 times of the length of the plain part has to be used.

3.6.3 The plain portion of corrugated fire tubes 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.

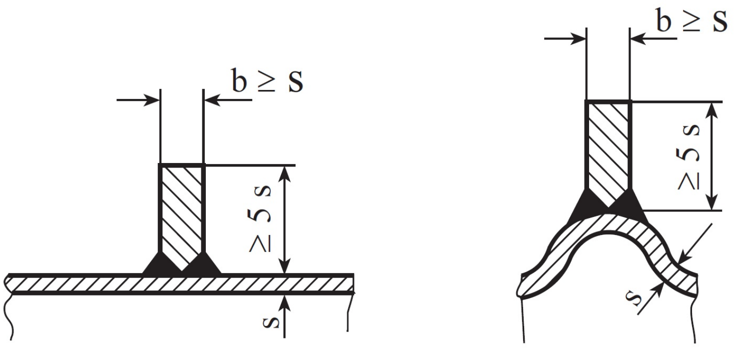


Figure 7.4: Effective stiffening

3.7 Safety factor S_k

A 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 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.

3.8 Modulus of elasticity

Table 7.6 shows the modulus of elasticity for steel in relation to the design temperature.

Table 7.6: Modulus of elasticity 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 are to be interpolated

3.9 Allowance for corrosion and wear

An allowance of 1,0 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 fire tubes shall be at least 7,0 mm, that of corrugated fire tubes at least 10 mm. For small boilers, non-ferrous metals and stainless steels, smaller wall thicknesses are allowable. The maximum wall thickness shall 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 fire tubes, the length l between two stiffeners shall not exceed 6,0 · d The greatest unsupported length shall not exceed 6,0 m, in the first pass from the front end-plate, 5,0 m. Stiffening's of the type shown in Fig 7.4 are to be avoided in the flame zone, i. e. up to approximately 2,0 · d behind the lining.

3.12 Out-of-roundness

The out-of-roundness [%]

$$u = \frac{2 \cdot (d_{max} - d_{min})}{d_{max} + d_{min}} \cdot 100$$

for new plain tubes is to be given the value u = 1,5% in the design formula.

In the case of used fire tubes, the out-of-roundness is to be determined by measurements of the diameters according to Fig. 7.5.

$$u = \frac{4 \cdot a}{d} \cdot 100$$

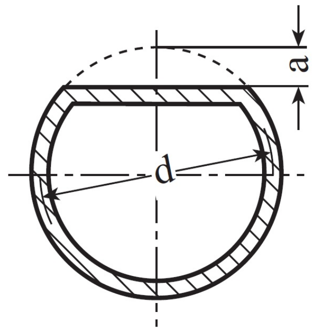


Figure 7.5: Parameters of out - of –roundness

3.13 Fire tube spacing

The clear distance between the fire tube and boiler shell at the closest point shall be at least 100 mm. The distance between any two fire tubes shall be at least 120 mm.

4. Dished endplates under internal and external pressure

4.1 Scope

4.1.1 The following requirements apply to the design of unstayed dished endplates under internal or external pressure (see Fig. 7.6). The following requirements are to be complied with:

The radius R of the dished end shall not exceed the outside endplate diameter D_a, and the knuckle radius r shall not be less than $0{,}1 \cdot D_a$

The height H shall not be less than $0{,}18 \cdot D_a$

The height of the cylindrical portion h, with the exception of hemispherical endplates, shall be at least 3,5 · s, s being taken as the thickness of the unpierced plate even if the endplate is provided with a manhole. The height of the cylindrical portion need not, however, exceed the values shown in Table 7.7.

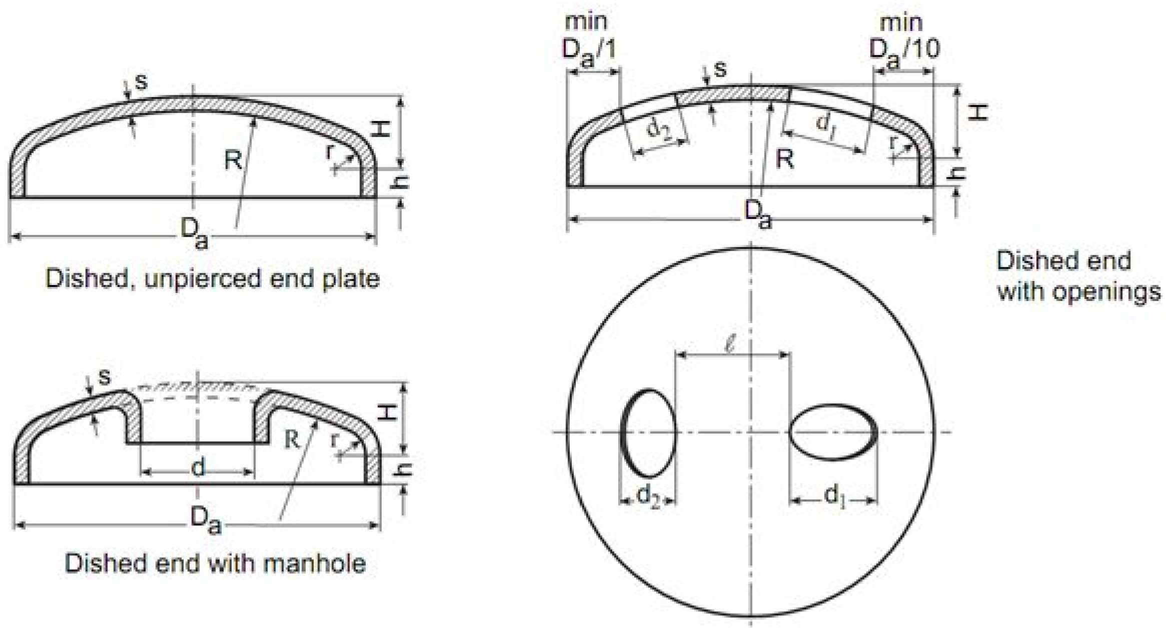


Figure 7.6: Parameters for unstayed dished endplates

Table 7.7: Height h of cylindrical portion

Wall thickness s [mm]	h [mm]
$s \leq 50$	150
$50 < s \leq 80$	120
$80 < s \leq 100$	100
$100 < s \leq 120$	75
$s > 120$	50

4.1.2 These requirements also apply to welded dished endplates. Due account is to be taken of the weakening factor of the weld (see 4.5).

4.2 Symbols

p_c = design pressure [bar]
s = wall thickness of endplate [mm]
D_a = outside diameter of endplate [mm]
H = height of end-plate curvature [mm]
R = inside radius of dished end [mm]
h = height of cylindrical portion [mm]
d = diameter of opening measured along a line passing through the centers of the endplate and the opening. In the case of openings concentric with the endplate, the maximum opening diameter [mm]
σ_{perm} = allowable stress (see 1.4) [N/mm^2]
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 = modulus of elasticity at design temperature [N/mm^2]
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 [mm^2]
A_σ = supporting cross-sectional area [mm^2]
S_k = safety factor against elastic buckling
S'_k = safety factor against elastic buckling at test pressure

4.3 Calculation for internal pressure

4.3.1 The necessary wall thickness is given by the expression:

$$s = \frac{D_a \cdot p_c \cdot \beta}{40 \cdot \sigma_{perm} \cdot v} + c \tag{6}$$

The finished wall thickness of the cylindrical portion is to be at least equal to the required wall thickness of a cylindrical shell without weakening.

4.3.2 Design coefficients β and β_o

The design coefficients are shown in Fig. 7.7 in relation to the ratio H/D_a and parameters $d / \sqrt{D_a \cdot s}$ and s/D_a.

For dished ends of the usual shapes, the height H can be determined as follows:

Shallow dished end ($R = D_a$):

$$H \approx 0{,}1935 \times D_a + 0{,}55 \quad s$$

Deep dished end, ellipsoidal shape ($R = 0{,}8\ D_a$):

$$H \approx 0{,}255 \times D_a + 0{,}36 \quad s$$

The values of β for unpierced endplates also apply to dished ends with openings whose edges are located inside the spherical section and whose maximum opening diameter is $d \leq 4 \cdot s$, or whose edges are adequately reinforced. The width of the ligament between two adjacent, non-reinforced openings must be to be at least equal to the sum of the opening radii measured along the line connecting the centers 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 ligament 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 section are deemed to be adequately reinforced if the following expression relating to the relevant areas is satisfied.

$$\frac{p_c}{10} \cdot \left[\frac{A_p}{A_\sigma} + \frac{1}{2}\right] \leq \sigma_{perm} \qquad (7)$$

The area under pressure A_p and the supporting cross-sectional area A_σ are shown in Fig. 7.8.

The relationship between respective areas of cut outs exerting a mutual effect is shown in Fig. 7.9.

The edge of disk-shaped reinforcements is not permitted to extend beyond $0{,}8 \cdot D_a$.

In the case of tubular reinforcements, the following wall thickness ratio is applicable:

$$\frac{s_S - c}{s_A} \leq 2$$

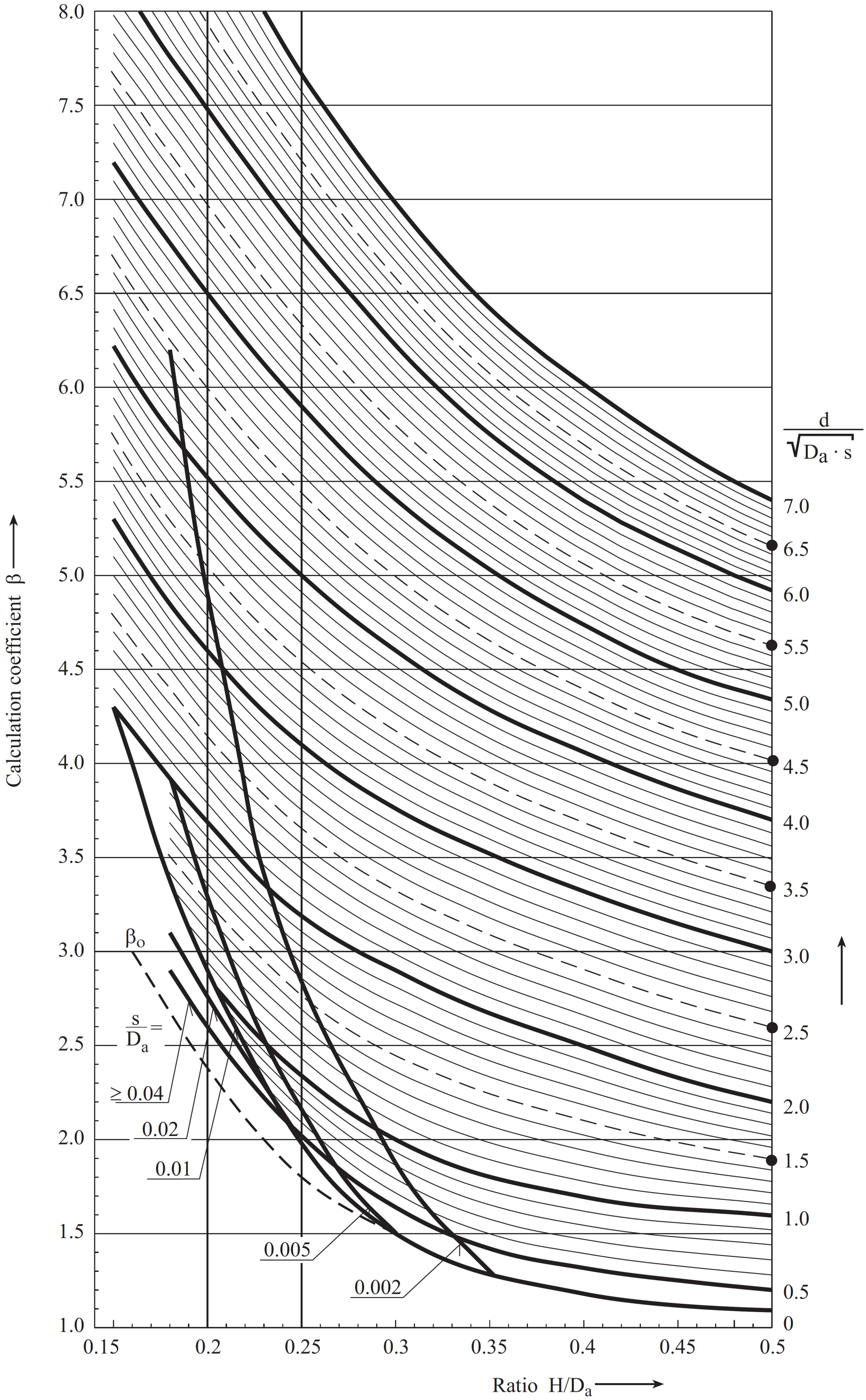


Figure 7.7: Values of coefficient β for the design of dished ends

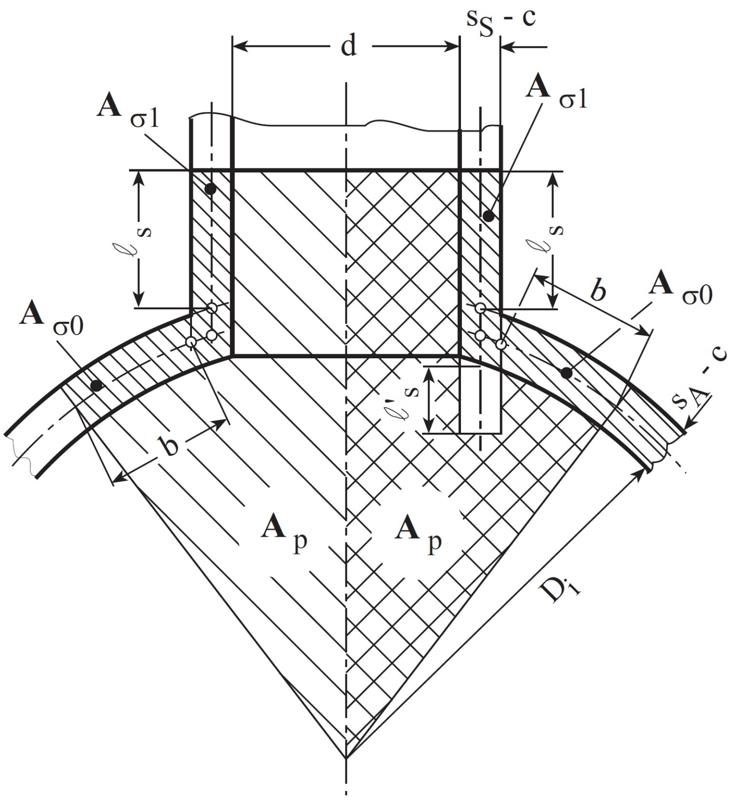


Figure 7.8: Openings in dished end plates

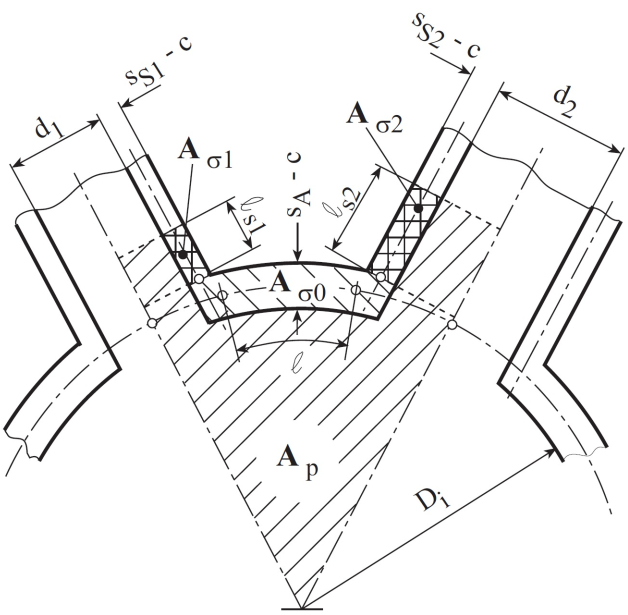


Figure 7.9: Mutual effect on openings

4.4 Design calculation for external pressure

4.4.1 The same formulae are to be applied to dished endplates 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 endplate is safe against elastic buckling.

The following relationship is to be applied:

$$p_c \leq 3,66 \cdot \frac{E_t}{S_k} \cdot \left[\frac{s-c}{R}\right]^2 \quad (8)$$

The modulus of elasticity Et for steel can be taken from Table 7.6.

The safety coefficient S_k against elastic buckling and the required safety coefficient S_k' at the test pressure are shown in Table 7.8.

Table 7.8: Safety coefficient against elastic buckling

$\frac{s-c}{R}$	S_k [1]	S_k' [1]
0,001	5,5	4,0
0,003	4,0	2,9
0,005	3,7	2,7
0,01	3,5	2,6
0,1	3,0	2,2

[1] Intermediate values are to be interpolated

4.5 Weakening factor

The weakening factor can be taken from Table 7.4 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. (see Fig. 7.10).

4.6 Minimum allowable wall thickness

The minimum allowable wall thickness for welding neck endplates is 5,0 mm. smaller minimum wall thicknesses are allowed for non-ferrous metals and stainless steels.

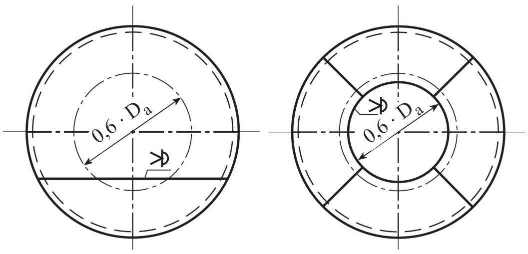


Figure 7.10: Welding seam within the apex area

5. Flat surfaces

5.1 Scope

The following requirements apply to stayed and unstayed flat, flanged endplates and to flat surfaces which are simply supported, 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 endplate with a stress relieving groove [mm]
D_b	=	inside diameter of a flat, flanged endplate or design diameter of an opening to be provided with means of closure [mm]
D_1, D_2	=	diameter of ring plates [mm]
D_ℓ	=	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 centers of non-uniformly spaced stays and stay bolts [mm]
f	=	cross-sectional area of ligament [mm^2]
r_K	=	inner corner radius of a flange, or radius of a stress relieving groove [mm]
h	=	inner depth of a flat, welding-neck endplate [mm]
h	=	height of the cylindrical portion of a flanged endplate or inner depth of a flat, welding neck endplate respectively [mm]
C	=	design coefficient (for unstayed surfaces see Table 7.11 and for stayed surfaces see Table 7.12
y	=	ratio
σ_{perm}	=	allowable stress (see 1.4) [N/mm^2]
c	=	allowance for corrosion and wear [mm]

5.3 Calculation of unstayed surfaces

5.3.1 Flat, circular, flanged, endplates (see Fig.7.11).

The required wall thickness s is given by the expression:

$$s = C \cdot (D_b - r_K) \sqrt{\frac{p_c}{10 \cdot \sigma_{perm}}} + c \qquad (9)$$

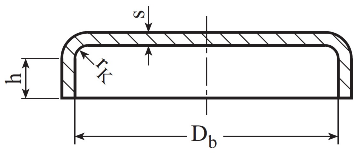


Figure 7.11: Flat, circular, flanged end plates

The height of the cylindrical portion h shall be at least 3,5 · s.

5.3.2 Circular plates

The required wall thickness s considering the Fig. 7.12 – Fig. 7.14 is given by the expression:

$$s = C \cdot D_b \cdot \sqrt{\frac{p_c}{10 \cdot \sigma_{perm}}} + c \qquad (10)$$

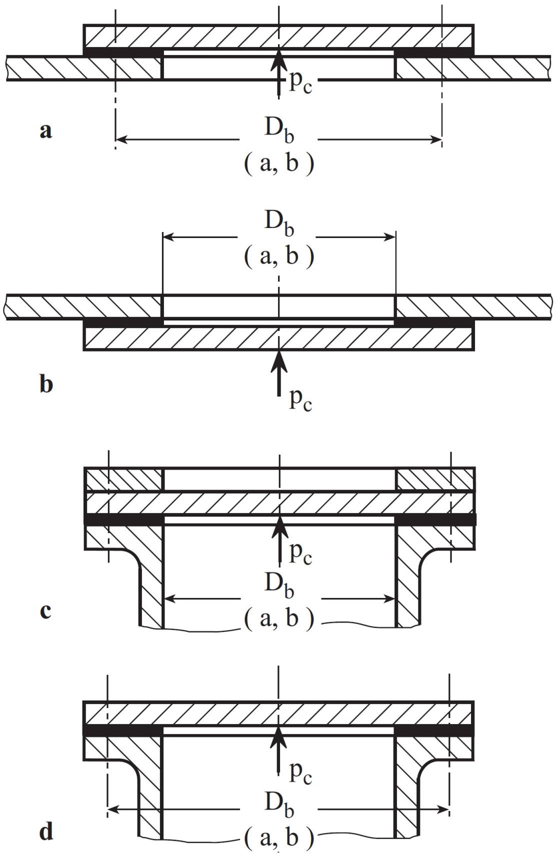


Figure 7.12: Circular plates with flat sealing

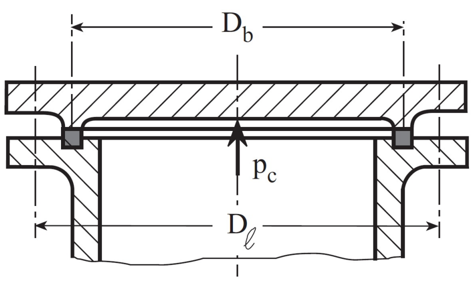


Figure 7.13: Circular plate with sealing ring

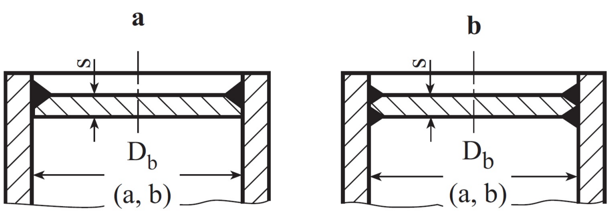


Figure 7.14: Circular welded-in endplates

5.3.3 Rectangular and elliptical plates.

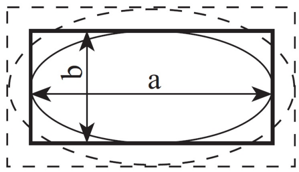


Figure 7.15: Parameters of rectangular and elliptical plates

The required wall thickness s considering Fig. 7.15 is given by the expression:

$$s = C \cdot D_b \cdot \sqrt{\frac{p_c}{10 \cdot \sigma_{perm}}} + c \qquad (11)$$

5.3.4 Welding-neck endplates.

For welding-neck endplates of headers additional requirements are to be found in 5.5.2.

The thickness of the plates is determined by applying formula (10) or (11) as appropriate.

In the case of endplates with a stress relieving groove, the effective relieving of the welded seams has to be guaranteed. The wall thickness s1 in the stress relieving groove shall therefore satisfy the following conditions, see Fig. 7.17:

For round endplates: $s \leq 0{,}77 \cdot s_2$

For round endplates: $s < 0{,}55 \cdot s_2$

Here s_2 represents the wall thickness of the cylindrical or rectangular header in [mm]. In addition, provision has to be made to ensure that shear forces occurring in the cross-section of the groove can be safely absorbed.

It is therefore necessary that for round endplates:

$$s_1 \geq \frac{p_c}{10} \cdot \left(\frac{D_b}{2} - r_k\right) \cdot \frac{1,3}{\sigma_{perm}} \qquad (12)$$

and for rectangular endplates

$$s_1 \geq \frac{p_c}{10} \cdot \frac{a \cdot b}{a + b} \cdot \frac{1,3}{\sigma_{perm}} \qquad (13)$$

Radius r_K shall be at least 0,2 · s and not less than 5,0 mm. Wall thickness s_l is to be at least 5,0 mm.

Where welding-neck endplates in accordance with Fig. 7.16 or Fig. 7.17 are manufactured from plates, the area of the connection to the shell is to be tested for lamination, e. g. ultrasonically.

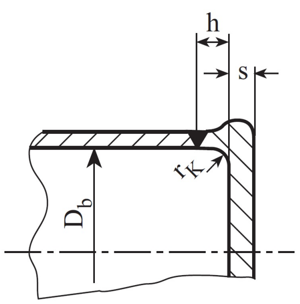


Figure 7.16: Welded-neck endplates

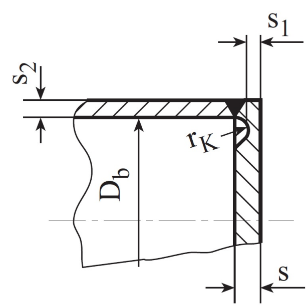


Figure 7.17: Welded-neck endplates with relieving groove

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, see Fig. 7.18.

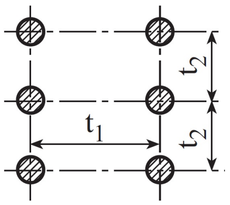


Figure 7.18: Uniformly braced plates

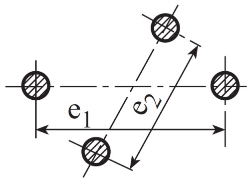


Figure 7.19: Non-uniformly braced plates

The required wall thickness s inside the stayed areas is given by the expression:

$$s = C \cdot \sqrt{\frac{p_c \cdot (t_1^2 + t_2^2)}{10 \cdot \sigma_{perm}}} \tag{14}$$

5.4.2 For flat plates which are non-uniformly braced by stay bolts, circular stays and stay tubes, see Fig. 7.19.

The required wall thickness s inside the stayed areas is given by the expression:

$$s = C \cdot \frac{e_1 + e_2}{2} \cdot \sqrt{\frac{p_c}{10 \cdot \sigma_{perm}}} + c \tag{15}$$

5.4.3 For flat plates which are braced by gusset stays, supports or other means and flat plates between arrays of stays and tubes, see Fig. 7.20.

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 favourable position from the point of view of stress being decisive in each case.

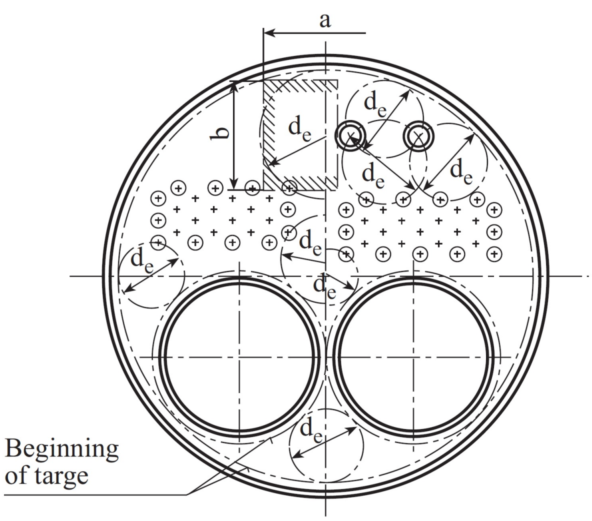


Figure 7.20: Braced flat plates

The required wall thickness s is given by the expression:

$$s = C \cdot d_e \cdot \sqrt{\frac{p_c}{10 \cdot \sigma_{perm}}} + c \tag{16}$$

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 Fig. 7.21.

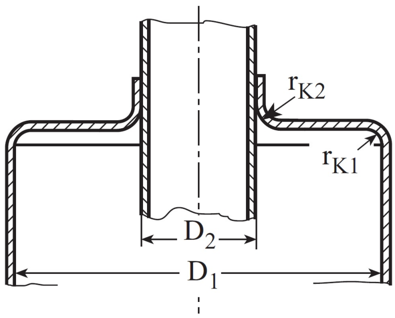


Figure 7.21: Flat annular plate with central longitudinal staying

The required wall thickness s is given by the expression:

$$s = 0,25 \cdot (D_1 \cdot D_2 \cdot r_{K1} \cdot r_{K2}) \cdot \sqrt{\frac{p_c}{10 \cdot \sigma_{perm}}} + c \quad (18)$$

5.5 Requirements for flanges

5.5.1 Application of the above formulae to flanged endplates and to flanges as a means of staying is subject to the provision that the corner radii of the flanges should have the following minimum values in relation to the outside diameter of the endplate (see Table 7.9).

In addition, the flange radii r_K (Figs. 7.11, 7.20 and 7.21) shall be equal to at least 1,3 times the wall thickness.

5.5.2 In the case of welding-neck endplates without a stress relieving groove for headers, the flange radius shall be $r_k \geq 1/3 \cdot s$, subject to a minimum of 8 mm, and the inside depth of the endplate is to be h $\geq$ s, s for endplates with openings being the thickness of an unpierced endplate of the same dimensions, see Fig. 7.16.

Table 7.9: Minimum corner radii of flanges

Outside diameter of endplate D_a[mm]	Corner radius of flanges r_K[mm]
$D_a \leq 500$	30
$500 < D_a \leq 1400$	35
$1400 < D_a \leq 1600$	40
$1600 < D_a \leq 1900$	45
$D_a > 1900$	50

5.6 Allowable stress and design temperature

5.6.1 The allowable stress for unheated flat surfaces is to be determined according to 1.4.

5.6.2 For flat surfaces heated by radiation, flue or exhaust gases the design temperature shall be defined according to Table 7.5. In this case the allowable stress is to be determined by $R_{eH,t}/2{,}0$

5.7 Ratio coefficient y

The ratio coefficient 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, see Table 7.10.

Table 7.10: Ratio coefficient y

Shape	Ratio b/a [1]				
	1,0	0,75	0,5	0,25	$\leq$ 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.

5.8 Calculation coefficient

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 7.11 or 7.12.

Where different values of C are applicable to parts of a plate due to different kinds of stiffening according to Table 7.12 coefficient C is to be determined by the arithmetical mean value of the different stiffening.

Table 7.11: Values of coefficient C for unstayed flat surfaces

Type of endplate or cover	C
Flat, forged and plates or endplates with machined recesses for headers and flat, flanged endplates	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 man-hole 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). Inserted, flat plates welded on one side	0,45
Plates which are bolted at their circumference and are thereby subjected to an additional bending moment according to the ratio: D_ℓ/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 7.12: Values of coefficient C for stayed surfaces

Type of stiffening and/or stays	C
Boiler shell, header or combustion chamber wall, stay plate or tube area	0,35
Stay bolts in arrays with maximum stay bolt centre 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 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 shall be for:

steel $f = 15 + 3{,}4 \cdot d_a$ $[mm^2]$

copper $f = 25 + 9{,}5 \cdot d_a$ $[mm^2]$

5.10 Minimum and maximum wall thickness

5.10.1 With expanded tubes, the minimum plate thickness is 12 mm. concerning safeguards against the dislodging of expanded tubes, see 6.3.2.

5.10.2 The wall thickness of flat endplates should not exceed 30 mm in the radiation heated portion.

5.11 Reinforcement of openings

When calculating the thickness special allowance is to be for cut outs, branches, etc. in flat surfaces which lead to undue weakening of the plate.

The dimension of the flat surface with cut out is to be calculated following a Standard recognized by BKI, e.g. EN 12953 or equivalent.

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.

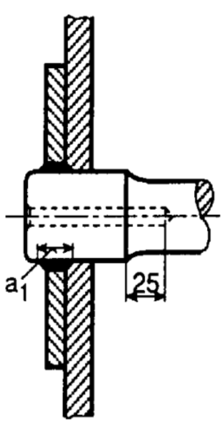


Figure 7.22:

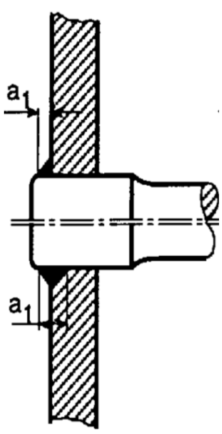


Figure 7.23:

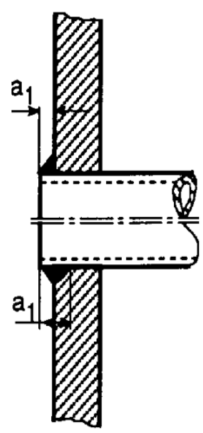


Figure 7.24:

Parameter for welding of stays, stays tubes, and stay bolts

6.2 Symbols

p_c	=	design pressure [bar]
F	=	load on a stay, stay tube or stay bolt [N]
A_1	=	calculated required cross-section area of stays, stay tube and stay bolt [mm^2]
A_2	=	supported area of expanded tubes [mm^2]
A_p	=	plate area supported by one stay, stay bolt or stay tube [mm^2]
d_a	=	outside diameter of stay, stay tube bolt 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 [mm]
σ_{perm}	=	allowable stress [N/mm^2]

6.3 Calculation

The supporting action of other boiler parts may be taken into consideration when calculating the size of stays, stay tubes and stay bolts. For flat end plates the loads up to the half distance can be assumed as to be supported by the directly adjacent boiler shell.

Where the boundary areas of flanged endplates are concerned, calculation of the plate Area (A_p) is to be based on the flat surface extending to the beginning of the endplate flange.

6.3.1 For longitudinal stays, stay tubes or stay bolts, the necessary cross-sectional area is given by:

$$A_1 = \frac{F}{\sigma_{perm}} \qquad (19)$$

6.3.2 Where expanded tubes are used, a sufficient safety margin is additionally to be applied to prevent the tubes from being pulled out of the tube plate. Such a safety margin is deemed to be achieved if the permissible load on the supporting area does not exceed the values specified in Table 7.13.

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 :

$A_2 = 0{,}1 \cdot d_a \cdot \ell_o$

Table 7.13: Loading of expanded tube connections

Type of expanded connection	Permissible load on supporting area [N/mm^2]
Plain	$\frac{F}{A_2} \leq 150$
With groove	$\frac{F}{A_2} \leq 300$
With flange	$\frac{F}{A_2} \leq 400$

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 stays, stay tubes or stay bolts are welded in, the cross-section of the weld subject to shear shall be at least 1,25 times the required bolt or stay tube cross-section:

$$d_a \cdot \pi \cdot a_1 \geq 1{,}25 \cdot A_1 \qquad (20)$$

6.3.4 Shape and calculation of gusset stays shall be carried out following a Standard recognized by BKI, e.g. EN 12953-3 or equivalent, but the allowable stress and adjacent parts shall be calculated according to B. and D.

6.4 Allowable stress

The allowable stress is to be determined in accordance with 1.4.1. Deviating from this, however, a value of $\frac{R_{eH,t}}{1,8}$ is to be applied 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 super heater 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/mm^2]
v	=	weld quality rating of longitudinally welded tubes

7.3 Calculation of wall thickness

The necessary wall thickness s is given by the expression:

$$s = \frac{d_a \cdot p_c}{20 \cdot \sigma_{perm} \cdot v + p_c} \tag{21}$$

7.4 Design temperature

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 of the expected medium passing through 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 $\frac{R_{EH,t}}{2,0}$ is to be applied.

7.6 Welding factor

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 permissible minus tolerance on the wall thickness (see 1.1.2) need only be taken into consideration for tubes which outside diameter exceeds 76,1 mm.

7.8 Maximum wall thickness of boiler tubes

The wall thickness of intensely heated boiler tubes (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 super heater support tubes.

8. Plain rectangular tubes and sectional headers

8.1 Symbols

p_c	=	design pressure [bar]
s	=	wall thickness [mm]
2·m	=	clear width of the rectangular tube parallel to the wall in question [mm]
2·n	=	clear width of the rectangular tube perpendicular to the wall in question [mm]
Z	=	coefficient according to formula (23) [mm^2]
a	=	distance of relevant line of holes from center line of side [mm]
t	=	pitch of holes [mm]
d	=	distance of relevant line of holes from center line of side [mm]
v	=	weakening factor for rows of holes under tensile stress
v^1	=	weakening factor for rows of holes under bending stress
r	=	inner radius at corners [mm]
σ_{perm}	=	allowable stress [N/mm^2]

8.2 Calculation

8.2.1 The wall thickness is to be calculated for the center 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:

$$s = \frac{p_c \cdot n}{20 \cdot \sigma_{perm} \cdot v} + \sqrt{\frac{4,5 \cdot Z \cdot p_c}{10 \cdot \sigma_{perm} \cdot v^1}} \qquad (22)$$

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:

$$\left| \frac{1}{3} \cdot \frac{m^3 + n^3}{m + n} - \frac{1}{2} \cdot \left(m^2 - a^2\right) \right| \qquad (23)$$

8.3 Weakening factor v

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^1 are to be determined as follows:

$$v = \frac{t - d}{t}$$

$$v^1 = v = \frac{t - d}{t} \quad \text{for holes where } d < 0{,}6 \cdot m$$

$$v^1 = \frac{t - 0{,}6 \cdot m}{t} \quad \text{for holes where } d \geq 0{,}6 \cdot m$$

8.3.2 In determining the values of v and v^1 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^1, the value of d in the expressions $d < 0{,}6 \cdot m$ and $d \geq 0{,}6 \cdot m$ 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 (Fig. 7.25).

8.3.4 For oblique ligaments, Z is calculated by applying the formula:

$$Z = \left| \frac{1}{3} \cdot \frac{m^3 + n^3}{m + n} - \frac{1}{2} \cdot \left(m^2 - a^2\right) \right| \cdot \cos\alpha$$

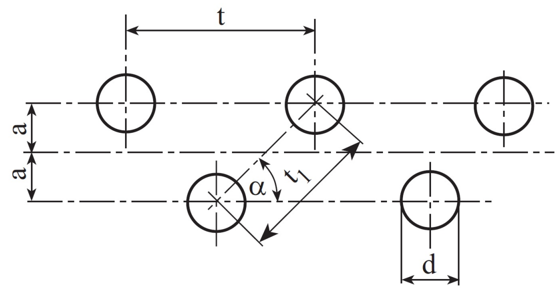


Figure 7.25: Length of ligament for staggered rows of holes

8.4 Stress at corners

In order to avoid undue stresses at corners, the following conditions are to be satisfied:

r > 1/2 , subject 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 shall 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 shall not be less than 1/4 of the distance between the tube centers.

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 continuously. 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 center lines of girders [mm]
l	=	free length between girder supports [mm]
b	=	thickness of girder [mm]
h	=	height of girder [mm]
W	=	section modulus of one girder [mm^3]
M	=	bending moment acting on girder at given load [Nmm]
z	=	coefficient for section modulus
σ_{perm}	=	allowable stress (see 1.4) [N/mm^2]

9.4 Calculation

9.4.1 The unsupported girder shown in Fig. 7.26 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.

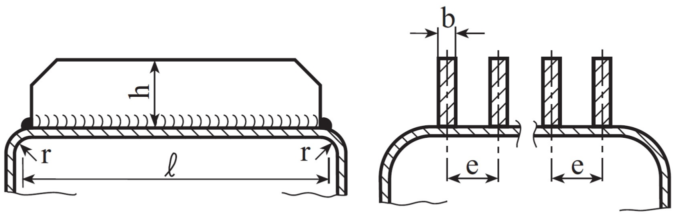


Figure 7.26: Unsupported girder

9.4.2 The required section modulus of a ceiling girder is given by:

$$W = \frac{M_{max}}{1,3 \cdot \sigma_{perm} \cdot Z} \le \frac{b \cdot h^2}{6} \tag{24}$$

The coefficient Z for the section modulus takes account of the increase in the section modulus due to the flat plate forming part of the ceiling plate. It may in general be taken as Z = 5/3.

For the height h, a value not exceeding 8·b is to be inserted in the formula.

9.4.3 The maximum bending moment is given by the expression:

$$M_{max} = \frac{F \cdot l}{8} \tag{25}$$

where,

$$F = \frac{p_c}{10} \cdot l \cdot e \tag{26}$$

10. Bolts

10.1 Scope

The following requirements relate 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

Where standard pipe flanges are used, the strength requirements for the flanges are considered to be satisfied if these flanges comply with a Standard recognized by BKI, e.g. EN 1092-1 or equivalent and conform to the specifications contained therein in respect of the materials used. The maximum allowable working pressure and the service temperature and the materials of the screws have been selected in accordance to EN 1515-1 and EN 1515-2.

Bolts with a shank diameter of less than 10 mm are not allowed.

Bolts shall not be located in the path of heating gases.

At least 4 bolts are to be used to form a connection.

To achieve small sealing forces, the sealing material should be made as narrow as possible.

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 > 40 bar.

All bolts > metric size M 30 are to be necked-down bolts.

Necked-down bolts are bolts with a shank diameter $d_s = 0{,}9 \cdot d_k$. The connection with necked-down bolts is to be designed in accordance to a Standard recognized by BKI, e.g. DIN 2510 or equivalent. In the calculation special allowance is to be made for shank diameters $< 0{,}9 \cdot d_k$.

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_{S_o}	=	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 seal under service conditions [N]
F_{D_o}	=	force to close seal in assembled condition [N]
F_Z	=	additional force due to loaded condition in connected 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 a necked-down bolt [mm]
d_k	=	root diameter of thread [mm]
n	=	number of bolts forming connection [mm]
σ_{perm}	=	allowable stress [N/mm^2]
Φ	=	surface finish coefficient
c	=	additional allowance [mm]
k_1	=	sealing factor for service condition [mm]
k_o	=	sealing factor for assembled condition [Nmm]
K_D	=	sealing material deformation factor [N/mm^2]

10.4 Calculation

10.4.1 Bolted joints are to be designed for the following load conditions:

a) Service conditions (design pressure p_c and design temperature t),

b) Load at test pressure (test pressure p’, t = 20 °C) and

c) Assembled condition at zero pressure (p = 0 bar, t = 20 °C).

10.4.2 The necessary root diameter of a bolt in a bolted joint comprising n bolts is given by:

$$d_k = \sqrt{\frac{4 \cdot F_S}{\pi \cdot \sigma_{perm} \cdot \varphi \cdot n}} + c \tag{27}$$

10.4.3 The total load on a bolted joint is to be calculated as follows:

for service conditions

$$F_S = F_B + F_D + F_Z \tag{28}$$

$$F_B = \frac{{D_b}^2 \cdot \pi}{4} \cdot \frac{p_c}{10} \tag{29}$$

$$F_D = D_b \cdot \pi \cdot k_1 \cdot \frac{p_c}{10} \cdot 1,2 \tag{30}$$

(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 is to be calculated due to the load condition of connected piping. F_Z is 0 in the case of bolted joints with no connected pipes. Where connecting pipes are installed in a normal manner and the service temperatures are < 400 °C, F_Z may be determined, as an approximation, by applying the expression :

$$F_Z \approx \frac{d_i^2 \cdot \pi}{4} \cdot \frac{p_c}{10}$$

for the test pressure:

$$F^1{}_S = \frac{p_p}{p_c} \cdot \left(F_B + \frac{F_D}{1,2}\right) + F_Z \qquad (31)$$

For calculating the root diameter of the thread, F_s is to be substituted by F_s' in formula (27). for the zero-pressure, assembled condition:

$$F_{So} = F_{Do} + F_Z \qquad (32)$$

$$F_{Do} + D_b \cdot n \cdot k_0 \cdot K_D \qquad (33)$$

For calculating the root diameter of the thread, F_s is to be substituted by F_{So} in formula (27).

In the zero-pressure, assembled condition, the force F_{Do} is to be exerted on the bolts during assembly to effect an intimate union with the jointing material and to close the gap at the flange bearing surfaces.

If the force exerted on assembly F_{Do} > F_s, this value may be replaced by the following where malleable jointing materials with or without metal elements are used:

$$F_{Do}' = 0,2 \cdot F_{Do} + 0,8 \cdot \sqrt{F_a} \cdot F_{Do} \qquad (34)$$

Factors k_o, 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 7.16 and 7.17.

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 10.4.1 a) to 10.4.1 c).

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 7.14.

10.7 Quality coefficient Φ

10.7.1 Full-shank bolts are required to have a surface finish of at least grade mg according to DIN EN ISO 898. Necked-down bolts are to be machined all over.

10.7.2 In the case of unmachined, plane-parallel bearing surfaces, φ = 0,75. Where the bearing surfaces of the mating parts are machined, a value of φ = 1,0 may be used. Bearing surfaces which are not plane-parallel (e.g. on angle sections) are not permitted.

Table 7.14: 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	$\frac{R_{eH,20°}}{1,1}$	$\frac{R_{eH,20°}}{1,2}$

10.8 Allowance c

The allowance c shall be as shown in Table 7.15.

Table 7.15: Allowances c

Condition	c [mm]
For service conditions: up to M 24 M 27 up to M 45 M 48 and over	 3,0 $5 - 0,1 \cdot d_k$ 1,0
for test pressure	0
for assembled condition	0

E. Equipment and Installation

1. General

1.1 The following requirements apply to steam boilers which are not constantly and directly monitored during operation.

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 vessel.

1.3 In the case of steam boilers which have a maximum water volume of 150 litres, a maximum allowable working pressure of 10 bar and where the product of water volume and maximum allowable working pressure is less than 500 [bar 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 Electrical Installations (Pt.1, Vol. IV), and Rules for Automations (Pt.1, Vol.VII), are to be observed.

The equipment of steam boilers is to be suitable for the use on steam boilers and ships.

2. Safety valves

2.1 Each steam boiler 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 m^2 are to be equipped with one, with a heating surface above 50 m^3 with at least two, suitable type-approved, spring-loaded 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. bellow valves).

2.2.2 As far as steam boilers with a great water space which are exhaust gas heated and can be shut-off are not equipped with safety valves according to 2.2.1, a burst disc is to be provided in addition to the existing safety valves. This disc shall exhaust the maximum quantity of steam produced during continuous operation. The activation pressure of the burst disc shall not exceed 1,25 times the maximum allowable working pressure.

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 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 super heaters with no shut-off capability, one safety valves is to be located at the discharge from the super heater . The safety valve at the super heater discharge has to be designed for at least 25% of the necessary exhaust capacity.

Super heaters with shut-off capability are to be fitted with at least one safety valve designed for the full steam capacity of the super heater.

When designing the capacity of safety valves, allowance is to be made for the increase in the volume of steam caused by super heating.

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-offside 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 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) 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 boiler control station respective from the station for control of the water level.

3.8 The connection pipes between steam generator 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 chamber of the 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 approved 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 indicators

4.1 At least one pressure gauge directly connected to the steam space is to be fitted on each boiler. The maximum allowable working pressure is to be marked on the dial by means of a permanent and easily visible red mark. The indicating range of the pressure gauge shall include the testing pressure.

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 space 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 shall have a water trap and is to be of a blow-off type. A connection for a test gauge is to be installed close to the pressure gauge. In the case of pressure gauges which are at a lower position the test connection have to 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 shall be well illuminated.

5. Temperature indicators

5.1 A temperature indicator is to be fitted to the flue gas outlets of fired steam boilers.

5.2 Temperature indicators are to be fitted to the exhaust gas inlet and outlet of steam boilers heated by exhaust gas.

5.3 Temperature indicators are to be fitted at the outlets from super heaters or super heater sections, at the inlet and outlet of attemporators, and also at the outlet of once-through forced flow boilers, where this is necessary to assess the behavior of the materials used.

5.4 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

5.5 The maximum allowable temperature is to be marked at the indicator

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 oil burners. In main boilers, the control facility is to be capable of safely controlling all rates of speed and maneuvers so that the steam pressure and the temperature of the super-heated 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 The steam pressure shall 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 steam generators which have a specified minimum water level, the water level is to be regulated automatically by controlling the supply of feed water.

6.4 In the case of forced-circulation steam generators whose heating surface consists of a steam coil and of once-through forced flow steam generators, the supply of feed water may be regulated as a function of fuel supply.

6.5 In the case of steam generators which are fitted with super heaters, the temperature of the superheated steam shall be automatically regulated unless the calculated temperature is higher than the maximum attainable temperature of the super heater 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 The proof of the suitability of alarm transmitters for e.g. pressure, water level, temperature and flow for the use at steam boilers and on ships is to be demonstrated by a type approval examination according to the requirements of BKI Rules listed in I.A.2.1.

7.2 A warning device is to be fitted which is tripped when the specified maximum water level is exceeded.

7.3 In exhaust-gas heated steam generators, a warning device is to be fitted which is tripped before the maximum allowable working pressure is reached.

7.4 In exhaust-gas heated steam generators with a specified minimum water level, a warning device suitable for this purpose is to be fitted which is tripped when the water falls below this level.

7.5 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.

7.6 Where there is a possibility of oil or grease getting into the steam or condensate or hot water system, a suitable automatic and continuously operating unit is to be installed which trips an alarm and cuts off the feed water supply or the circulation resp. if the concentration at which boiler operation is put at risk is exceeded. The control device for oil respectively grease ingress may be waived for a dual circulation system.

7.7 Where there is a possibility of acid, lye or seawater getting into the steam, condensate or hot water 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. The control device for oil resp. grease ingress may be waived for a dual circulation system

7.8 It shall 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.

7.9 The monitoring devices have to trip visual and audible fault warnings at steam boiler control panel.

8. Safety devices (Limiters)

8.1 The proof of the suitability of limiters for e.g. pressure, water level, temperature and flow for the use at steam boilers and on ships is to be demonstrated by a type approval examination according to the requirements of BKI Rules listed in I.A.2.1.

8.2 Fired Steam Generator are to be equipped with a pressure limiters which cuts out and interlocks the oil burner the maximum allowable working pressure is reached.

8.3 In steam generator on whose heating surfaces a highest flue is specified, two mutually independent water level limiters have to respond to cut out and interlock the firing system when the water falls below the specified minimum water level.

The water level limiter shall also be independent of the water level control devices.

8.4 The receptacles for water level limiters located outside the steam boiler are to be connected to the boiler by means of lines which have a minimum inner diameter of 20 mm. Shut-off devices in these lines shall have a nominal diameter of at least 20 mm and have to 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 are to have an inner diameter of at least 40 mm.

Operation of the oil burner shall only be possible when the shut-off devices are open or else, after closure, the shut-off devices are reopening 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 is to be carried out.

8.5 In the case of forced-circulation steam generator with a specified lowest water level, two mutually independent safety devices are to be fitted in addition to the requisite water level limiters, which will cut out and interlock the oil burner in the event of any unacceptable reduction in water circulation.

8.6 In the case of forced-circulation steam generator where the heating surface consists of a single coil and once-through forced flow steam generator, two mutually independent safety devices are to 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 oil burner.

8.7 In steam boilers with super heaters, 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 Hot water generators are to be equipped with the following safety equipment

8.8.1 A pressure limiter, which shuts-down and interlocks the oil burner in case the maximum allowable working pressure is exceeded (high pressure limiter), shall be provided at each hot water generator with membrane expansion vessel. 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.

8.8.2 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.

8.8.3 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.

8.8.4 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.

8.8.5 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.

8.8.6 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.

8.9 The safety devices have to trip visual and audible alarms at the steam boiler control panel.

8.10 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.

8.11 To reduce the effects due to sea conditions, water level limiters can be fitted with a delay function provided that this does not cause a dangerous drop in the water level.

8.12 The electrical interlocking of the oil burner following tripping by the safety devices is only to be cancelled out at the oil firing system control panel itself.

8.13 If an equivalent degree of safety cannot be achieved by the self-monitoring of the equipment, the functional testing of the safety devices shall be practicable even during operation. In this case, the operational testing of water level limiters shall be possible without dropping the surface of the water below the lowest water level.

8.14 For details of additional requirements relating to once-through forced flow steam boilers, see 3.4.

9. Feed and circulation devices

9.1 For details of boiler feed and circulation devices see Section 11, F. The following requirements are also to be noted:

9.2 The feed devices are to be fitted to the steam generator 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 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 boilers which have different maximum allowable working pressures give off their steam into common lines, it has to be ensured that the maximum working pressure allowable for each boiler cannot be exceeded in any of the boilers.

10.3 Where there are several boilers which are connected by common pipes and the shut-off devices for the steam, feed and drain lines are welded to the boiler, for safety reasons while the boilers are running, two shut-off devices in series which are to be protected against unauthorized operation are each to be fitted with an interposed venting device.

10.4 For plants consisting of boilers without own steam space, which are using an oil fired boiler 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 and sampling devices

11.1 Steam 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 are to be protected from the effects of the heating gases and capable of being operated without risk. Self-closing sludge removal valves shall 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, drain or venting lines, plus valves and fittings, are to be designed to allow for the maximum allowable working pressure of the boiler.

11.5 With the exception of once-through forced flow steam generator, devices for taking samples from the water contained in the steam generator to be fitted to generator

11.6 Scum removal, sludge removal, drain and sampling devices are to be capable of safe operation. The media 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 is to 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 are to be made of ductile materials as specified in Table 7.1 and all their components shall 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 7.1, but shall not be employed for valves and fittings which are subjected to dynamic loads, e.g. safety valves and blow-off valves.

Testing of materials for valves and fittings is to be carried out as specified in Table 7.2

13.2 Type of 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 are to 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 maximum allowable working pressure. In this case, the safety factor in respect of the 20 °C yield strength value shall 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 maximum allowable 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 times maximum allowable working pressure; maximum 2 bar)
- tightness test with saturated or superheated steam (test pressure shall not exceed the maximum allowable working pressure)
- a 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 BKI Surveyor.

14. Installation of boilers

14.1 Mounting

Boilers are to be installed in the ship with care and have to 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 seating are to be well accessible from all sides or shall be easily made accessible.

14.2 Fire precautions

See Section 12.

F. Testing of Steam Boilers

1. Constructional check

After completion, boilers are to undergo a constructional check.

The constructional check includes verification that the steam boiler agrees with the approved drawing and is of satisfactory construction. For this purpose, all parts of the steam boiler are to be accessible to allow adequate inspection. If necessary, the constructional check 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.

2. Hydrostatic pressure tests

2.1 A hydrostatic pressure test is to be carried out on the boiler before refractory, insulation and casing are 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. Steam Boiler surfaces have to withstand the test pressure without leaking or suffering permanent deformation.

2.2 The test pressure is generally required to be 1,5 times the maximum allowable working pressure, see A.4.2. In case the maximum allowable working pressure is less than 2 bar, the test pressure has to be at least 1 bar higher than the maximum allowable working pressure.

Hot water generators are to be subjected to a minimum test pressure of 4 bar

2.3 In the case of once-through forced flow boilers, the test pressure has to 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.

2.4 For steam 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 I.D.1.2.4.

3. Acceptance test after installation on board

3.1 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.

3.2 Test of safety valves

3.2.1 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.

3.2.2 The sufficient blow-off performance of the safety valves has to be proven by a blow-off test. For oil fired steam boilers the sufficient blow-off performance may also be demonstrated by calculation.

For steam boiler 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% burner performance and the above mentioned conditions for operation of the exhaust gas boiler.

3.3 **Functional test** The complete equipment of the boiler, including control and monitoring devices, are to be subjected to a functional test.

4. Constructional check and hydrostatic pressure test and acceptance test shall be carried out by or in the presence of the BKI Surveyor.

G. Hot Water Generators Plants

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 8.

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 pre-pressurized 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 oil-fired hot water generator shall be carried out if the flow falls below the specified minimum value.

H. Flue Gas Economizers

1. Definition

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 sub section I.B.

3. Calculation

The formulae given under I.D are to be applied in the calculation. The design pressure is to be at least the maximum allowable working pressure of the economizer.

The design temperature is the maximum feed water temperature plus 25 °C for plain tube economizers and plus 35 °C for finned tube economizers.

The feed water temperature at the economizer outlet shall be 20 °C below the saturation temperature corresponding to the working pressure of the boiler.

4. Equipment

4.1 Pressure gauges

The inlet side of each economizer is to be provided with a 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 at that it starts to blow-off if the maximum allowable working pressure is exceeded.

The safety valve is to be designed that, even if shut-off 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 indicating device

Each economizer is to be equipped with one temperature indicating device. The permissible outlet temperature of the feed water is to be marked in red on the temperature meter.

4.4 Shut-off devices

Each economizer is to be equipped with shut-off device at the feed water 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 feed water 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

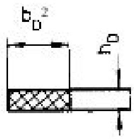
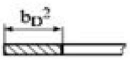
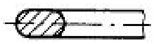
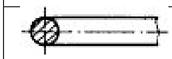
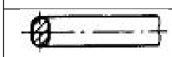
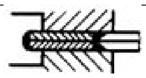
A name plate giving the following details is to be fitted to every economizer:

— manufacturer’s name and address

— serial number and year of manufacture

— maximum allowable working pressure of economizer in bar

Table 7.16: Gasket factors

Gasket type	**Shape**	**Description**	**Material**	**Gasket factor** [1]					
				for liquids			**for gases and vapours**		
				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 according to DIN EN 1514-1	Impregnated sealing material	—	20 b_D	b_D	—	—	—
			Rubber	—	b_D	0,5 b_D	—	2 b_D	0,5 b_D
			Teflon	—	20 b_D	1,1 b_D	—	25 b_D	1,1 b_D
			It [4]	—	15 b_D	b_D	—	$200\sqrt{\frac{b_D}{h_D}3}$	1,3 b_D
Combined metal and soft gaskets		Spirally wound gasket	Unalloyed steel	—	15 b_D	b_D	—	50 b_D	1,3 b_D
		Corrugated gasket	Al	—	8 b_D	0,6 b_D	—	30 b_D	0,6 b_D
			Cu, Ms	—	9 b_D	0,6 b_D	—	35 b_D	0,7 b_D
			Mild steel	—	10 b_D	0,6 b_D	—	45 b_D	1,0 b_D
		Metal-sheated gasket	Al	—	10 b_D	b_D	—	50 b_D	1,4 b_D
			Cu, Ms	—	20 b_D	b_D	—	60 b_D	1,6 b_D
			Mild steel	—	40 b_D	b_D	—	70 b_D	1,8 b_D
Metal gaskets		Flat gasket according to DIN EN 1514-4	—	0,8 b_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 according to DIN 2696	—	1,6	—	6	2	—	6
Metal gaskets	 Z = Number of teeth	Corrugated gasket to DIN 2697	—	0,4 $\sqrt{Z}$	—	9+0,2 · Z	0,5 $\sqrt{Z}$	—	9+0,2 · Z
		Membrane welded	—	0	—	0	0	—	0

[1] applicable to flat, machined, sound, sealing surfaces.

[2] where ko cannot be specified, the product $k_o \cdot K_D$ is given here

[3] a gastight grade is assumed

[4] non asbestos compressed fibre jointing material

Table 7.17: Deformation factors

Materials	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

Note

At room temperature K_D is to be substituted by the deformation factor at 10% compression or alternatively by the tensile strength R_m.

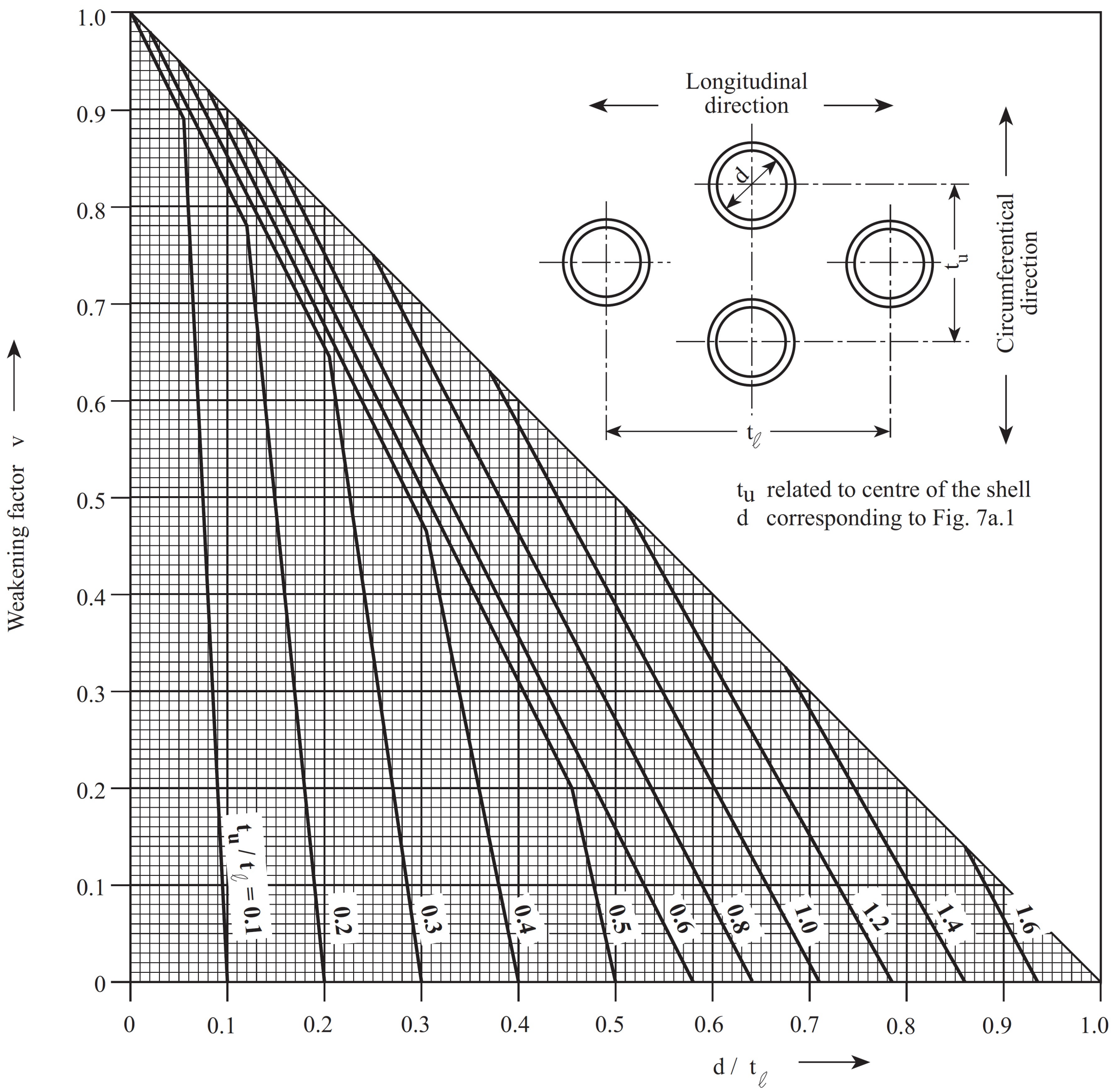


Figure 7.27: Weakening factor v for cylindrical shells with symmetrically staggered rows of holes

6. Tests

Before they are installed, finished economizers are to be subjected at the maker's works to a constructional check and a hydrostatic pressure test at 1,5 times the maximum allowable working pressure in the presence of a BKI Surveyor.

7. Shell Type Exhaust Gas Heated Economizers

This is applicable to 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.

All shell type exhaust gas heated economizers that may be isolated from the steam plant system in a flooded condition and which are fitted on board ships contracted for construction on or after 1 January 2007 are to comply with this section.

7.1 Design and Construction

Design and construction of shell type economizers are to pay particular attention to the welding, heat treatment and inspection arrangements at the tube plate connection to the shell.

7.2 Pressure Relief

7.2.1 Where a shell type economizer is capable of being isolated from the steam plant system, it is to be provided with at least one safety valve, and when it has a total heating surface of 50 m2 or more, it is to be provided with at least two safety valves in accordance with the classification society requirements.

7.2.2 To avoid the accumulation of condensate on the outlet side of safety valves, the discharge pipes and/or safety valve housings are to be fitted with drainage arrangements from the lowest part, directed with continuous fall to a position clear of the economizer where it will not pose threats to either personnel or machinery. No valves or cocks are to be fitted in the drainage arrangements.

7.2.3 Full details of the proposed arrangements shall be submitted for approval.

7.3 Pressure Indication

Every shell type economizer is to be provided with a means of indicating the internal pressure. A means of indicating the internal pressure is to be located so that the pressure can be easily read from any position from which the pressure may be controlled.

7.4 Lagging

Every shell type economizer is to be provided with removable lagging at the circumference of the tube end plates to enable ultrasonic examination of the tube plate to shell connection.

7.5 Feed Water

Every economizer is to be provided with arrangements for pre-heating and de-aeration, addition of water treatment or combination thereof to control the quality of feed water to within the manufacturer's recommendations.

7.6 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.

II. Thermal Oil Systems

A. General

1. Scope

The following requirements apply to thermal oil systems in which organic liquids (thermal oils) are heated by oil fired burners, exhaust gases or electricity to temperatures below their initial boiling point at atmospheric pressure.

2. Other applicable requirements

In addition, the following BKI Rules and Guidelines are to be applied analogously:

Section 7.I, B, C, and D	For materials, fabrication and design of the heaters
Section 8, B, C and D	For materials fabrication and design of the expansion vessel and the tanks
Section 9, A and B	For oil burners and oil firing systems (additional shutdown criteria see II.B.4 and II.C.4)
Section 10, A, B and D	For thermal oil tanks
Section 11, A to D, Q and R	For pipes, valves and pumps
Section 12	For fire protection and firefighting equipment
Rules for Electrical Installations (Pt.1, Vol.IV)	For electrical equipment items
Rules for Automations (Pt.1, Vol.VII)	For automated machinery systems
Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W)	For type approved components

3. Definitions

3.1 The “maximum allowable working pressure” is the maximum pressure which may occur in the individual parts of the equipment under service conditions.

3.2 The “thermal oil temperature” is the temperature of the thermal oil at the centre of the flow cross-section.

3.3 The “discharge temperature” is the temperature of the thermal oil immediately at the heater outlet.

3.4 The “return temperature” is the temperature of the thermal oil immediately at the heater inlet.

3.5 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.

4. Documents for approval

The following documents are to be submitted for approval to BKI in electronic format:

- a description of the system stating the discharge and return temperatures, the maximum allowable film temperature, the total volume of the system and the physical and chemical characteristics of the thermal oil
- drawings of the heaters, the expansion vessel and other pressure vessels
- circuit diagrams of the electrical control system, respectively monitoring and safety devices with limiting values
- a functional diagram with information about the safety and monitoring device and valves provided (for information)

If specially requested, mathematical proof of the maximum film temperature in accordance with DIN 4754 is to be submitted.

5. Thermal Oils

5.1 The thermal oil has to 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.

5.2 Thermal oil may only be used within the limits set by the manufacturer. A safety margin of about 50°C is to be maintained between the discharge temperature and the maximum allowable film temperature specified by the manufacturer.

5.3 Precautions are to be taken to protect the thermal oil from oxidation.

5.4 Copper and copper alloys, which lead due to their catalytic effect to an increased ageing of the thermal oil, are to be avoided or oils with specific additives are to be used.

6. Manual operation

6.1 For thermal oil heaters 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.

6.1.1 At least the temperature limiter on the oil side and the flow limiter shall remain operative at the oil- fired heater.

6.1.2 The heater heated by exhaust gas may be operated without temperature and flow monitoring if the allowable discharge temperature can be kept.

6.1.3 The safety equipment not required for manual operation may only be deactivated by means of a key- operated switch. The actuation of the key operated switch is to be indicated.

6.1.4 For details of requirements in respect of the manual operation of the oil firing equipment, see Section 9.

6.2 Manual operation demands constant and direct supervision of the system.

B. Heaters

1. Acceptable materials

Heaters of thermal oil systems are to be fabricated from the same materials as boilers as per I.B.2.

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 I.B.3.

For coils with a maximum allowable working pressure up to 10 bar and an allowable operating temperature up to 300 °C Manufacturer Inspection Certificates[2)]

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 10 bar.

3.3 Heaters heated by exhaust gas are to be designed that damages by resonances resulting from oscillation of the exhaust gas column cannot occur.

3.4 The exhaust gas intake is to be arranged that the thermal oil cannot penetrate the engine or the turbocharger in case of a leakage in the heater respectively the cleaning medium 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.

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.

4. Equipment

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 and alarm transmitters e.g. temperature, flow and leakage detection is to be demonstrated by a type approval examination according to the requirements of BKI Rules listed in II.A.2.

4.1.2 The alarms and the activation of the limiters have to create optical and acoustic fault signal at the thermal oil system panel.

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 indicating devices

4.3.1 Pressure indicating 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 indicated on the scale by a red mark which is permanently fixed and well visible. The indicating range has to include the test pressure.

[2)] See Rules for Materials (Pt. 1, Vol.V), Section 1

4.3.2 Temperature indicating devices are to be fitted at the discharge and return line of both oil fire heaters and heaters heated by exhaust gas.

4.3.3 Temperature indicating devices are also to be fitted in the flue gas or exhaust gas outlet at the heater's respectively.

4.3.4 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 9.

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 recooling 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 oil burner is to be switched off and interlocked by temperature limiters.

Parallel-connected heating surfaces are to be monitored individually at the discharge side of each coil. At the oil-fired 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.

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.

4.5.3 If the specified maximum flue gas temperature of the oil fired heaters is exceeded, the firing system is to be switched off and be interlocked.

4.5.4 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 are to 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 is to 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 is to be prevented by interlocks if the circulating pump is at stand still.

4.6.4 A flow monitor is to 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 provided for the case that the flow through the heater heated by exhaust gas falls below the minimum value (e.g. at standstill of the circulating pump, closed shut-off valves), when 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 oil burner. If the oil fired heater is in "stand-by" the starting of the oil 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.

4.8 Shut-off devices

4.8.1 Heaters are to be fitted with shut-off devices and, if necessary with by-pass valves, which can 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 extinguishing system

4.9.1 The temperature switch for fire detection, required according to Section 12, C.4.3 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.

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 12, Table 12.1 and L.2.2.

C. Vessels

1. Approved materials

Vessels are to be fabricated from the materials conforming to Section 8, B.3., 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 8, B.4

3. Design

3.1 All vessels, including those open to the atmosphere, are to be designed for a pressure of at least 2 bar, unless provision has to be made for a higher working pressure. Excepted from this requirement are tanks designed and dimensioned according to Rules for Hull (Pt.1, Vol.II) Sec.12.

3.2 An expansion vessel is to be placed at the high level in the system. 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 litres. The volume is the total quantity of thermal oil contained in the equipment up to the lowest liquid level in the expansion vessel.

3.3 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.

3.4 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.

3.5 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 the expansion vessel

4.1 General

4.1.1 The equipment on the expansion vessel has to be suitable for use at thermal oil system and on ships. The proof of suitability of the level indicator and the limiters and alarm transmitters for e.g. filling level is to be demonstrated by a type approval examination according to the requirements of the Rules listed in II.A.2.

4.1.2 The alarms and the activation of the limiters have to create optical and acoustic fault signals at the thermal oil system control panel.

4.2 Level indication device

4.2.1 The expansion vessel is to be equipped with a liquid 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 alarm

4.3.1 A limit switch is to be fitted which shuts down and interlocks the oil burner 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 level indicator which gives an early warning of a falling liquid level in the expansion vessel (e.g. in the event of 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 actuation of the emergency shut off device shall activate an alarm. At the same time a non safety related shut-down of the oil burner at the oil fired heater should be carried out.

4.4.5 The dimensions of the drainage and venting pipes are to be applied according to Table 7.18.

Table 7.18: 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 Nominal diameter	Drainage and venting pipes Nominal diameter DN
$\leq$ 600	25	32
$\leq$ 900	32	40
$\leq$ 1.200	40	50
$\leq$ 2.400	50	65
$\leq$ 6.000	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 in a way that that a pressure increase 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 to the drainage tank.

4.5.4 All parts of the system in which thermal oil can expand due t 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 7.18.

4.6 Pre-pressurized system

4.6.1 Pre-pressurized 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.

4.6.3 A pressure limiter is to be provided at the expansion vessel which gives an alarm and shuts down and interlocks the oil burner at a set pressure below the set-pressure of the safety valve.

5. Equipment of the drainage and storage tank

For the equipment of the drainage and storage tank see Section 11.P.4.

D. Equipment Items

1. Approved materials

1.1 Materials for pipes, valves and pumps see Section 11, B.

1.2 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 11, B.3.

3. Equipment

3.1 Pipes, valves and pumps are governed, in addition to the following specifications, by the provisions of Section 11, P

3.2 The outlets of the circulating pumps are to be equipped with pressure gauges.

3.3 It shall 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.

3.4 Devices for safe sampling are to be provided at a suitable location in the thermal oil circuit.

3.5 Means of venting are to be provided at the highest point of the isolatable sections of the thermal oil system and drainage devices at the lowest points.

Venting and drainage via open funnels are to be avoided.

3.6 For filling and draining pumps see Section 11, P.1.2

3.7 Electric equipment items are governed by the Rules for Electrical Installations (Pt.1, Vol.IV).

E. Marking

1. Heaters

The following information shall be stated on a durable manufacturer's name plate 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 2 bar is taken as the design basis in accordance with II.C.

F. Fire Protection

The fire precautions are governed by the provisions of Section 12.

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 BKI 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 functional tests in the presence of the BKI Surveyor.

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Section 8 Pressure Vessels and Heat Exchangers

A. General

1. Scope

1.1 The following requirements apply to essential pressure vessels (gauge or vacuum pressure) see Section 1, H. They also apply to independent cargo containers if these are subjected to internal or external pressure in service.

Gas cylinders are subject to the requirements in G.

1.2 These requirements do not apply to pressure vessels with

- a maximum allowable working pressure of up to 1 bar gauge and a total capacity, without deducting the volume of internal fittings, of not more than 1000 ℓ, or
- a maximum allowable working pressure of up to 0,5 bar gauge, or
- a capacity of $\leq$ 0,5 ℓ

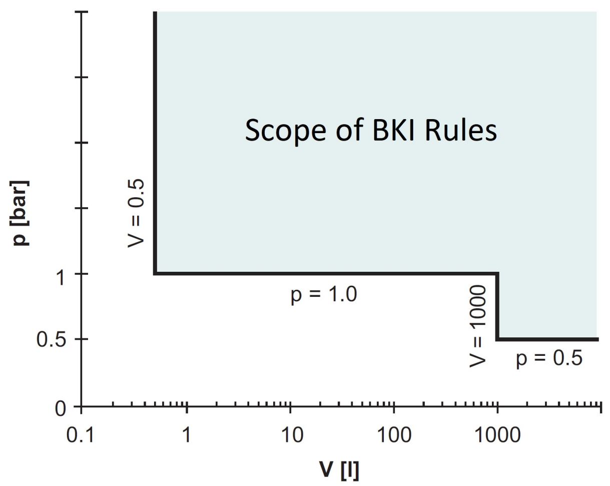

Figure 8.1: Scope of BKI Rules for pressure vessels and heat exchangers

1.3 Ship's service pressure vessels manufactured to 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 hydrophore tanks with a maximum allowable working pressure of up to 7 bar gauge and a maximum working temperatures of 100 °C an examination of the drawings can be dispensed with.

1.5 For warm water generators with an 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 a recognized Standard or Directive. The stresses coming from the installation onboard ships have to be considered.

1.6 The pressure vessels and equipment mentioned in 1.3 and 1.4 and 1.5 are demonstrated to the BKI Surveyor for constructional check and for a hydrostatic pressure test in accordance with F.1. For the materials Manufacturer Test Reports[1)] are to be presented.

1.7 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 7.I.A-B

Surface condensers are additionally subject to Section 3.I and 3.II.

For charge air coolers, see Section 2, an examination of the drawing of the drawings can be dispensed with.

For heat exchangers of cooling systems for electrical machinery an examination of the drawings can be dispensed with, further requirements see the Rules for Electrical Installations (Pt.1, Vol.IV), Sec. 20.

Cargo containers and process pressure vessels for the transport of liquefied gases in bulk are additionally subject to Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol.IX).

For reservoirs in hydraulic systems additionally Section 14, F. is to be applied.

For filters additionally Section 2, G.3. (diesel engines) as well as Section 11, 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.

1.8 Pressure vessels and heat exchangers produced in series may be approved, tested and certified according to Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W) Sec.2.N.

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 BKI in electronic format. In particular, are to be specified:

- intended use, substance to be contained in the vessels
- maximum allowable working pressure and temperatures, if necessary, secondary loads, volume of the individual pressure spaces
- design details of the pressurized parts
- materials to be used, welding details, heat treatment

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).

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 8.1, have to comply with the Rules for Materials (Pt.1, Vol.V).

[1)] See Rules for Materials (Pt.1, Vol. V), Principles Covering the Manufacture and Testing of Materials, Section 1

1.2 Parts such as gussets, girders, lugs, 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 8.1 are also subject to the Rules for Welding (Pt.1, Vol.VI).

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 8.1.

2.2 Pressure vessels filled partly with liquids and partly with air or gases or which are blown out by air or gases are to be classified as pressure vessels containing air or gas.

Table 8.1: Pressure vessel classes

Operating medium	**Design pressure p_c [bar] Design temperature t [°C]**		
Pressure vessel class	**I**	**II**	**III**
Testing of Materials / Test Certificates	see 4.1	see 4.2	see 4.3
Liquefied gases (propane, butane, etc), toxic and corrosive media	All	—	—
Refrigerants	Group 2	Group 1	—
Steam, compressed air, gases	$p_c > 16$ or $t > 300$	$p_c \leq 16$ and $t \leq 300$	$p_c \leq 7$ and $t \leq 170$
Thermal oils	$p_c > 16$ or $t > 300$	$p_c \leq 16$ and $t \leq 300$	$p_c \leq 7$ and $t \leq 150$
Liquid fuels, lubricating oils, flammable hydraulic fluids	$p_c > 16$ or $t > 150$	$p_c \leq 16$ and $t \leq 150$	$p_c \leq 7$ and $t \leq 60$
Water non-flammable hydraulic fluids	$p_c > 40$ or $t > 300$	$p_c \leq 40$ and $t \leq 300$	$p_c \leq 16$ and $t \leq 200$

3. Approved materials

The materials specified in Table 8.2 are to be used for the classes stated in 2.

4. Testing of Materials

4.1 Tests according to Rules for Materials (Pt.1, Vol.V), are prescribed for materials belonging to pressure vessel class I used for :

- all parts subject to pressure with the exception of small parts such as welded pads, reinforcing discs, branch pieces and flanges of nominal diameter ≤ DN 50 mm, together with forged or rolled steel valve heads for compressed air receivers.
- forged flanges for service temperatures > 300 °C and for service temperatures ≤ 300 °C if the product of the maximum allowable working pressure (gauge) PB [bar] and DN [mm] is > 2.500 or the nominal diameter is > DN 250.
- bolts of metric size M 30 and above made of steels with a tensile strength of more than 500 N/mm^2 and alloyed or heat-treated steel bolts of metric size M 16 and above.

- nuts of metric size M 30 and above made of steels with a tensile strength of more than 600 N/mm^2.
- bodies of valves and fittings, see Section 11, B.

The results of the material tests are to be proven by BKI Material Certificate [1)].

4.2 For pressure vessel class II parts subject to mandatory testing, proof of material quality may take the form of Manufacturer Inspection Certificates[1)] provided that the test results certified therein comply with the Rules for Materials (Pt.1, Vol.V).

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 [bar] DN [mm] ≤ 2.500 and the nominal diameter DN ≤ 250 mm for service temperature ≤ 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[1)].

C. Manufacturing Principle

1. Manufacturing processes

Manufacturing processes shall be suitable for the materials.

Materials which grain structure has been adversely affected by hot or cold working are to undergo heat treatment in accordance with the Rules for Materials (Pt.1, Vol.V) Sec. 6.A.

2. Welding

The execution of welding work, the approval of welding shops and the qualification testing of welders are governed by the Rules for Welding (Pt.1, Vol.VI), Sec. 14.

Table 8.2: Approved materials

<table>
<tr><th colspan="2" rowspan="2">Materials and product form</th><th colspan="3">Grades of materials in accordance with the (Rules for Materials (Pt.1, Vol. V) Pressure vessel class</th></tr>
<tr><th>I</th><th>II</th><th>III</th></tr>
<tr><td rowspan="13">Rolled and forged steel</td><td rowspan="5">Steel plate, shapes and bars</td><td colspan="3">Plates for boilers and pressure vessels acc. to Section 4, E</td></tr>
<tr><td colspan="3">Low-temperature steels acc. to Section 4, F</td></tr>
<tr><td colspan="3">Austenitic stainless steels acc. to Section 4, G</td></tr>
<tr><td rowspan="2">Specially killed steels acc. to Section 4, C. (with testing of each rolled plate),</td><td colspan="2">General structural steels acc. to Section 4, C [1)]</td></tr>
<tr><td>—</td><td>Shipbuilding steels acc. to Section 4, B.</td></tr>
<tr><td rowspan="3">Pipes</td><td colspan="3">Seamless and welded ferritic steel pipes acc. to Section 5, B. and C.</td></tr>
<tr><td colspan="3">Low temperature steel pipes acc. to Section 5, D. for design temperatures below -10 °C</td></tr>
<tr><td colspan="3">Austenitic stainless-steel pipes acc. to Section 5, E.</td></tr>
<tr><td rowspan="3">Forgings</td><td colspan="3">Forgings acc. to Section 6, E.</td></tr>
<tr><td colspan="3">Low temperature steel forgings acc. to Section 6, F. for design temperatures below -10 °C</td></tr>
<tr><td>—</td><td colspan="2">Forgings for general plant engineering acc. to Section 6, B.</td></tr>
<tr><td rowspan="3">Bolts and nuts</td><td colspan="3">Bolts for general plant engineering to recognized standards, e.g. DIN 267 or ISO 898</td></tr>
<tr><td colspan="3">High-temperature steels for design temperatures >300 °C</td></tr>
<tr><td colspan="3">Low-temperature steels for design temperatures below -10 °C</td></tr>
<tr><td rowspan="6">castings</td><td rowspan="4">Cast steel</td><td colspan="3">Steel casting for boilers, pressure vessels and pipelines, Section 7, D.</td></tr>
<tr><td colspan="3">High-temperature steel casting for design temperature >300 °C</td></tr>
<tr><td colspan="3">Low temperature steel castings, Section 7, E. for design temperature below - 10 °C</td></tr>
<tr><td colspan="2">—</td><td>Steel casting for general application</td></tr>
<tr><td>Nodular cast iron</td><td colspan="3">Nodular cast iron according to Section 8, B.
— Ferritic grades only
— Standard grades up to 300 °C
— Special grades up to 350 °C</td></tr>
<tr><td>Grey cast iron</td><td colspan="2">—</td><td>At least grade GG 20, Section 8, C.
Not permitted for vessels in thermal oil systems</td></tr>
<tr><td rowspan="2">Non-ferrous metals</td><td>Pipes and castings of copper and copper alloys</td><td colspan="3">Copper alloys according to Section 11, within following limits:
— copper-nickel alloys up to 300 °C
— high temperature bronzes up to 260 °C
— others up to 200 °C</td></tr>
<tr><td>Plates, pipes and castings of aluminium alloys</td><td colspan="3">Aluminium alloys according to Section 10, within the following limits:
— Design temperature up to 200 °C
— only with the special agreement of BKI</td></tr>
<tr><td colspan="5">1) Instead of unalloyed structural steel also hull structural steel according to Section 4,B may be applied</td></tr>
</table>

Table 8.3: 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 (Pt.1, Vol. VI) Rules for Welding, Sec. 2	required	required	—
Welding Procedure Test, see (Pt.1, Vol. VI) Rules for Welding, Sec. 4	required	required	—
Testing of Materials / Test Certificates	BKI Material Certificates, see 4.1	Manufacturer Inspection Certificates, see 4.2	Manufacturer Test Report, see 4.3
BKI 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, see (Pt.1, Vol. VI) Rules for Welding, Sec. 10	required	required	required
	for welding seams radiographic examination depends on weld factor v		

3. End plates

3.1 The flanges of dished ends may not be unduly hindered in their movement by any kind of fixtures, e.g. fastening plates of 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 dimensioned as to enable additional external stresses to be safely absorbed. The wall thickness of welded-in branch pipes shall 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 11 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

Vessels and equipment exposed to accelerated corrosion owing to the medium which they contain (e.g. warm seawater) are to be protected in a suitable manner.

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 7.I.C.8.

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 transversed does not exceed 250 mm.

Vessels over 2,0 m in length are to have inspection openings at each end at least or shall contain a manhole. Vessels with an inside diameter of more than 800 mm are to 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. 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 maximum allowable temperature of the pressurized parts. On smaller items of equipment, an indication of the working pressures is sufficient.

D. Calculation

1. Principles

1.1 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 7.I.D.) and otherwise in accordance with the general rules of engineering practice[2)]. The calculations parameters according to 1.2 to 1.7 are to be used.

1.2 Design pressure p_c

1.2.1 The design pressure pc is generally the maximum allowable working pressure (gauge) P_B. 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 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 1 bar 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 1 bar.

[2)] The TRB/AD (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 Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol.IX). Vessels and equipment in refrigerating installations are governed by Rules for Refrigerating Installations (Pt.1, Vol.VIII) Sec. 1, C.

1.3 Allowable stress

The dimensions of components are governed by the allowable stress σ_{perm} [N/mm^2]. With the exception of cargo containers and process pressure vessels according to Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol.IX). the smallest value determined from the following expressions is to be applied in this case:

1.3.1 Rolled and forged steels

For design temperatures up to 350 °C

$$\sigma_{perm} = \min\left\{\frac{R_{m,20°}}{2,7}, \frac{R_{eH20°}}{1,7}, \frac{R_{eH,t}}{1,6}\right\}$$

$R_{m,20°}$ = guaranteed minimum tensile strength [N/mm^2] at room temperature (may be dispensed with in the case of recognized fine-grained steels with with $R_{eH} \leq 360$ N/mm^2)

$R_{eH,20°}$ = guaranteed yield strength or minimum value of the 0,2 % proof stress at room temperature [N/mm^2]

$R_{eH,t}$ = guaranteed yield strength or minimum value of the 0,2 % proof stress at design temperatures above 50 °C [N/mm^2]

In case of austenitic steel, value of proof stress is 1%

For design temperatures above 350 °C

$$\sigma_{perm} = \frac{R_{m,100000,t}}{1,5}$$

$$\sigma_{perm} = \frac{R_{eH,t}}{1,6}$$

$R_{m,100000,t}$ = mean value of the 100000 h fatigue strength at design temperature t [N/mm^2]

$R_{eH,t}$ = guaranteed yield strength or minimum value of the 0,2 % proof stress at design temperatures above 50 °C [N/mm^2]

1.3.2 Cast materials

Cast steel :

$$\sigma_{perm} = \min\left\{\frac{R_{m,20°}}{3,2}, \frac{R_{eH,t}}{2,0}, \frac{R_{m,100000,t}}{2,0}\right\}$$

Nodular cast iron :

$$\sigma_{perm} = \min\left\{\frac{R_{m,20°}}{4,8}, \frac{R_{eH,t}}{3,0}\right\}$$

Grey cast iron:

$$\sigma_{perm} = \frac{R_{m,20°}}{11}$$

1.3.3 Non-ferrous metals

Copper and copper wrought alloys :

$$\sigma_{perm} = \frac{R_{m,t}}{4,0}$$

Aluminum and aluminum wrought alloys:

$$\sigma_{perm} = \frac{R_{m,t}}{4,0}$$

With non-ferrous metals supplied in varying degrees of hardness it shall 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 7.I, Table 7.3 is to be applied as appropriate. Where electrical heating is used, Table 7.3 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.

1.5 Weakening factor

For the weakening factors v for the calculation of walls or parts of walls, see Section 7.I, Table 7 I. 4.

1.6 Allowance for corrosion and wear

The allowance for corrosion and wear is generally c = 1,0 mm. It may be dispensed with in the case of plate thicknesses of 30 mm or more, stainless steels and other corrosion-resistant materials.

1.7 Minimum wall thicknesses

1.7.1 The wall thickness of the shells and end plates shall generally not be less than 3 mm.

1.7.2 Where the walls of vessels are made from pipes of corrosion resistant materials or for vessels and equipment in class III, a minimum wall thickness of 2,0 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 7.I or in accordance with the general rules of engineering practice, other methods, e.g bursting pressure test according to recognized standards or numerical methods (FE-Analysis) 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 shutoff 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 is to be equipped with a pressure gauge, also capable of being shut-off. The measuring range and calibration are to extend to the test pressure with a red mark to indicate the maximum allowable working pressure.

2.2 Equipment need only be fitted with pressure gauges when this is 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 is to 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 are to be designed and set in such a way that the max. allowable working pressure cannot be exceeded by more than 10 %. Means shall be provided to prevent the unauthorized alteration of the safety valve setting. Valve cones are to 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. Media flowing out of safety valves are to be drained off safely, preferably via a pipe.

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. If vacuum will occur by e.g. condensating an appropriate safety device is necessary.

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.

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 with a safety valve at the cold water inlet.

3.8 Rupture discs are permitted only with the consent of BKI 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 damage from outside. The fragments of the rupture element shall not 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 $PB\ [bar] \cdot V\ [\ell] \leq 200$.

3.10 Electrically heated equipment has to be equipped with a temperature limiter besides of a temperature controller.

3.11 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 oil burner.

Warm water generators heated by exhaust gases are to be equipped with the corresponding alarms.

3.12 The equipment on pressure vessels has to be suitable for the use on ships. The limiters for e.g. pressure, temperature and flow are safety devices and have to be type approved and have to be provided with appropriate type approval certificate. For safety valves the requirements of the Guidance for Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W) have to be fulfilled.

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 are to 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 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 shall not be larger than necessary and shall preferably be round. Sight glasses are to be protected against mechanical damage, e.g. by wire mesh. With combustible, explosive or poisonous media, sight glasses shall 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 pressure vessels onboard ship care is to be taken to ensure that the loads due to the contents and the structural weight of the vessel and to movements of the ship and vibrations cannot give rise to any excessive stress increases in the vessel's surfaces. Walls in the region of supports and brackets are to be fitted with reinforcing plates. The corners of the plates have to be rounded adequately to avoid increased welding stress. Exceptions have to be agreed with BKI.

7.2 Pressure vessels and equipment are to be installed in such a way as to provide for practicable allround 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 shall be installed at an angle and parallel to the fore-and-aft line of the ship. The angle shall be at least 10 degree (with the valve head at the top.) Where 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 pressure tests. No permanent deformation of the walls may result from these tests.

During the hydrostatic pressure test, the loads specified below shall not be exceeded:

for materials with a definite yield point $\frac{R_{eH,20°}}{1,1}$

for materials without a definite yield point $\frac{R_{m,20°}}{2,0}$

1.2 The test pressure PP for pressure vessels and heat exchangers is generally 1,5 times the maximum allowable working pressure PB, subject to a minimum of PB + 1 bar 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 a 2 bar pressure in excess of atmospheric pressure.

For the test pressures to be applied to steam condensers, see Section 3.I.

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 with a test pressure of 1,5 times the maximum allowable working pressure PB, subject to a minimum of 5 bar. On the steam side, the test is to be performed as specified in F.1.2.

1.4 Pressure vessels in water supply systems which correspond to standard DIN 4810 are to be tested at pressure of 5,2 bar, 7,8 bar or 13,0 bar 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 4 bar.

1.6 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.

1.7 Pressure tests with media other than water may be agreed to in special cases.

2. Tightness tests

For vessels and equipment containing dangerous substances (e.g. liquefied gases), BKI reserve the right to call for a special test of gas tightness.

3. Testing after installation on board

Following installation onboard ship, a check is to be carried out on the fittings of vessels and equipment and on the arrangement and setting of safety appliances, and operating tests are to be performed wherever necessary.

G. Gas Cylinders

1. General

1.1 For the purposes of these requirements, gas cylinders are bottles with a capacity of not more than 150 l 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 on board ship where the pressurized gases are used, see also Section 12.

1.2 These Rules are not valid for gas cylinders with

— a maximum allowable working pressure of maximum 0,5 bar, or

— a capacity ≤ 0,5 ℓ.

1.3 These Rules are only valid in a limited range for gas cylinders with

- a maximum allowable working pressure of maximum 200 bar and
- a capacity > 0,5 ℓ and < 4 ℓ

For these gas cylinders a 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 from of stamp are to be submitted in form of electronic format

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 have to be designed that they are well capable 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 BKI Head Office.

3.2 The manufacturing process for seamless gas cylinders is to be approved by BKI.

3.3 Gas cylinders with the basic body made by welding are for the aforementioned requirements subject of this Section.

4. Calculation

4.1 Term used

p_c = design pressure (specified test pressure) [bar]

S = wall thickness [mm]

C = corrosion allowance [mm]

= 1,0 mm, if required

D_a = outside diameter of gas cylinder [mm]

R_{eH} = guaranteed upper yield point [N/mm^2]

$R_{p0,2}$ = guaranteed 0,2% proof stress [N/mm^2]

R_m = guaranteed minimum tensile strength [N/mm^2]

R_e = yield point needed as comparative value for the determination of R [N/mm^2]

either $R_e = R_{eH}$

or $R_e = R_{p0,2}$

R = in each case the smaller of the following two values [N/mm^2]:

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_{max} = allowable stress = $\frac{R}{4/3}$ [N/mm^2]

β = design coefficient for dished ends (see Section 7.I, D.4.)

V weakening factor (see Section 7.I ,D.2)

4.2 Test pressure

The specified test pressure for CO_2 bottles with a filling factor of 0,66 kg/l is 250 bar gauge. For other gases, the test pressure may be agreed with BKI. If not agreed otherwise the test pressure is to be at least 1,5 times the maximum allowable working pressure $p_{e,perm}$.

4.3 Cylindrical surfaces

$$s = \frac{D_a \cdot p_c}{20\sigma_{perm} \cdot v + p_c} + c$$

4.4 Spherical ends

$$s = \frac{D_a \cdot p_c}{40\sigma_{perm} \cdot v + p_c} + c$$

4.5 Ends dished to outside

$$s = \frac{D_a \cdot p_c \cdot \beta}{40\ \sigma_{perm}} + c$$

4.6 Ends dished to inside

The conditions applicable to dished ends are shown in the Figure .8.2.

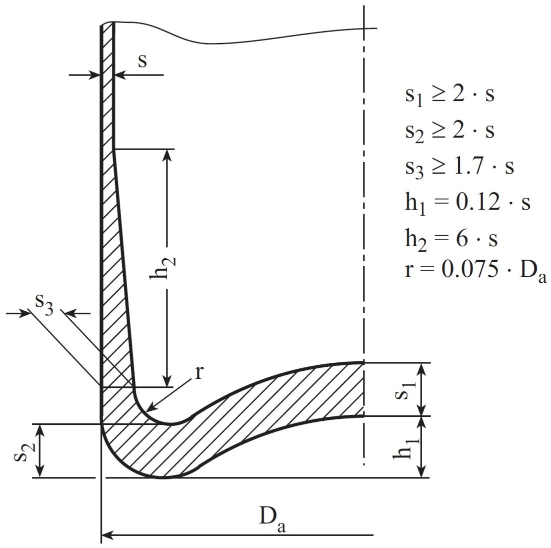

Figure 8.2: End dished to inside

4.7 Alternative calculation

Alternatively a calculation according to EN 1964-1 or ISO 9809-1 may be performed, provided that the result are at least equivalent.

5. Testing of gas cylinders

5.1 Approval procedure

BKI may approve according to the following procedures:

5.1.1 Single test in lots

After approval of the documentation by BKI Head Office, the required tests according to 5.3 to 5.5 are to be performed.

The facilitations according to 5.5.3 are not to be applied.

5.1.2 Type approval and single test in lots

After approval of the documentation by BKI Head Office, 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 5.5.3 may apply.

5.1.3 Type approval and test arrangement

After approval of the documentation by BKI Head Office, the manufacturer may make special arrangements with BKI 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 all gas cylinders

5.3.1 For all gas cylinders submitted for testing a hydrostatic pressure test with a test pressure according to 4.2 is to be performed.

5.3.2 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 BKI 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 BKI Surveyor.

5.3.3 The manufacturer has to establish the volumetric capacity and weight of each cylinder.

5.3.4 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.

5.4 Testing on the first sample cylinder

5.4.1 From the first sample cylinder according to 5.2 one longitudinal tensile test specimen, three transverse bending test specimens and a set of ISO V-type notched bar impact test specimens are to be taken in longitudinal or transverse direction. The notched bar impact test specimens are to be tested at -20 °C. The average impact work shall be at least 35 Joule.

5.4.2 The cylindrical wall thickness of the first sample cylinder is to be measured in transverse planes at three levels (neck, middle and base) and the end plate is to be sawn through and the thickness measured.

5.4.3 At the first sample cylinder examination of the inner surface of the neck and bottom portions to detect possible manufacturing defects.

5.5 Testing on the second sample cylinder

5.5.1 The second sample cylinder is subjected to a bursting test according to 5.5.2.

5.5.2 Bursting Test

5.5.2.1 Test bottles intended to be subjected to a bursting test are to be clearly identified as to the lot from which they have been taken.

5.5.2.2 The required bursting pressure has to be at least 1,8 times the test pressure pp.

5.5.2.3 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 is to be carried out a room temperature.

5.5.2.4 During the first stage, the pressure has to increase continuously up to the value at which plastic deformation starts; the pressure increase shall not exceed 5 bar/sec.

Once the point of plastic deformation has been reached (second stage), the pump capacity shall not exceed double the capacity of the first stage; it has then to be kept constant until bursting of the cylinder.

5.5.2.5 The appearance of the fracture has to be evaluated. It shall not be brittle and no breaking pieces are to be detached.

5.5.3 For lots of less than 400 pieces of normalized cylinders respectively for lots of less than 200 quenched and tempered cylinders the bursting pressure is waived for every second lot.

5.6 Presence of the BKI Surveyor

As far as not agreed otherwise (see 5.1.3) the presence of the BKI Surveyor is required for the test according to 5.3.1, 5.3.2, 5.4 and 5.5.2.

6. Marking

Each gas cylinder is to be marked with the following:

- name or trade name of the manufacturer
- serial number
- type of gas
- design strength value [N/mm^2]
- capacity [l]
- test pressure [bar]
- empty weight [kg]
- date of test
- test stamps

7. Recognition of equivalent tests

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 BKI is submitted, already manufactured gas cylinders checked by single test in lots may be recognized by BKI.

7.1.2 Here with the complete documentation including manufacturing records is to be made available to BKI Head Office and has to be evaluated with positive results.

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 BKI, an approval procedure according to 5.1.1 has to be performed.

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Section 9 Oil Burners and Oil Firing Equipment

A. General

1. Scope

1.1 The following requirements apply to oil burners and oil firing equipment that are to be used for burning of liquid fuels according to Section 1, D.12 installed on main steam boilers, auxiliary steam boilers, thermal oil heaters, hot water generators as well as inert gas generators according to Section 15, D.6., in the following referred to as heat generators.

1.2 Where oil burners and oil firing equipment are to be used for burning of different liquid fuels or fuels divergent to Section 1, D.12 as e.g. low sulphur distillate oils (LSDO), waste oil or oil sludge, the necessary measures are to be agreed with the Head Office of BKI in each single case.

2. Applicable Rules

The following BKI Rules and Guidances are to be applied analogously:

Section 7.I	for steam boilers and hot water generators
Section 7.II	for thermal oil systems
Section 8	for warm water generators and pressure vessels (e.g. preheating equipment)
Section 11 A. to D., Q. and R.	for pumps, pipelines, valves and fittings
Section 12	for fire detection and fire extinguishing equipment
Rules for Electrical Installation (Pt.1, Vol.IV)	for electrical installations
Rules for Automations (Pt.1, Vol.VII)	for automated machinery system (OT)
Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W)	for component requiring type approval

3. Documents for approval

Oil burner for the installation on heat generators have to fulfil the following requirements. The following documents are to be submitted to BKI for approval. To facilitate a smooth and efficient approval process, the drawings could be submitted in electronic format.

- 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
- firing equipment are suitable for the fuels intended to be used.

B. Requirements regarding Oil Firing Equipment

1. General

1.1 Heat generators without constant and direct supervision are to be operated with automatic firing systems.

1.2 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.

1.3 Oil firing equipment including the oil burner used with different fuel oils with regard to chemical composition and physical properties are to be equipped or are to be able to be operated respectively in a manner that any change over to another fuel oil ensures in any case a safe automatic operation.

1.4 Manual Operation

1.4.1 For oil burners at heat generators, 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.

1.4.2 Flame monitoring shall remain active.

1.4.3 The safety equipment not required for manual operation may only be set out of function by means of a key-operated switch. The actuation of the key operated switch is to be indicated.

1.4.4 Manual operation requires constant and direct supervision of the system.

2. Equipment of the heat generators and burner arrangements

2.1 Oil burners are to be designed, fitted and adjusted in such a manner as to prevent the flame from causing damage to the boiler surfaces or tubes which border the combustion space. Boiler parts which might otherwise suffer damage are to be protected by refractory lining.

The firing system shall be arranged as to prevent the flame from blowing back into the boiler or engine room and to allow unburned fuel to be safely drained.

2.2 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.

3. Simultaneous operation of oil burners and internal combustion machinery

The operation of oil burners in spaces containing other plants 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 The 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 the fuel oil. Preheating with open flame is 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 generators.

When a change is made from heavy to light oil, the light oil shall not be passed through the heater or be excessively heated (alarm system).

4.5 The fuel oil supply 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 10, B.5. are to be complied with.

The design and construction of pressurized fuel oil heaters are subject to the requirements in Section 8.

4.6 Temperature or viscosity control shall be done automatically. For monitoring purposes, a thermometer or viscometer is to be fitted to the fuel oil pressure line in front of the burners.

4.7 Should the fuel oil supply temperature or viscosity deviate above or below the permitted limits, an alarm system has to signal this fact to the heat generator control panel.

5. Pumps, pipelines, valves and fittings

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.12.

C. Requirements to Oil Burners

1. Safety equipment

1.1 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.

1.2 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.

1.3 In an emergency it shall be possible to close automatic quick-closing devices from the heat generators control platform and - where applicable - from the engine control room.

1.4 The automatic quick closing devices shall not release the oil supply to the burner during start up and have to interrupt the oil supply during operation (automatic restart possible) if one of the following faults occur:

a)
- Failure of the required pressure of the atomizing medium (steam and compressed - air automizers)
- Failure of the oil pressure needed for atomization (oil pressure atomizers)
- Exceeding of the maximum allowable pressure in the return line (burners with return line)
- Insufficient rotary speed of spinning cup or primary air pressure too low (rotary atomizers)

b) Failure of combustion air supply[1)]

c) Failure of control power supply

d) Failure of induced-draught fan or insufficient opening of exhaust gas register

e) Burner not in operating position

[1)] Where there are no oil or air supply monitoring devices or spring-loaded fast closing devices 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.

1.5 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 1.7)
- The flame is extinguished during operation and attempt to restart the burner within the safety period is unsuccessful (see 1.7) or
- Limit switches are actuated.

1.6 The return line of burners with return lines have also to be provided with an automatic quick closing device. The device in the return line may be dispensed with if the return line is not under pressure and no oil is able to flow back when the burner is shut down.

1.7 Every burners is to be equipped with a safety device for flame monitoring suitable for the particular fuel oil (spectral range of the burner flame is to be observed) in use. 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. Measures are to be taken to ensure that safety period for the main flame is not prolonged by the action of the igniters (e.g. ignition burners).

1.8 The equipment in the oil firing system has to be suitable for the use in oil firing systems and on ships. The proof of the suitability of the limiters and alarm transmitters for e.g. burner control box, flame monitoring device, automatic quick-closing device is to be demonstrated by a type approval examination according to the requirements of BKI Rules listed in A.2.

1.9 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.

1.10 The electrical interlocking of the firing system following tripping by the safety and monitoring devices is only to be cancelled out at the heat generator or of the firing system respectively.

2. Design and construction of burners

2.1 The type and design of the burner and its atomizing and air turbulence equipment shall ensure virtually complete combustion.

2.2 Equipment use, especially pumps and shut off devices, shall be suitable for the particular application and the oils in use.

2.3 Burners, which can be retracted or pivoted are to be provided with a catch to hold the burner in the swung out position. Additionally, the requirements according to 1.4 e) are to be observed.

2.4 Steam atomizers have to be fitted with appliances to prevent fuel oil entering the steam system.

2.5 Where an installation comprises several burners supplied with combustion air by a common fan, each burner is to be fitted with a shut off device (e.g. a flap). Means are to be provided for retaining the shut off device in position shall be indicated.

2.6 Every burner is to be equipped with an igniter. The ignition 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.

2.7 Where burners are blown through after shutdown, provision is to be made for the safe ignition of the residual oil ejected.

[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

3. Purging of combustion chamber and flues, exhaust gas ducting

3.1 The combustion chamber and flues are to be adequately purged with air prior burner start-up. A warning sign is to be mounted to this effect.

3.2 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.

3.3 Bends and dead corners in the exhaust gas duct 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 lines is reduced below a certain minimum value. The position of the damper has to be indicated at the boiler control platform.

3.4 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.

3.5 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

4. Electrical equipment

Electrical equipment and its degree of protection have to comply with the Rules for Electrical Installations (Pt.1, Vol.IV).

High voltage igniters have to be sufficiently safe against unauthorized operation.

5. Marking

The following information shall be stated on a durable manufacturer’s name plate attached to the burner:

- manufacturer’s name plate
- type and size
- serial number
- year of manufacture
- min./max. oil flow
- fuel oils to be used
- degree of protection

D. Testing

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 documented by a BKI approval Certificate:

- visual inspection and completeness check
- pressure test of the oil preheated, if available and required according to Section 8
- pressure test of the burner
- insulation resistance test
- high voltage test
- functional test of the safety related equipment

2. Tests on board

2.1 After installation a pressure and tightness test of the fuel system including fittings has to be performed, see Section 11, B.4.

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
- 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.
- proof regarding combustion properties like CO_2, possibly O_2, CO-volumetric content and soot number at minimum, means and maximum power, in case of statutory requirements

The correct combustion at all settings as well as function of safety equipment has to be verified. A BKI approval Certificate of the oil burner regarding examination at the manufacturer's shop is to be presented to BKI during functional testing.

Section 10 Storage of Liquid Fuels, Lubricating, Hydraulic and Thermal Oils as well as Oily Residues

A. General

1. Scope

The following requirements apply to the storage of liquid fuels, lubricating, hydraulic and thermal oils as well as to oily residues.

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.

3. Tank Plan

A tank plan is to be submitted for approval. Particulars regarding arrangement, medium and volume of the tanks are to be included. To facilitate a smooth and efficient approval process, the drawings could be submitted in electronic format.

B. Storage of Liquid Fuels

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 Section 11, Q.

2. Distribution, location and capacity of fuel tanks

2.1 Distribution of fuel tanks

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 regardless its size, no fuel tanks or tanks for the carriage of flammable liquids may be arranged forward of the collision bulkhead.

2.1.2 Provision is to be made to ensure that internal combustion engines and boiler plants operating on heavy fuel 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 BKI.

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 to used lubricating oil which will not be used on board anymore.

2.1.4 On small ships the arrangement of cofferdams according to 2.1.3 may, with the approval of BKI, be dispensed with, provided that the common boundaries between the tanks are arranged in accordance with Rules for Hull (Pt.1, Vol.II), Sec. 12.A.5.2.

2.1.5 Fuel oil tanks adjacent to lubricating oil circulating tanks are not permitted.

2.1.6 On oil and chemical tankers, carrying liquid cargoes having a flashpoint not exceeding 60°C and/or toxic liquid cargoes[1)], fuel tanks located with a common boundary to cargo or slop tanks shall not be situated within nor extend partly into the cargo tank block. Such tanks may, however, be situated aft and/or forward of the cargo tank block. They may be accepted when located as independent tanks on open deck in the cargo area subject to spill and fire safety considerations.

The arrangement of independent fuel tanks and associated fuel piping systems, including the pumps, can be as for fuel tanks and associated fuel piping systems located in the machinery spaces. For electrical equipment, requirements to hazardous area classification must however be met.

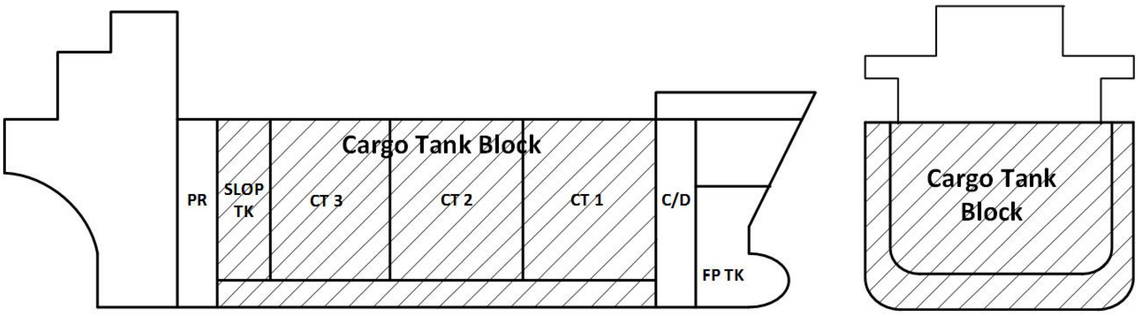


Figure 10.1: Cargo tank block

Cargo tank block is the part of the ship extending from the aft bulkhead of the aftmost cargo or slop tank to the forward bulkhead of the forward most cargo or slop tank, extending to the full depth and beam of the ship, but not including the area above the deck of the cargo or slop tank.

2.2 Arrangements of fuel tanks

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 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 BKI. For oil tank with capacity more than 600 m3, the arrangement of fuel tanks adjacent to cofferdams required by MARPOL I Reg. 12A shall apply

[1)] For the purpose of this Rules, toxic liquid cargoes include those for which toxic vapour detection is specified in column "k" of the Rules for Ships Carrying Chemicals in Bulk (P t.1, Vol.X) Section 17.

2.2.3 Tanks adjacent to refrigerated cargo holds are subject to the Rules for Refrigerating Installations (Pt.1, Vol.VIII), Sec. 1, M.

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 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.

2.2.5 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 2.2.4 is available at any time. An appropriate low level alarm is to be provided, see Rules for Electrical Installations (Pt.1, Vol.IV), Sec. 3, D.2.6.

2.2.6 Number and capacity of fuel oil service tanks, see Section 11, G.10.

3. Fuel tank fittings and mountings

3.1 For filling and suction lines see Section 11, G; for air, overflow and sounding pipes, see Section 11, Q.

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.

3.3 Tank gauges

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

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 BKI.

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 3.3.1.

3.3.4 Sight glasses and oil gauges fitted directly on the side of the tank and cylindrical glass oil gauges are not permitted.

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.

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.

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 cooks.

4. Fastening of appliances and fittings on fuel tanks

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.

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.

5. Tank heating system

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.

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 3,0 m 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.

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.

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.

5.5 Tanks for fuel which requires preheating are to be fitted with thermometers and, where necessary, with thermal insulation.

5.6 For the materials, wall thickness and pressure testing of heating coils, see Section 11.

6. Hydraulic pressure tests

Fuel tanks are to be tested for tightness in accordance with the Rules Rules for Hull (Pt.1, Vol.II).

7. Fuels with a flash point of $\leq$ 60 °C

For the storage of liquid fuels with a flash point of $\leq$ 60 °C , see Section 1, D.12.

C. Storage of Lubricating and Hydraulic Oil

1. Tank arrangement

For the arrangement of the tanks, B.2.2.1 and analogously Rules for Hull (Pt.1, Vol.II), Sec.12 are to be applied.

2. Tank fittings and mountings

2.1 For filling and suction lines of lubricating oil and hydraulic oil tanks, see Section 11, H.2.2

2.2 For tank sounding devices for oil tanks, see B.3.3.1, B.3.3.4 and B.3.3.6.

2.3 For the fastening of appliances and fittings on the tanks, B.4 is to be applied analogously.

2.4 For tank heating systems the requirements of B.5.4 are to be observed.

3. Capacity and construction of tanks

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.

3.2 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 contents 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 Lubricating oil circulating tanks are to be equipped with sufficiently dimensioned vents.

D. Storage of Thermal Oils

1. Arrangements of tanks

For the arrangement of the tanks B.2.2.1 and analogously Rules for Hull (Pt.1, Vol.II), Sec.12 are to be applied.

2. ank fittings and mountings

2.1 For tank measuring devices for thermal oil tanks, see B.3.3.1 and Section 7 - II. Expansion tanks are to be fitted with type approved level indicating devices.

2.2 For the mounting of appliances and fittings on the tanks, B.4 is to be applied analogously.

2.3 For filling and suction lines from thermal oil tanks, see Section 11, H.2.2.

E. Storage of Oil Residues

1. Tank heating system

To ensure the pump ability of the oil residues a tank heating system in accordance with B.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 .

2. Sludge tanks

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[2)3)].

2.2 Fittings and mountings of sludge tanks

2.2.1 For tank sounding devices B.3.3.2 and B.3.3.5 are to be applied analogously.

2.2.2 For air pipes, see Section 11, Q.

F. Storage of Gas Bottles for Domestic Purposes

1. Storage of gas bottles shall be located on open deck or in well ventilated spaces which only having access to open deck only.

2. Gaseous fuel systems for domestic purposes shall comply with recognized standard[2)].

[2)] National requirements, if any, are to be observed.
[3)] Reference is made to MEPC Circular 235

Section 11 Piping Systems, Valves and Pumps

A. General

1. Scope

These requirements apply to pipes and piping systems, including valves, fittings and pumps, which are necessary for the operation of the main propulsion plant together with its auxiliaries and equipment. They 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 in other Sections.

Cargo and process piping on ships for the carriage of liquefied gases in bulk is additionally subject to the provisions of the Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1 Vol.IX).

Cargo piping for the carriage of chemicals in bulk is additionally subject to the provisions of the Rules for Ships Carrying Dangerous Chemical in Bulk (Pt.1, Vol.X).

Gas welding equipment is subject to the approval of BKI Head Office and tested in presence of BKI Surveyor

Ventilation systems are subject to rules to the provisions of Guidance for Ventilation System on Board Seagoing Ships (Pt.1, Vol.A)

Closed fuel oil overflow systems are subject to Guidance for Construction, Equipment and Testing of Closed Fuel Overflow System (Pt.1, Vol.J)

Fuel systems for ships with gas as fuel are subject to BKI Guidelines for the Use of Gas as Fuel for Ships (Pt.1,Vol.1)

2. Documents for approval

2.1 The following drawings/documents are to be submitted for approval in electronic format.

2.1.1 Diagrammatic plans of the following piping systems including all the details necessary for approval (e.g. lists of valves, fittings and pipes):

- steam systems (steam, condensate and boiler feed water systems)
- thermal oil systems
- fuel systems (bunkering, transfer and supply systems)
- seawater cooling systems
- fresh water cooling systems
- lubricating oil systems
- starting air, control air and working air systems
- exhaust gas systems
- bilge systems
- ballast systems
- cross-flooding arrangements
- air, overflow and sounding pipes including details of filling pipe cross sections
- closed overflow systems
- sanitary systems (potable water, fresh water, seawater, sewage)
- equipment for the treatment and storage of bilge water and fuel oil residues

2.1.2 For remotely controlled valves:

- diagrammatic piping plans and diagrammatic plans of the arrangement of piping and control stands in the ship
- diagrammatic plans and electrical circuit diagrams of the control stations and power units, as well as drawings of the remotely controlled valves, control stands and the corresponding pressure accumulators

2.1.3 For steam lines with working temperatures > 400 °C, the corresponding stress calculations together with isometric data are to be submitted.

3. Pipe classes

For the testing of pipes, selection of joints, welding and heat treatment, pipes are subdivided into three classes as indicated in Table 11.1.

Table 11.1: Classification of pipes into pipe classes

Medium/type of pipeline	Design pressure PR [bar] Design temperature t [°C]		
Pipe Class	**I**	**II**	**III**
Toxic media	All	—	—
Corrosive media Inflammable media with service temperature above the flash point Inflammable media with a flash point below 60 °C or less Liquefied gases (LG)	All	1)	—
Steam	PR > 16 or t > 300	PR ≤ 16 and t ≤ 300	PR ≤ 7 and t ≤ 170

Table 11.1: Classification of pipes into pipe classes *(continued)*

Medium/type of pipeline	Design pressure PR [bar] Design temperature t [°C]		
Pipe Class	**I**	**II**	**III**
Thermal oil	PR >16 or t > 300	PR ≤ 16 and t ≤ 300	PR ≤ 7 and t ≤ 150
Air, gas Non-flammable hydraulic fluid Boiler feed water, condensate Seawater and freshwater for cooling Brine in refrigerating plant Urea for SCR systems 2)	PR > 40 or t > 300	PR ≤ 40 and t ≤ 300	PR ≤ 16 and t ≤ 200
Liquid fuels, lubricating oil, flammable hydraulic fluid	PR > 16 or t > 150	PR ≤ 16 and t ≤ 150	PR ≤ 7 and t ≤ 60
Cargo pipelines for oil tankers	—	—	All
Cargo and venting lines for gas and chemical tankers	All	—	—
Refrigerants	—	All	—
Open-ended pipelines (without shutoff), e.g. drains, venting pipes, overflow lines and boiler blow down lines	—	—	All

1) Classification in Pipe Class II is possible if special safety arrangements are available and structural safety precautions are arranged

2) When piping materials selected according to ISO 18611-3:2014 for Urea in SCR systems.

B. Materials, Testing

1. General

Materials are to be suitable for the proposed application and comply with the Rules for Materials (Pt.1, Vol.V).

In case of especially corrosive media, BKI may impose special requirements on the materials used. For the materials used for pipes and valves for steam boilers, see Sections 7.I.

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.

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 BKI 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 BKI. 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 behaviour and their strength property according to C.2.3 after 100000 h of operation are in accordance with national or international regulations or standards and if such values are guaranteed by the steel manufacturer. Otherwise, alloy steels in accordance with Rules for Materials (Pt.1, Vol.V), are to be used.

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 according to a method approved by BKI. Copper pipes for Classes I and II must be seamless.

In general, copper and copper alloy pipe lines are not to be used for media having temperatures above the following limits:

— copper and aluminium brass 200 °C
— copper nickel alloys 300 °C
— high-temperature bronze 260 °C

2.4 Pipes, valves and fittings of nodular cast Iron

Pipes, valves and fittings of nodular cast iron according to the Rules for Materials (Pt.1, Vol.V), may be accepted for bilge, ballast and cargo pipes within double-bottom tanks and cargo tanks and for other purposes approved by BKI. In special cases (applications corresponding in principle to classes II and III) and subject to BKI special approval, valves and fittings made of 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 has to comply with Rules for Materials (Pt.1, Vol.V)) (see also Rule 22 of the 1966 International Convention on Load Lines)

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 BKI for Class III. Pipes of grey cast iron may be used for cargo pipelines 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 the Rules for Ships Carrying Dangerous Chemical in Bulk (Pt.1, Vol.X),
— for pipes, valves and fittings for media having temperatures above 220 °C and for pipelines subject to water hammer, severe stresses or vibrations
— for sea valves and pipes fitted on the ship sides and for valves fitted on the collision bulkhead
— for valves on fuel and oil tanks subject to static head
— for relief valves

The use of grey cast iron in cases other than those stated is subject to BKI approval.

2.6 Plastic piping systems

2.6.1 Terms and Condition

.1 “Plastic(s)” means both thermoplastic and thermosetting plastic materials with or without reinforcement, such as PVC and fibre reinforced plastics (FRP). Plastic includes synthetic rubber and materials of similar thermal/mechanical properties.

.2 “Pipes/piping systems” means those made of plastic(s) and include the pipes, fittings, system joints, method of joining and any internal or ex ternal liners, coverings and coatings required to comply with the performance criteria.

.3 “Joint” means joining pipes the location at which two pieces of pipe or a pipe and a fitting are connected together. The joint may be made by adhesive bonding, laminating, welding, flanges and mechanical joints according to Table 11.13

.4 “Fittings” means bends, elbows, and fabricated branch pieces etc. of plastic materials.

.5 “Nominal pressure” means the maximum permissible working pressure which should be determined in accordance with the requirements in 2.6.3.1.

.6 “Design pressure” means the maximum working pressure which is expected under operation conditions or the highest set pressure of any safety valve or pressure relief device on the system, if fitted.

.7 “Fire endurance” means the capability of piping to maintain its strength and integrity (i. e. capable of performing its intended function) for some predetermined period of time while exposed to fire.

.8 ”Essential to the safety of ship” means all piping systems that in event of failure will pose a threat to personnel and the ship[1)]

.9 ”Essential services” are those services essential for propulsion and steering and safety of the ship as specified in Guidance for Code and Convention Interpretations (Pt.1, Vol.Y) Sec.11.SC 134.

2.6.2 Scope and application

.1 These requirements are applicable to piping systems on ships, including pipe joints and fittings, made predominately of other material than metal.

.2 The use of mechanical joints approved for the use in metallic piping systems only are not permitted.

.3 Piping systems intended for non-essential services are to meet only the requirements in 2.6.3.1 ii), 2.6.6, 2.6.9 and for prototype testing representative samples of pipes and fittings are to be selected to the satisfaction of BKI and recognized standards.

.4 Depending on the location of installation and the medium three different levels of fire endurance for plastic pipe systems are to be distinguished (see IMO Resolution A.753 (18), Appendix 1 and 2)

.5 Permitted use of piping depending on fire endurance, location and type of system is given in Table 11.1a.

2.6.3 General requirement

Plastic piping systems are to be type approved by BKI. The requirements are defined in Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W), Sec.3.O.

The specification of piping is to be in accordance with a recognised national or international standard acceptable to BKI. In addition, the following requirements apply:

[1)] Examples for piping systems essential to the safety are provided by Table 11.1a

.1 Strength

1) The strength of the pipes is to be determined by a hydrostatic test failure pressure of a pipe specimen under the standard conditions: atmospheric pressure equal to 100 kPa, relative humidity 30%, environmental and carried fluid temperature 298 kPa (25°C).
2) The strength of fittings and joints is to be not less than that of the pipes.
3) The nominal pressure is to be determined from the following conditions:
   i) Internal Pressure
      For an internal pressure the following is to be taken whichever is smaller:

      $P_{n\ int} \leq P_{sth}/4,0$ or $P_{n\ int} \leq P_{lth}/2,5$

   where:
   P_{sth} = For an internal pressure the following is to be taken whichever is s maller:
   P_{lth} = long-term hydrostatic test pipe failure pres sure (> 100.000 h)

   ii) 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 8 -1 of SOLAS Chapter II -1, as amended by IMO resolutions up to MSC.436 (99), or for any pipes that would allow progressive flooding to other compartments through damaged piping or through open ended pipes in the compartments).
      For an external pressure:

      $P_{n\ ext} \leq P_{col}/3,0$

   where:
   P_{col} = Pipe collapse pressure.

      In no case is the pipe collapse pressure to be less than 3 ,0 bar.
      The maximum work ing external pressure is a sum of the vacuum inside the pipe and a head of liquid acting on the outs ide of the pipe.
4) Notwithstanding the requirements of 3.i) or 3.ii) 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 3.ii) above are to be met.
5) The max imum permissible working pressure is to be specified with due regard for maximum possible working temperatures in accordance with Manufacturer ’s recommendations.

.2 Axial Strength

1) The sum of the longitudinal stresses due to pressure, weight and other loads is not to exceed the allowable stress in the longitudinal direction.
2) In the case of fibre reinforced plastic pipes, the sum of the longitudinal stresses is not to exceed half of the nominal circumferential stress derived from the nominal internal pressure condition see 2.6.1.1.

.3 Impact Resistance

1) Plastic pipes and joints are to have a minimum resistance to impact in accordance with recognized national or international standards.

2) After the test the specimen is to be subjected to hydrostatic pressure equal to 2,5 times the design pressure for at least 1 hour.

.4 Temperature

1) The permissible working temperature depending on the working pressure is to be in accordance with Manufacturer's recommendations, but in each case it is to be at least 20 °C lower than the minimum heat distortion/deflection temperature of the pipe material, determined according to ISO 75 -2:2013 method A, or equivalent e. g. ASTM D648-18.

2) The minimum heat distortion/deflection temperature is to be not less than 80°C

2.6.4 Quality control during manufacture

.1 Prototypes of pipes and fittings are to be tested to determine short-term and long-term design strength, fire endurance and low surface flame spread characteristics (if applicable), electrical resistance (for electrically conductive pipes), impact resistance in accordance with this section.

.2 For prototype testing representative samples of pipes and fittings are to be selected to the satisfaction of the BKI.

.3 The manufacturer is to have a quality system that meets ISO 9001:2015 series standards or equivalent. The quality system is to consist of elements necessary to ensure that pipes and fittings are produced with consistent and uniform mechanical and physical properties.

Table 11.1a: Fire endurance requirements matrix

Piping system		Location										
No.	**Description**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
Flammable cargoes (Flash point ≤ 60 °C)												
1	Cargo lines	NA	NA	L1	NA	NA	0	NA	0	0	NA	L1[2]
2	Crude oil washing lines	NA	NA	L1	NA	NA	0	NA	0	0	NA	L1[2]
3	Vent lines	NA	NA	NA	NA	NA	0	NA	0	0	NA	X
Inert gas												
4	Water seal effluent line	NA	NA	0[1]	NA	NA	0[1]	0[1]	0[1]	0	NA	0
5	Scrubber effluent line	0[1]	0[1]	NA	NA	NA	NA	NA	0[1]	0	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 (Flash point > 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 & branches	L1[7]	L1[7]	L1	X	X	NA	0	0	0	NA	L1
13	Fire main & water spray	L1	L1	L1	X	NA	NA	NA	0	0	X	L1
14	Foam system	L1W	L1W	L1W	NA	NA	NA	NA	NA	0	L1W	L1W
15	Sprinkler system	L1W	L1W	L3	X	NA	NA	NA	0	0	L3	L3
16	Ballast	L3	L3	L3	L3	X	0[10]	0	0	0	L2W	L2W
17	Cooling water, essential services	L3	L3	NA	NA	NA	NA	NA	0	0	NA	L2W
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
Freshwater												
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	Crude oil washing lines	0	0	NA	0	0	NA	0	0	0	0	0
25	Vent lines	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 (Flash point > 60 °C)	0	0	0	0	0	0[10]	0	0	0	0	0
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
34	Urea transfer/supply system (SCR installations)	L1[12]	L1[12]	NA	NA	NA	NA	NA	NA	0	L3[11]	0

Table 11.1a: Fire endurance requirements matrix *(continued)*

Location definition:

A	Machinery spaces of category A	Machinery spaces of category A as defined in SOLAS[1] Regulation II-2/Reg. 3, 31
B	Other machinery spaces and pump room	Spaces other than category A machinery spaces and cargo pump rooms, containing propulsion machinery, boilers, fuel oil units, steam and internal combustion engine generators and major electrical machinery, pumps, oil filling stations, refrigerating, stabilizing, ventilation and air-conditioning machinery and similar spaces and trunks and trunks to such spaces
C	Cargo pump rooms	Spaces containing cargo pumps and entrances and trunks to such spaces
D	Ro-ro cargo holds	Ro-ro cargo holds are ro-ro cargo spaces and special category as defined in Regulations 3.41, and 3.46 of SOLAS Chapter II-2
E	Other dry cargo holds	All spaces other than ro-ro cargo holds used for non-liquid cargo and trunks to such spaces
F	Cargo tanks	All spaces used for liquid cargo and trunks to such spaces
G	Fuel oil tanks	All spaces used for fuel oil (excluding cargo tanks) and trunks
H	Ballast water tanks	All spaces used for ballast water and trunks to such space
I	Cofferdams, Voids etc	Cofferdams and voids are those empty spaces between two bulkheads, separating two adjacent compartments
J	Accommodation, service	Accommodation spaces, service and control station as defined in Regulations 3.1, 3.45, and 3.18 of SOLAS Chapter II-2.
K	Open Decks	Open Deck as defined in Regulations 9.2.3.3.2 (5) of SOLAS Chapter II-2.

[1]SOLAS Chapter II-2

Abbreviations:

L1	Fire endurance test (appendix 1 of IMO Resolution A.753(18), as amended by IMO Resolutions MSC.313(88) and MSC.399(95) in dry conditions, 60 min.
L1W	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 (see 2.6.5.2)
L2	Fire endurance test (appendix 1 of IMO Resolution A.753(18), as amended by IMO Resolutions MSC.313(88) and MSC.399(95)) in dry conditions, 30 min.
L2W	Piping systems similar to level 2 systems except a maximum 5% flow los in the system after exposure is acceptable (see 2.6.5.2)
L3	Fire endurance test (appendix 2 of IMO Resolution A.753(18), as amended by IMO Resolutions. MSC.313(88) and 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

Foot notes:

1) Where non-metallic piping is used, remotely controlled valves are to be provided at ship's side (valve is to be controlled from outside space)
2) Remote Closing valves to be provided at the cargo tanks
3) When cargo tanks contain flammable liquids with flash point > 60 °C, "0" may replace "NA" or "X"
4) For drains serving only the space concerned, "0" may replace "L1W"
5) When controlling function are not required by statuary requirement, "0" may replace "L1"
6) For pipes between machinery space and deck water seal, "0" may replace "L1"
7) For passenger vessels, "X" is to replace "L1"
8) Scuppers serving open decks in position 1 and 2, as defined in Regulation 13 of protocol of 1988 relating to the International Convention of Load Lines, 1966, as amended by IMO Resolutions up to MSC.375(93), should be "X" throughout unless fitted at the upper deck with the means of closing capable of being operated from a position above the freeboard deck in order to prevent down flooding.
9) For essential services, such as fuel oil tank heating and ship's whistle. "X" is to replace "0"

Table 11.1a: Fire endurance requirements matrix *(continued)*

10)	For tankers where compliance with paragraph 3.6 of Regulation 19 of MARPOL Annex I, as amended by IMO Resolutions up to MEPC.314(74) is required, "NA" is to replace "0"
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 ship subject to Regulation 21.4 of SOLAS Chapter II-2 (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.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 L1 standard.

.4 Each pipe and fitting is to be tested by the manufacturer at a hydrostatic pressure not less than 1,5 times the nominal pressure. Alternatively, for pipes and fittings not employing hand layup techniques, the hydrostatic pressure test may be carried out in accordance with the hydrostatic testing requirements stipulated in the recognized national or international standard to which the pipe or fittings are manufactured, provided that there is an effective quality system in place.

.5 Piping and fittings are to be permanently marked with identification. Identification is to include pressure ratings, the design standards that the pipe or fitting is manufactured in accordance with, and the material of which the pipe or fitting is made.

.6 In case the manufacturer does not have an approved quality system complying with ISO 9001:2015 or equivalent, pipes and fittings are to be tested in accordance with Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W).

.7 Depending upon the intended application by BKI may require the pressure testing of each pipe and/or fitting.

2.6.5 Fire endurance

.1 Pipes and their associated joints and fittings whose integrity is essential to the safety of ships, including plastic piping required by SOLAS 11-2/21.4 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 Resolution A.753(18), as amended by IMO Resolutions. MSC.313(88) and IMO Res. MSC. 399(95).

.2 Unless instructed otherwise by the Flag Administration, fire endurance tests are to be carried out with specimen representative for pipes, joints and fittings[2)]:

i) Pipes

- for sizes with outer diameter < 200 mm the minimum outer diameter and wall thickness[3)]
- for sizes with outer diameter $\geq$ 200 mm one test specimen for each category of t/d (D = outer diameter, t = structural wall thickness). A scattering of $\pm$10% for t/D is regarded as the same group. Minimum size approved is equal to the diameter of specimen successfully tested.

ii) Joints

- Each type of joint applicable for applied fire endurance level tested on pipe to pipe specimen

[2)] A test specimen incorporating several components of a piping system may be tested in a single test.

[3)] Test conditions are most demanding for minimum wall thickness and thus larger wall thickness is covered. A key factor determining the fire performance of a pipe component variant is the thickness-to-diameter (t/D) ratio and whether it is larger or smaller than that of the variant which has been fire-tested.

If fire-protective coatings or layers are included in the variant used in the fire test, only variants with the same or greater thickness of protection, regardless of the (t/D) ratio, shall be qualified by the fire test.

.3 Means are to be provided to ensure a constant media pressure inside the test specimen during the fire test as specified in Appendix 1 or 2 of the IMO Res.A.753(18), as amended by IMO Resolutions MSC.313(88) and MSC.399(95). During the test it is not permitted to replace media drained by fresh water or nitrogen.

.4 Depending on the capability of a piping system to maintain its strength and integrity, three different levels of fire endurance for plastic pipe systems are to be distinguished (see IMO Resolution A.753 (18), Appendix 1 and 2).

i) Level 1 - Piping having passed the fire endurance test specified in Appendix 1 of IMO Resolution. A753(18), as amended by IMO Resolutions. MSC.313(88) and 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).

ii) Level 2 - Piping having passed the fire endurance test specified in Appendix 1 of IMO Resolution. A753(18), as amended by IMO Resolutions. MSC.313(88) and 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).

iii) Level 3 - Piping having passed the fire endurance test specified in Appendix 2 of IMO Resolution. A753(18), as amended by IMO Resolutions. MSC.313(88) and MSC.399(95) for a duration of a minimum of 30 minutes in the wet condition is considered to meet level 3 fire endurance standard (L3)

.5 Permitted use of piping depending on fire endurance, location and type of system is given in Table 11.1a.

.6 For safe Return to Port purposes (SOLAS II-2/21.4), plastic piping can be considered to remain operational after a fire casually if the plastic pipes and fittings have been tested to L1 standard.

2.6.6 Flame Spread

.1 All pipes, except those fitted on open decks and within tanks, cofferdams, 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 surface flame spread characteristics not exceeding average values listed in Appendix 3 of IMO Resolution A753(18), as amended by IMO Res. MSC. 313(88) and MSC. 399(95).

.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 also as listed in Appendix 3 of IMO Resolution A.753(18), as amended by IMO Res. MSC.313(88) and MSC.399(95).

.3 Surface flame spread characteristics may also be determined using the text 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.

2.6.7 Fire Protection Coatings

Where a fire protective coating of pipes and fittings is necessary for achieving the fire endurance level required, it is to meet the following requirements:

1) The pipes are generally to be delivered from the manufacturer with the protective coating on.

2) The fire protection properties of the coating are not to be diminished when exposed to salt water, oil or bilge slops. It is to be demonstrated that the coating is resistant to products likely to come into contact with the piping.

3) In considering fire protection coatings, such characteristics as thermal expansion, resistance against vibrations, and elasticity are to be taken into account.

4) The fire protection coatings are to have sufficient resistance to impact to retain their integrity.

2.6.8 Electrical Conductivity

Where electrical conductivity is to be ensured, the resistance of the pipes and fittings is not to exceed 1 x 10^5 Ohm/m.

2.6.9 Installation

.1 Supports

.1.1 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 the 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. Combination of loads is to be considered.

.1.2 Heavy components such as valves and expansion joints are to be independently supported.

.1.3 Each support is to evenly distribute the load of the pipe and its contents over the full width of the support. Measures are to be taken to minimize wear of the pipes where they contact the support.

.2 Expansion

.2.1 Suitable provision is to be made in each pipeline to allow for relative movement between pipes made of plastic and the steel structure, having due regard to:

i) the difference in the coefficients of thermal expansion;

ii) deformations of the ship 's hull and its structure

.2.2 When calculating the thermal expansions, account is to be taken of the difference between the operating temperature of the system and the ambient temperature during installation.

.3 External Loads

.3.1 When installing the piping, allowance is to be made for temporary point loads, where applicable. Such allowances are to include at least the force exerted by a load (person) of 100 kg at mid-span on any pipe of more than 100 mm nominal outside diameter

.3.2 Besides for providing adequate robustness for all piping including open-ended piping a minimum wall thickness, complying with the strength of the pipes, may be increased taking into account the conditions encountered during service on board ships

.3.3 Pipes are to be protected during installation and service from mechanical damage where necessary.

.4 Strength of Connections

.4.1 The strength of connections is to be not les s than that of the piping system in which they are installed.

.4.2 Pipes may be assembled using adhesive-bonded, welded, flanged or other joints.

.4.3 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.

.4.4 Tightening of joints is to be performed in accordance with Manufacturer's instructions.

.5 Installation of Conductive Pipes

.5.1 In piping systems for fluid with conductivity less than 1000 picosiemens per metre [pS/m] such as refined products and distillates use is to be made of conductive pipes.

.5.2 Regardless of the medium, electrically conductive plastic piping is to be used if the piping passes through hazardous areas. The resistance to earth from any point in the piping system is not to exceed 1x10^6 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.

.5.3 After completion of the installation, the resistance to earth is to be verified. Earthing connections are to be arranged in a way accessible for inspection.

.6 Application of Fire Protection Coating

.6.1 Fire protection coatings are to be applied on the joints, where necessary for meeting the required fire endurance as for 2.6.6, after performing hydrostatic pressure tests of the piping system.

.6.2 The fire protection coatings are to be applied in accordance with Manufacturer's recommendations, using a procedure approved in each particular case.

.7 Penetration of Divisions

.7.1 Where plastic pipes pass through "A" or "B" class divisions, arrangements are to be made to ensure that the fire endurance is not impaired. These arrangements are to be tested in accordance with Recommendations for fire test procedures for "A", "B" and "F" bulkheads specified in Part 3 of Annex 1 to the 2010 FTP Code, (Resolution MSC.307 (88) as amended by Resolution MSC.437 (99)).

.7.2 Pipe penetrations through watertight bulkheads or decks as well as through fire divisions are to be type approved by BKI. When plastic pipes pass through watertight bulkheads or decks, the watertight integrity of the bulkhead or deck is to be maintained. For pipes not able to satisfy the requirements in 2.6.3.1.3) ii), a metallic shut-off valve operable from above the freeboard deck should be fitted at the bulkhead or deck.

.7.3 To meet the fire endurance according to Table 11.1a the pipes and fittings may be provided with flame protection covers, coatings or isolations. The installation instructions of the manufacturer have to be considered.

The execution of hydrostatic pressure tests has to be established before the installation of these coverings.

.7.4 In case the bulkhead or deck is also a fire division and destruction of plastic pipes by fire may cause flooding of watertight compartments a metallic shut-off valve is to be fitted at the bulkhead or deck. The operation of this valve is to be provided for from above the freeboard deck.

.8 Control During Installation

.8.1 Installation is to be in accordance with the Manufacturer 's guidelines.

.8.2 Prior to commencing the work, joining techniques are to be approved by BKI.

.8.3 The tests and explanations specified in this Requirement are to be completed before shipboard piping installation commences.

.8.4 The personnel performing this work are to be properly qualified and certified to the satisfaction of BKI.

.8.5 The procedure of making bonds is to include:

i) materials used,
ii) tools and fixtures,
iii) joint preparation requirements,
iv) cure temperature,
v) dimensional requirements and tolerances, and
vi) tests acceptance criteria upon completion of the assembly.

.8.6 Any change in the bonding procedure which will affect the physical and mechanical proper ties of the joint is to require the procedure to be requalified.

.9 Bonding Procedure Quality Testing

.9.1 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.

.9.2 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.

.9.3 Selection of the pipes used for test assembly, is to be in accordance with the following:

i) 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.

ii) 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.

.9.4 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.

2.6.10 Testing after installation on board

1) Piping systems for essential services are to be subjected to a test pressure not less than 1,5 times the design pressure or 4 bar whicever is greater. Notwithstanding the requirement above, the requirement in 2) may be applied to open ended pipes (drains, effluent, etc.).
2) Piping systems for non-essential services are to be checked for leakage under operational conditions.
3) For piping required to be electrically conductive, earthing is to be checked and random resistance testing is to be conducted.

2.7 Aluminium and aluminium alloys

Aluminium and aluminium alloys are to comply with Rules for Materials (Pt.1, Vol.V), and may in individual cases, with the agreement of BKI, be used under the same restrictions as plastic pipes (refer to 2.6 and Table 11.a) and for temperatures up to 200 °C. They are not acceptable for use in fire extinguishing systems.

2.8 Application of materials

For the pipe classes mentioned in A.3 materials must be applied according to Table 11.2.

3. Testing of materials

3.1 For piping systems belonging to class I and II, tests in accordance with Rules for Materials (Pt.1, Vol.V), and under BKI supervision are to be carried out in accordance with Table 11.3 for :

— pipes, bends and fittings

— valve bodies and flanges

— valve bodies and flanges > DN 100 in cargo and process pipelines on gas tankers with design temperature < -55 °C

3.2 Welded joints in pipelines of classes I and II are to be tested in accordance with Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1 Vol.IX).

4. Hydraulic tests on 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.

Table 11.2: Approved materials

<table>
<tr><th colspan="2" rowspan="2">Material or application</th><th colspan="3">Pipe class</th></tr>
<tr><th>I</th><th>II</th><th>III</th></tr>
<tr><td rowspan="3">Steels</td><td>Pipes</td><td>Steel pipes for high temperatures above 300 °C, pipes made of steel with high/low temperature toughness at temperatures below – 10 °C, stainless steel pipes for chemicals</td><td>Pipes for general applications</td><td>Steel not subject to any special quality specification, weldability in accordance with Rules for Welding</td></tr>
<tr><td>Forgings, plates, flanges, steel sections and Bars</td><td colspan="3">Steel suitable for the corresponding service and processing conditions
High temperature steel for temperatures above 300 °C
Steel with high/low-temperature toughness for temperatures below −10 °C</td></tr>
<tr><td>Bolts, Nuts</td><td>Bolts for general machinery constructions, high-temperature steel for temperatures above 300 °C, steel with high /low temperature toughness for temperatures below −10 °C</td><td colspan="2">Bolts for general machine construction</td></tr>
<tr><td rowspan="3">Castings (valves, fittings, pipes)</td><td>Cast steel</td><td>High-temperature cast steel for temperatures above 300 °C, cast steel with high /low temperature toughness at temperatures below −10 °C, stainless castings for aggressive media</td><td colspan="2">Cast steel for general applications</td></tr>
<tr><td>Nodular cast iron</td><td colspan="3">Only ferritic grades, elongation A5 at least 15%</td></tr>
<tr><td>Cast iron with lamellar graphite</td><td>—</td><td>—</td><td>Up to 220 °C, grey cast iron is not permitted for valves and fittings on ship’s side, on collision bulkhead on fuel and oil tanks and for relief valves</td></tr>
<tr><td rowspan="2">Non-ferrous metals (valves, fittings, pipings)</td><td>Copper, copper alloys</td><td>In cargo lines on chemical tankers only with special approval, low-temperature copper-nickel alloys by special agreement</td><td colspan="2">For seawater and alkaline water only corrosion resistant copper and copper alloys</td></tr>
<tr><td>Aluminium, aluminium alloys</td><td>In cargo and processing lines on gas tankers</td><td colspan="2">Only with the agreement of BKI up to 200 °C, not permitted in fire extinguishing systems</td></tr>
<tr><td>Non-metallic materials</td><td>Plastics</td><td>—</td><td>—</td><td>On special approval (see B.2.6)</td></tr>
</table>

Table 11.3: Approved Materials and Types of Material Certificates

Type of Component	Approved materials	Design temperature	Pipe class	Nominal diameter DN	Type of Certificate[2] A	B	C
Pipes [1], Pipe elbows, Fittings	Steel, Copper, Copper alloys, Aluminium Aluminium alloys Plastics	—	I + II	> 50	X	—	—
				≤ 50	—	X	—
			III	All	—	—	X
Valves [1], Flanges,	Steel, Cast steel, Nodular cast iron	> 300 °C	I, II	DN > 100	X	—	—
	Copper, Copper alloys	> 225 °C		DN ≤ 100	—	X	—
	Steel, Cast steel, Nodular cast iron	≤ 300 °C	I, II	PB × DN > 2500 or DN > 250	X	—	—
				PB × DN ≤ 2500 or DN ≤ 250	—	X	—
	Steel, Cast steel, Nodular cast iron, Grey cast iron	—	III	All	—	—	X
	Copper, Copper alloys	≤ 225 °C	I, II	PB × DN > 1500	X	—	—
	Aluminium, Aluminium alloys	≤ 200 °C		PB×DN≤1500	—	X	—
	Plastics	Acc. to Type Approval Certificate	III	All	—	—	X
Semi-finished products, Screws and other component	According to Table 11.2	—	I, II	—	—	X	—
			III	—	—	—	X

1) Casings of valves and pipes fitted on ship's side and bottom and bodies of valves fitted on collision bulkhead are to be included in pipe class II

2) Test Certificates acc. to Rules for Materials (Pt.1, Vol.V), Sec. 1-3. with the following abbreviations:
A: BKI Material Certificate, B: Manufacturer Inspection Certificate, C: Manufacturer Test Report

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 is to be chosen according to Table 11.4.

Table 11.4: Design pressure for fuel pipes

Max. working temperature / Max. working pressure	$T \le 60$ °C	T > 60 °C
PB $\le$ 7 bar	3 bar or max. working pressure, whichever is greater	3 bar or max. working pressure, whichever is greater
PB > 7 bar	max. working pressure	14 bar or max. 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, feed water 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, if this is provided, are to be subjected to a hydraulic pressure test in the presence of the Surveyor at the following value of pressure:

$$p_p = 1{,}5\ p_c \qquad [\text{bar}]$$

where p_c is the design pressure. For steel pipes and their integral fittings intended to be used in systems with working temperature above 300 °C the test pressure PP is to be as follows:

$$p_p = 1,5 \cdot \frac{\sigma_{perm(100°)}}{\sigma_{perm(t)}} \cdot p_c$$

$\sigma_{perm(100°)}$ = permissible stress at 100 °C
$\sigma_{perm(t)}$ = permissible stress at the design temperature t [°C]

However, the test pressure need not exceed:

$$p_p = 2\ p_c \qquad [\text{bar}]$$

With the approval of BKI, this pressure may be reduced to 1,5 p_c where it is necessary to avoid excessive stress in way of bends, T-pieces and other shaped components.

In no case may the membrane stress exceed 90% of the yield strength or 0,2% of the maximum elongation.

4.2.2 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 BKI for approval for testing pipe connections on board, particularly in respect of welding seams.

4.2.3 Where the hydraulic pressure test of piping is carried out on board, these tests may be conducted in conjunction with the tests required under 4.3.

4.2.4 Pressure testing of pipes with less than DN 15 may be omitted at BKI'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 BKI Surveyor.

In general, all pipe systems are to be tested for leakage under operational conditions. If necessary, special techniques other than hydraulic pressure tests are to be applied.

4.3.2 Heating coils in tanks and pipe lines for fuels are to be tested to not less than 1,5 PR but in no case less than 4,0 bar.

4.3.3 Pneumatic leak testing may be carried out on water sensitive systems, in lieu of hydrostatic testing. In certain circumstances, a combined hydrostatic – pneumatic strength test may also be applied, where the system is partially filled with water and the free space above is pressurized with a test gas (typically air or nitrogen). When pneumatic tests cannot be avoided, the safety precautions in Guidance for Marine Industry (Pt.1, Vol.AC) Sec.7 R-140, Part F, are to be observed.

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 BKI Surveyor:

— valves of pipe classes I and II to 1,5 PR

— valves on the ship's side to not less than 5,0 bar

Shut-off devices of the above type are to be addition ally tested for tightness with the nominal pressure.

Shut-off devices for boilers, see Section 7.I.E.13.

5. Structural tests, heat treatment and non-destructive testing

Attention should be given to the workmanship in construction and installation of the piping systems according to the approved data. For details concerning non-destructive testing following heat treatments, etc, see Rules for Materials (Pt.1, Vol.V).

C. Calculation of Wall Thickness and Elasticity

1. Minimum wall thickness

1.1 The pipe thicknesses stated in Tables 11.5 to 11.8 are 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 11.6 may, with BKI's agreement, be reduced by up to 1 mm, the amount of the reduction is to be in relation to the wall thickness.

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 location is to be as stated in Tables 11.5.

1.2 The minimum wall thicknesses for austenitic stainless steel pipes are given in Table 11.7.

1.3 For the minimum wall thickness of air, sounding and overflow pipes through weather decks, see Table 11.22a.

For CO_2 fire extinguishing pipelines, see Section 12, Table 12.6.

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.

Table 11.5: Minimum wall thickness groups N, M and D of steel pipes and approved locations

<table>
<tr><th rowspan="2">Piping system</th><th colspan="16">Location</th></tr>
<tr><th>Machinery space</th><th>Cofferdams / void spaces</th><th>Cargo holds</th><th>Ballast water tanks</th><th>Fuel and changeover tanks</th><th>Fresh coding water tanks</th><th>Lubricanting oil tanks</th><th>Hydraulic oil tanks</th><th>Drinking water tanks</th><th>Thermal oil tanks</th><th>Condensate and feed water tanks</th><th>Accomodation</th><th>Cargo tanks, tank ships</th><th>Cofferdams, tank ships</th><th>Cargo pump rooms</th><th>Weather deck</th></tr>
<tr><td>Bilge lines</td><td rowspan="3">M</td><td rowspan="13">M</td><td>M</td><td>D</td><td rowspan="3">D</td><td rowspan="5">X</td><td rowspan="4">X</td><td rowspan="4">X</td><td rowspan="9">X</td><td rowspan="5">X</td><td rowspan="6">X</td><td>M</td><td>X</td><td>M</td><td rowspan="2">M</td><td>–</td></tr>
<tr><td>Ballast lines</td><td rowspan="3">D</td><td rowspan="2">M</td><td>X</td><td>[1]</td><td rowspan="7">–</td><td rowspan="12">N</td></tr>
<tr><td>Seawater lines</td><td>M[2]</td><td rowspan="3">X</td><td>M</td></tr>
<tr><td>Fuel lines</td><td rowspan="10">N</td><td>D</td><td>N</td><td rowspan="3">X</td><td rowspan="2">–</td></tr>
<tr><td>Lubricating lines</td><td>–</td><td>X</td><td>X</td><td>N</td><td rowspan="4">–</td></tr>
<tr><td>Thermal oil lines</td><td rowspan="8">M</td><td rowspan="3">M</td><td rowspan="3">M</td><td rowspan="3">M</td><td rowspan="3">M</td><td>N</td><td rowspan="3">M</td><td rowspan="3">N</td></tr>
<tr><td>Steam lines</td><td rowspan="5">X</td><td rowspan="3">N</td><td rowspan="2">N</td></tr>
<tr><td>Condensate lines</td></tr>
<tr><td>Feedwater lines</td><td rowspan="3">X</td><td rowspan="2">X</td><td rowspan="2">X</td><td rowspan="2">X</td><td rowspan="3">X</td><td>X</td><td rowspan="4">X</td><td rowspan="2">X</td><td rowspan="2">X</td></tr>
<tr><td>Drinking water lines</td><td>N</td><td rowspan="4">X</td><td>N</td></tr>
<tr><td>Fresh cooling water lines</td><td>D</td><td>N</td><td>D</td><td rowspan="3">X</td><td>X</td><td>–</td><td>–</td></tr>
<tr><td>Compressed air lines</td><td rowspan="2">M</td><td rowspan="2">M</td><td>M</td><td>M</td><td rowspan="2">N</td><td>N</td><td>N</td><td rowspan="2">N</td><td rowspan="2">N</td></tr>
<tr><td>Hydraulic lines</td><td>X</td><td>X</td><td>X</td><td>X</td><td>N</td></tr>
</table>

[1] See Section 15, B.4.3

[2] Seawater discharge lines, see Section 11, T.

X Pipelines are not to be installed.

(–) Pipelines may be installed after special agreement with BKI

Table 11.6: Minimum wall thickness for steel pipes

Group N				Group M		Group D	
d_a	**s**	**d_a**	**s**	**d_a**	**s**	**d_a**	**s**
[mm]	**[mm]**	**[mm]**	**[mm]**	**[mm]**	**[mm]**	**[mm]**	**[mm]**
from 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 660,0	7,1	From 38,0	3,6	From 88,9	7,1
From 20,0	2,0	From 762,0	8,0	From 51,0	4,0	From 114,3	8,0
From 48,3	2,3	From 864,0	8,8	From 76,1	4,5	From 152,4 up to 457,2	8,8
From 70,0	2,6	From 914,0	10,0	From 117,8	5,0		
From 88,9	2,9			From 193,7	5,4		
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 323,9	5,6			From 914,4	10,0		

Table 11.7: Minimum wall thickness for austenitic stainless steel pipes

Pipe outside diameter d_a [mm]	Minimum wall thickness s [mm]
Up to 17,2	1,0
Up to 48,3	1,6
Up to 88,9	2,0
Up to 168,3	2,3
Up to 219,1	2,6
Up to 273,0	2,9
Up to 406,9	3,6
Over 406,9	4,0

Table 11.8: Minimum wall thickness for copper and copper alloy pipes

Pipe 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. Calculation of pipe wall thicknesses

2.1 The following formula is to be used for calculating the wall thicknesses of cylindrical pipes and bends subject to internal pressure:

$$s = s_o + c + b \qquad [mm] \qquad (1)$$

$$s_o = \frac{d_a \cdot p_c}{20 \cdot \sigma_{perm} \cdot v + p_c} \qquad [mm] \qquad (1a)$$

s = minimum wall thickness [mm], see 2.7

s_o = calculated thickness [mm]

d_a = outer diameter of pipe [mm]

σ_{perm} = maximum permissible design stress [N/mm2], see 2.3

b = allowance for bends [mm], see 2.2

v = weld efficiency factor, see 2.5

c = corrosion allowance [mm], see 2.6

p_c = design pressure[4)] [bar], see B.4.1.4

2.2 straight cylindrical pipes which are to be bent, an allowance (b) is to be applied for the bending of the pipes. The value of (b) is to 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:

$$b = 0,4 \cdot \frac{d_a}{R} \cdot s_o \quad (2)$$

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 (1a) is to be chosen as the lowest of the following values:

a) design temperature ≤ 350 °C

$$\sigma_{perm} = \min\left\{\frac{R_{m,20°}}{A}, \frac{R_{eH,t}}{B}, \frac{R_{po,2,t}}{B}\right\}$$

$R_{m,20°}$ = specified minimum tensile strength at room temperature

$R_{eH,t}$ = specified minimum yield stress at design temperature; or

$R_{po,2,t}$ = minimum value of the 0,2% proof stress at design temperature

b) design temperature > 350 °C, whereby it is to be checked whether the calculated values according to a) give the decisive smaller value

$$\sigma_{perm} = \min\left\{\frac{R_{m,100000,t}}{B}, \frac{R_{p1,100000,t}}{B}, \frac{R_{m,100000,(t+15)}}{B}\right\}$$

$R_{m,100000,t}$ = minimum stress to produce rupture in 100000 hours at the design temperature t

$R_{p1,100000,t}$ = average stress to produce 1% creep in 100000 hours at the design temperature t

$R_{m,100000,(t+15)}$ = average stress to produce rupture in 100000 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 BKI and

— are made of material tested by BKI, BKI may, on special application, agree to a safety factor B of 1,6 (for A and B see Table 11.10).

4) For pipes containing fuel heated above 60 °C the design pressure is to be taken not less than 14 bar

2.3.2 Pipes made of metallic materials without a definite yield point

Materials without a definite yield point are covered by Table 11.9. For other materials, the maximum permissible stress is to be stated with BKI agreement, but is to be at least

$$\sigma_{perm} \leq \frac{R_{m,t}}{5}$$

$R_{m,t}$ is the minimum tensile strength at the design temperature.

2.3.3 The mechanical characteristics of materials which are not included in the Rules for Materials (Pt.1, Vol.V), are to be agreed with BKI, reference to Table 11.10.

Steel pipes without guaranteed properties may be used only up to a working temperature of 120 °C where the permissible stress σ_{perm} ≤ 80 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 11.9: Permissible stress σ_{perm} for copper and copper alloys (annealed)

Pipe material		Minimum tensile strength	Permissible stress σ_{perm} [N/mm^2]										
		[N/mm^2]	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 alloy	Cu Ni 5 Fe Cu Ni 10 Fe	275	68	68	67	65,5	64	62	59	56	52	48	44
	Cu Ni 30 Fe	365	81	79	77	75	73	71	69	67	65,5	64	62

Table 11.10: Coefficient A,B for determining the permitted 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
Steelwithyieldstrength[1] > 400N/mm^2	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

2.4.2 Design temperatures for superheated steam lines are as follows:

a) pipes behind desuperheaters:

— with automatic temperature control:

the working temperature[5)] (design temperature)

— with manual control:

the working temperature + 15 °C[5)]

b) pipes before desuperheaters:

— the working temperature + 15 °C[5)]

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 taken according to the works acceptance test of BKI.

2.6 Corrosion allowance

The corrosion allowance c depends on the application of the pipe, in accordance with Tables 11.11a and 11.11b. With the agreement of BKI, the corrosion allowance of steel pipes effectively protected against corrosion may be reduced by not more than 50%.

With the agreement of BKI, no corrosion allowance need to be applied to pipes made of corrosion-resistant materials (e.g. austenitic steels and copper alloys) (see Table 11.7 and 11.8).

Table 11.11a: 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 blowdown 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 refrigerants	0,3
Refrigerant lines for Group 2 refrigerants	0,5
Seawater lines	3,0
Fresh water lines	0,8

[5)] Transient excesses in the working temperature need not be taken into account when determining the design temperature.

Table 11.11b: Corrosion allowance c for non-ferrous metals

Pipe material	**Corrosion allowance c [mm]**
Copper, brass and similar alloys	0,8
Copper-tin alloys except those containing lead	
Copper-nickel alloys (with Ni $\geq$ 10%)	0,5

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 calculated wall thickness so and specified as the tolerance allowance t.

The value of t may be calculated as follows:

$$t = \frac{a}{100 - a} \cdot s_o \quad [mm] \qquad (3)$$

a = negative tolerance on the thickness [%]
so = calculated wall thickness according to 2.1 [mm]

3. Analysis of elasticity

3.1 The forces, moments and stresses caused by impeded thermal expansion and contraction are to be calculated and submitted to BKI for approval for the following piping systems:

- 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. BKI reserve the right to perform confirmatory calculations.

For determining the stresses, the hypothesis of the maximum shear stress is to be considered. The resulting equivalent stresses due to primary loads, internal pressure and dead weight of the piping system itself (inertia forces) are not to exceed the maximum permissible stress according to 2.3. The equivalent stresses obtained by adding together the above mentioned primary forces and the secondary forces due to impeded expansion or contraction are not to exceed the mean low cycle fatigue value or the meantime yield limit in 100000 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 permissible stress as specified in 2.3 is to be proposed. Generally, the maximum permissible stress is equal to 70% of the value according to 2.3 for pipes with diameters over 300 mm. Below this figure, a reduction to 80% is sufficient. Where detailed stress measuring, calculations or approvals are available, higher stresses can be permitted.

5. Calculation of 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 values of the relevant stresses or the material are specified may be used at higher temperatures up to the following pressure:

$$p_{perm} = \frac{\sigma_{perm\ standard}}{\sigma_{perm(t,material)}} \cdot p_{standard}$$

$\sigma_{perm(t,material)}$	=	permissible stress according to 2.3 for proposed material at design temperature t
$\sigma_{perm\ standard}$	=	permissible stress according to 2.3 for the material at the temperature corresponding to the strength data specified in the standard
$p_{standard}$	=	nominal PN pressure specified in the standard

D. Principles for the Construction of Pipes, Valves, Fittings and Pumps

1. General principles

1.1 Piping systems are to be constructed and manufactured on the basis of standards generally used in shipbuilding.

1.2 For welding and brazed connections as well as similar joining methods the requirements according to Rules for Welding (Pt.1, Vol.VI), are to be observed.

1.3 Welded connections rather than detachable couplings are to be used for pipelines carrying toxic media and inflammable liquefied gases as well as for superheated steam pipes with temperatures exceeding 400 °C.

1.4 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.

1.5 Where pipes are protected against corrosion by special protective coatings, e.g. hot-dip galvanizing, rubber lining, etc., it is to be ensured that the protective coating will not be damaged during installation.

1.6 Seawater pipes in cargo holds for dry cargoes, including cargo spaces of container ships, ro-ro ships, are to be protected from impact of cargo where they are liable to be damaged.

2. Pipe connections

2.1 The following pipe connections may be used:

- full penetration butt welds with/without provision to improve the quality of the root
- socket 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, etc.) of an approved type

For the use of welded pipe connections, see Table 11.12

2.2 Flange connections

2.2.1 Dimensions of flanges and bolting are to comply with recognized standards.

Table 11.12: 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 weld brazed connections [1]	III	
	II	$\leq$ 60,3 mm

[1] For flammable liquids brazed connections are only permitted between pipes and components which are directly connected to machinery and equipment.
Brazed connections in piping systems conveying flammable media which are arranged in machinery spaces of category A are in general not permissible, deviations require BKI approval.

2.2.2 Gaskets are to be suitable for the intended media under design pressure and maximum working temperature conditions and their dimensions and construction is to be in accordance with recognized standards.

2.2.3 Steel flanges may be used as shown in Tables 11.16 and 11.17 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:

— welding neck flanges according to standard up to 200 °C or 300 °C according to the maximum temperatures indicated in Table 11.9; applicable to all classes of pipe

— loose flanges with welding collar; as for a)

— 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 Welded socket connections

Welded socket connections may be accepted according to Table 11.12. Following conditions are to be observed.

— The thickness of the sockets is to be in accordance with C.1.1 at least equal to the thickness of the pipe.

— The clearance between the pipes and the socket is to be as small as possible.

— The use of welded socket connections in systems of pipe class II may be accepted only under the condition that in the systems no excessive stress, erosion and corrosion are expected.

2.4 Screwed socket connections

2.4.1 Screwed socket connections with parallel and tapered threads are to comply with requirements of recognized national or international standards.

2.4.2 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). They are not permitted for systems for flammable media.

2.4.3 Screwed socket connections with tapered threads are permitted for the following:

— class I, outside diameter not more than 33,7 mm

— class II and class III, outside diameter not more than 60,3 mm

Screwed socket connections with tapered threads are not permitted for piping systems conveying toxic or flammable media or services where fatigue, severe erosion or crevice corrosion is expected to occur.

2.4.4 Screwed socket connections may be used for connecting small bore instrumentation equipment (e.g., pressure/temperature sensors) to piping systems conveying flammable media if such connections comply with a recognized national and/or international standard such as ASME B31.1 and ASME B31.3. The use of such threaded joints shall be limited to outside diameters of maximum 25mm.

2.5 Mechanical joints

2.5.1 The application and pressure ratings of different mechanical joints are to be approved by BKI. The approval is to be based on the Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W). Mechanical joints including pipe unions, compression couplings, slip-on joints and similar joints are to be of approved type for the service conditions and the intended application. See Table 11.13 for the example of mechanical joints.

2.5.2 Where appropriate, mechanical joints are to be of fire resistant type as required by Table 11.14.

2.5.3 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 fluids.

2.5.4 Where the application of mechanical joints results in reduction in pipe wall thickness due to the use of bite type rings or other structural elements, this is to be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.

2.5.5 Material of mechanical joints is to be compatible with the piping material and internal and external media.

2.5.6 Mechanical joints are to be tested where applicable, 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 BKI.

2.5.7 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.

2.5.8 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.

Table 11.13: Example of mechanical joints

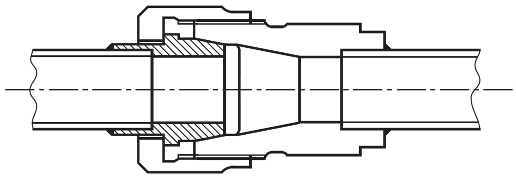
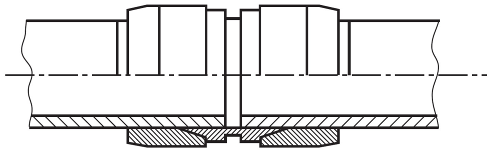
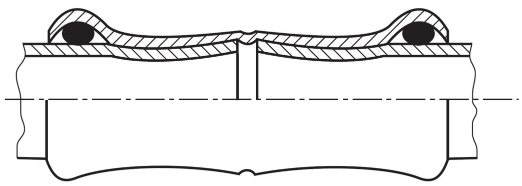
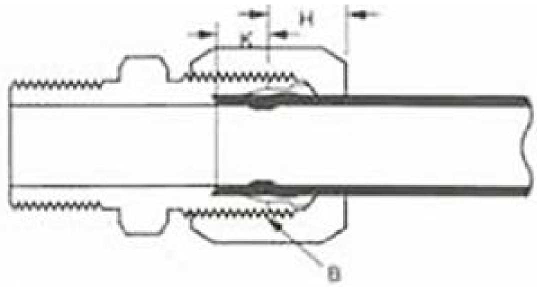
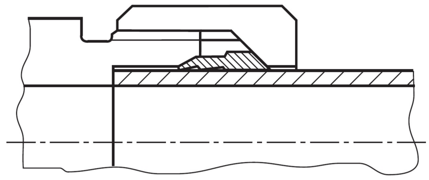
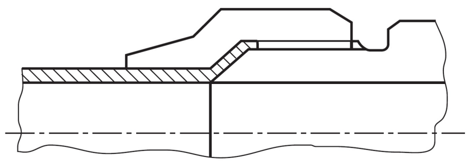
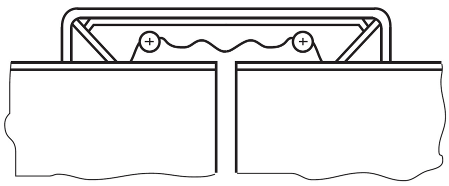
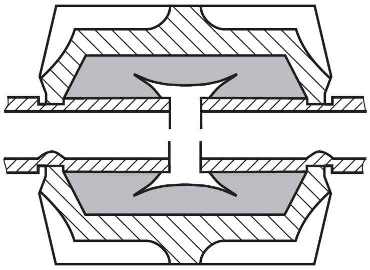
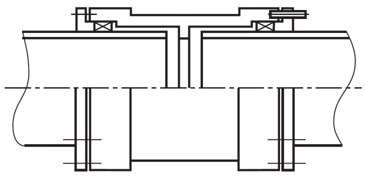
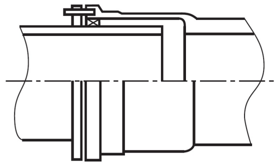
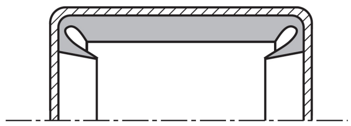
Pipe Unions	
Welded and brazed type	
Compression Couplings	
Swage type	
Press type	
Typical Compression Type	
Bite type	
Flared type	
Grip type	

Table 11.13: Example of mechanical joints *(continued)*

Slip-on Joints	
Machine grooved type	
Slip type	  

2.5.9 Application of mechanical joints and their acceptable use for each service is indicated in Table 11.14, dependence upon the Class of piping and pipe dimensions is indicated in Table 11.15.

2.5.10 Mechanical joints are to be tested in accordance with a program approved by the BKI, which is to include at least the following:

- leakage test
- vacuum test (where necessary)
- vibration (fatigue) test
- fire endurance test (where necessary)
- burst pressure test
- pressure pulsation test (for Class I and II mandatory, for Class III where necessary)
- assembly test (where necessary)
- pull out test (where necessary)

Table 11.14: Application of mechanical joints

Systems	Kind of connections			Classification of pipe system	Fire endurance test condition[7)]
	Pipe Unions	Compression couplings	Slip-on joints		
Flamable fluids (Flash point ≤ 60 °C)					
Cargo oil lines[1)]	+	+	+	dry	30 min dry (*)
Crude oil washing lines[1)]	+	+	+	dry	30 min dry (*)
Vent lines[3)]	+	+	+	dry	30 min dry (*)
Inert gas					
Water seal effluent lines	+	+	+	wet	30 min wet (*)
Scrubber effluent lines	+	+	+	wet	30 min wet (*)
Main lines[2&3)]	+	+	+	dry	30 min dry (*)
Distribution lines[1)]	+	+	+	dry	30 min dry (*)
Flamable fluids (Flash point >60 °C)					
Cargo oil lines[1)]	+	+	+	dry	30 min dry (*)
Fuel oil lines[2&3)]	+	+	+	wet	30 min wet (*)
Lubricating oil lines[2&3)]	+	+	+	wet	30 min wet (*)
Hydraulic oil[2&3)]	+	+	+	wet	30 min wet (*)
Thermal oil[2&3)]	+	+	+	wet	30 min wet (*)
Sea water					
Bilge lines[4)]	+	+	+	dry/wet	8 min dry + 22 min wet (*)
Permanent water filed fire extinguishing system, e.g. fire main, sprinkler systems[3)]	+	+	+	wet	30 min wet (*)
Non-permanent water filled fire exthingishing systems, e.g. foam, drencher systems and fire main[3)]	+	+	+	dry/wet	8 min dry + 22 min wet (*) For foam system FSS Code Chapter 6 to be observed
Ballast system[4)]	+	+	+	wet	30 min wet (*)
Cooling water system[4)]	+	+	+	wet	30 min wet (*)
Tank cleaning services	+	+	+	dry	Fire endurance test not required
Non essential system	+	+	+	dry dry/wet wet	Fire endurance test not required
Fresh Water					
Cooling water system[4)]	+	+	+	wet	30 min wet (*)
Condensate return4)	+	+	+	wet	30 min wet (*)
Non-essential system	+	+	+	dry dry/wet wet	Fire endurance test not required
Sanitary / Drains / Scuppers					
Deck drains (internal) [5)]	+	+	+	dry	Fire endurance test not required
Sanitary drains	+	+	+	dry	Fire endurance test not required

Table 11.14: Application of mechanical joints *(continued)*

Systems	Kind of connections			Classification of pipe system	Fire endurance test condition[7)]
	Pipe Unions	Compression couplings	Slip-on joints		
Scuppers and discharge (overboard)	+	+	+	dry	Fire endurance test not required
Sounding / Vent					
Water tanks/Dry spaces	+	+	+	dry wet	Fire endurance test not required
Oil tanks (F.P.>60 °C) [2&3)]	+	+	+	dry	Fire endurance test not required
Miscellaneous					
Starting/Control air [4)]	+	+	+	dry	30 min wet (*)
Service air (non-essential)	+	+	+	dry	Fire endurance test not required
Brine	+	+	+	wet	Fire endurance test not required
CO_2 system (outside protected space)	+	+	+	dry	30 min wet (*)
CO_2 system (inside protected space)	+	+	-	dry	Mechanical joints shall be constructed of materials with melting point above 925 °C. Reference to FSS Code Chapter 5
Steam	+	+	-[6)]	wet	Fire endurance test not required

Abbreviations:
- \+ Application is allowed
- – Application is not allowed
- * Fire endurance test

Footnotes:

Fire Resistant capacity:

If mechanical joints include any components which really deteriorate in case of fire, the following footnotes are to be observed:

1) Fire endurance test shall be applied when mechanical joints are installed in pump rooms and open deck
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 joints 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) Fire endurance test shall be applied when mechanical joints are installed inside machinery spaces of category A.

Footnote general

5) Only above bulkhead deck of passenger ships and freeboard deck of cargo ships.
6) Slip type slip-on joints as shown in Table 6. May be used for pipes on deck with a design pressure of 10 bar or less.
7) If a connection has passed the ”30 min dry” test, it is considered suitable also for applications for which the ”8 min dry+22 min wet” and/or ”30 min wet ” tests are required. If a connection has passed the ”8 min dry+22 min wet” test, it is considered suitable also for applications for which the ”30 min wet” test is required.

2.5.11 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.

2.5.12 In addition to the range of application specified in Table 11.14 the use of slip-on joints is not permitted in:

— bilge lines inside ballast and fuel tanks

— sea water and ballast lines including air and overflow pipes 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 overflow pipes in side cargo holds and ballast tanks

— fire extinguishing systems which are not permanently water filled

Table 11.15: Application of mechanical joints depending upon the class of piping

Types of joints	**Classes of piping systems**		
	I	**II**	**II**
Pipe Unions			
Welded and brazed type	+ (d_a ≤ 60,3 mm)	+ (d_a ≤ 60,3 mm)	+
Compression Couplings			
Swage type	+	+	+
Press type	–	–	+
Bite type	+	+	+
Flared type	+	+	
Typical compression type	+	+	+
Slip-on Joints			
Machine grooved type	+	+	+
Grip type	–	+	+
Slip type	–	+	+
Abbreviations: + Application is allowed – Application is not allowed			

Slip-on joints are not to be used in pipelines in cargo holds, tanks and other spaces which are not easily accessible (refer to MSC/Circ.734), except that these joints may be permitted in tanks that contain a medium of the same nature.

Usage of slip type slip-on joints as the main means of pipe connection is not permitted except for cases where compensation of lateral pipe movement is necessary.

Table 11.16: 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]	Type of flange	Temperature [°C]	Type of flange	Type of flange	Temperature [°C]	Type of flange
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
II	—	—	—	A, B, C, D, E	A, B, C, E	—	A, B, C, D, E, F[3)]

1) Type B only for outside diameter d_a < 150 mm

2) Type E only for t < 150 °C and PR < 16 bar

3) Type F only for water pipes and open-ended lines

2.5.13 In addition to the range of application specified in Table 11.14 the use of slip-on joints is not permitted in:

— bilge lines inside ballast and fuel tanks

— sea water and ballast lines including air and overflow pipes 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 overflow pipes in side 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 medium of the same nature.

Unrestrained slip on joints may be used only where required for compensation of lateral pipe movement.

3. Layout, marking and installation

3.1 Piping systems are to be adequately identified according to their purpose based on requirement in recognized standard. Valves are to be permanently and clearly marked.

3.2 Pipe penetrations leading through bulkheads/decks and tank walls are to be water and oil tight. Bolts through bulkheads are not permitted. Holes for fastening screws are not to be drilled in the tank walls.

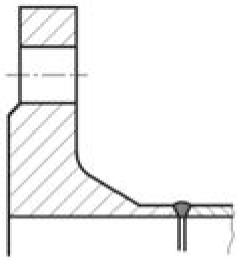
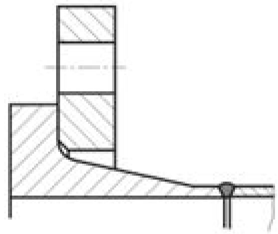
3.3 Sealing systems for pipes penetrating through watertight bulkheads and decks as well as through fire divisions are to be approved by BKI unless the pipe is welded into the bulkhead/deck (see Rules for Hull, (Pt.1, Vol.II) Sec. 29, C.8)[6)].

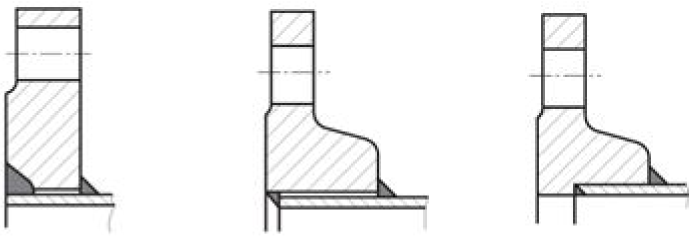
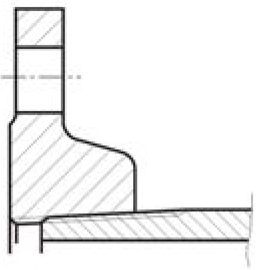
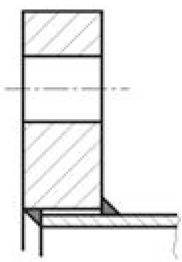
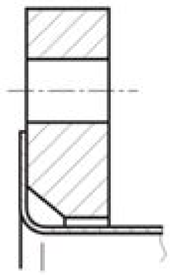
3.4 Piping close to electrical switchboards are to be so installed or protected that a leakage cannot damage the electrical installation.

6) Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W).

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 are to be equipped with special drain arrangements.

Table 11.17: Types of flange connections

<table>
<tr><td colspan="3">Type A


Welding neck flange Loose flange with welding neck</td></tr>
<tr><td colspan="3">Type B

Slip-on welding flange – fully welded</td></tr>
<tr><td colspan="3">Type C

Slip-on welding flange</td></tr>
<tr><td>Type D

Socket screwed flange
–conical threads-</td><td>Type E

Plain flange
–welded on both sided-</td><td>Type F

Lap joint flange
–on flanged pipi-</td></tr>
</table>

3.6 Pipe lines laid through ballast tanks, which are coated in accordance with Rules for Hull (Pt. 1,Vol.II), Sec. 35, F. are to be either effectively protected against corrosion from outside or they are to be of low susceptibility to corrosion.

The method of corrosion protection of tanks and pipes is to be compatible.

3.7 The wall thickness of pipes between ship's side and first shut-off device is to be in accordance with Table 11.20b, column B. Pipes are to be connected only by welding or flanges.

4. Shut-off devices

4.1 Shut-off devices are to 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 are to 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 are not to be used.

4.5 Valves are to be permanently marked. The marking is to comprise at least the following details:

— material of valve body

— nominal diameter

— nominal pressure.

5. Valves on the shell plating

5.1 For the mounting of valves on the shell plating, see Rules for Hull (Pt 1, Vol.II) Sec. 6, G.

5.2 Valves on the shell plating are to be easily accessible. Seawater inlet and outlet valves are to be capable of being operated from above the floor plates. Cocks on the shell plating are to be so arranged that the handle can only be removed when the cocks closed.

5.3 Valves with only one flange may be used on the shell plating and on the sea chests only after special approval.

5.4 On ships with > 500 GT, in periodically unattended machinery spaces, the controls of sea inlet and discharge valves are to be sited so as to allow to reach and operate sea inlet and discharge valves in case of influx of water within 10 minutes[7)] after triggering of the bilge alarm.

Non return discharge valves need not to be considered.

5.5 For ships contracted for construction on or after 1 January 2013, in periodically unattended machinery spaces, the controls of any valve serving a sea inlet, a discharge below the waterline or a bilge direct suction system shall be so placed as to allow adequate time for operation in case of influx of water to the space, having regard to the time likely to be required in order to reach and operate such controls. If the level to which the space could become flooded with the ship in the fully loaded condition so requires, arrangements shall be made to operate the controls from a position above such level.

6. Remote control of 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 valves important 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 15, B.2.3.3.

6.3 Arrangement of valves

6.3.1 The accessibility of the valves for maintenance and repair is to be taken into consideration.

Valves in bilge lines and sanitary pipes are to be always accessible.

[7)] Various flag state administrations have issued own requirements on this subject

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 are to be always 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 are to 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 Oil fuel lines located inside the damage area according to MARPOL I 12A

Remote controlled shut-off devices in fuel bunker lines on fuel tanks shall automatically close in case the power supply fails. Suitable arrangements are to be provided which prevent inadmissible pressure raise in the bunker line during bunkering if the valves close automatically.

Note:

To fulfill the above requirements for example the following measures could be taken:

- *Separated bunker and transfer lines (bunkering from tank top)*
- *Safety relief valves on the bunker lines leading to an overflow tank*

6.3.6 Cargo pipes

For remote controlled valves inside cargo tanks, see Section 15, B.2.3.3

6.4 Control stands

6.4.1 The control devices of remote controlled valves of a system 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 at the control stand.

6.4.4 The status of bilge valves ”open”/”close” is to be indicated by BKI approved position indicators.

6.4.5 For volumetric position indicators the remote control system shall trigger an alarm in the event of a position indicator malfunction due to e.g. pipe leakage or blocking of the valve.

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 may be supplied with air from the general compressed air system.

Where 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 audible 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 of Guidance for Design, Construction and Testing Pump (Pt.1, Vol.V) 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 BKI supervision.

— bilge pumps/bilge ejectors
— ballast pumps
— cooling sea water pumps
— cooling fresh water pumps
— fire pumps including pumps serving fixed fire extinguishing systems (e.g. sprinkler pumps)
— emergency fire pumps including drive units
— condensate pumps
— boiler feed water 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
— pumps serving water spraying systems dedicated to cooling purposes (drencher pumps)

Other hydraulic pump/motors, see Section 14.

8. Protection of piping systems against over pressures:

The following piping systems are to be fitted with safety valves to avoid excessive overpressures:

— piping systems and valves in which liquids can be enclosed and heated
— piping systems which may be exposed to pressures in excess of the design pressure

Safety valves are to be capable of discharging the medium at a maximum pressure increase of 10% of the allowable working pressure. Safety valves are to be type approved according to Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W). Safety valves are to be fitted on the low pressure side of reducing valves.

9. Piping on ships with Character of Classification ✠ or ✠

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 Rules for Hull (Pt.1, Vol.II) Sec. 29.K. as well as M.5 of this Section.

9.1.2 Liquefied gas tankers according to Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol.IX).

9.1.3 Chemical tankers according to Rules for Ships Carrying Dangerous Chemical in Bulk (Pt.1, Vol.X).

9.1.4 Other cargo ships according to Rules for Hull (Pt.1, Vol.II) Sec. 36, E.3

9.2 Rules for Hull (Pt.1, Vol.II) Sec. 21, D. is to be additionally applied for scuppers and discharge lines, Rules for Hull (Pt.1, Vol.II) Sec. 21, E. is to be additionally applied for vent, overflow and sounding pipes. For closed cargo holds on passenger ships, see M.4.4.

9.3 For pipe penetrations through watertight bulkheads, see Rules for Hull (Pt.1, Vol.II), Sec. 11, A.3.4.

9.4 Pipelines with open ends in compartments or tanks are to be laid out so that no additional compartments or tanks can be flooded in any damaged condition to be considered.

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 not possible to lay the pipelines outside the assumed damage zone, 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 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 are to be capable of being operated from a control panel located on the navigation bridge, where it is to 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 water-tight 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 most unfavourable 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 water tight bulkhead of the relevant compartment and is to be secured in open position to prevent unintended operation. The shut-off valves are to be capable of being operated from a control panel located on the navigation bridge, where it is to 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, they will be below the waterline the shut-off valves may be dispensed with.

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 Essential consumers are:

- all consuming units important for the propulsion, manoeuvrability and safe operation of the ship as well as the essential auxiliary machines according to Section 1, H.
- all consuming units necessary to the safety of the ship.

1.3 Every steam consuming unit is to be capable of being shut off from the system.

2. Calculation of pipelines

2.1 Steam lines and valves are to be constructed for the design pressure (PR) according to B.4.1.4.

2.2 Calculations of pipe thickness and analysis of elasticity 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 where 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 15.

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 supplied from a system with higher pressure, it is to be provided with reducing valves and with relief valves on the low pressure side.

3.9 Welded connections in steam lines are subject to the requirements specified in Rules for Welding (Pt.1, Vol.VI).

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 steamout 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 pipes for expanding. This can be in the form of measuring sections on straight length of pipes at the superheater outlet preferably. The length of these measuring sections is to be at least $2 \cdot d_a$.

F. Boiler Feed Water and Circulating Arrangement, Condensate Recirculation

1. Feed water pumps

1.1 At least two feed water pumps are to be provided for each boiler installation.

1.2 Feed water pumps are to be so arranged or equipped that no backflow of water can occur when the pumps are not in operation.

1.3 Feed water pumps are to be used only for feeding boilers.

2. Capacity of feed water pumps

2.1 Where two feed water 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 feed water pumps are installed, the capacity of all other feed water 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 feed water 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 feed water pumps for plants incorporating a combination of oil fired and exhaust gas boilers.

3. Delivery pressure of feed water pumps

Feed water 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 1,0 times the approved steam output at 1,1 times the allowable working pressure.

The flow resistance in the piping between the feed water pump and the boiler is to be taken into account. In the case of continuous flow boilers the total resistance of the boiler is to be taken into account.

4. Power supply to feed water pumps for main boilers

4.1 For steam-driven feed water 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 feed water 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. Feed water lines

Feed water lines may not pass through tanks which do not contain feed water.

5.1 Feed water lines for main boilers

5.1.1 Each main boiler is to be provided with a main and an auxiliary feed water line.

Where 2 adequately sized main boilers are provided the feed water to each of the boilers may be supplied by a single feed water line.

5.1.2 Each feed water 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 feed water 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 feed water line.

5.2 Feed water lines for auxiliary steam producers (auxiliary and exhaust gas boilers)

5.2.1 The provision of only one feed water line for auxiliary and exhaust gas boilers is sufficient if the preheaters and automatic regulating devices are fitted with bypass 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 feed water supply fail and that the feed water 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. Feed water supply, evaporators

7.1 The feed water 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 producer 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 testing devices See Section 10, B.5.4

G. Fuel Oil Systems

1. Bunker lines

The bunkering of fuel oils 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 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 is to be operated from a position outside this space.

2.2 Shut-off devices on fuel oil tanks having a capacity of less than 500 ℓ need not be provided with remote control.

2.3 Filling lines are to extend to the bottom of the tank. 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 Valves at the fuel storage tanks shall kept close at sea and may be opened only during fuel transfer operations if located within h or was defined in MARPOL 73/78 Annex I 12A. The valves are to be remote 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 freeboard or superstructure decks.

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 arranged far enough from the drains in the tank so that 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 12, B.10.

3. Pipe layout

3.1 Fuel lines may not pass through tanks containing feed water, 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 11.5.

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 Shut-off valves in fuel lines in the machinery spaces are to be operable from above the floor plates.

3.5 Glass and plastic components are not permitted in fuel systems. Sight glasses made of glass located in vertical overflow pipes may be permitted.

3.6 Fuel pumps are to be capable of being isolated from the piping system by shut-off valves.

3.7 For fuel flow-meters a by-pass with shutoff valve shall be provided.

4. Fuel transfer, feed and booster pumps

4.1 Fuel transfer, feed and booster pumps are to be designed for the intended operating temperature.

4.2 A fuel transfer pump is to be provided. Other service pumps may be used as a stand-by pump provided they are suitable for this purpose.

4.3 At least two means of oil fuel transfer are to be provided for filling the service tanks.

4.4 Where a feed or booster pump is required to supply fuel to main or auxiliary engines, stand-by pumps are to be provided. Where pumps are attached to the engines, stand-by 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 Fuel oil pumps referred to in G.4.4 shall

— be suitable for marine fuels with a sulphur content not exceeding 0,1% m/m and minimum viscosity of 2,0 cSt at the required capacity for normal operation of the propulsion machinery or

— when fuel oil pumps as in a) need to be operated in parallel in order to achieve the required capacity for normal operation of propulsion machinery, one additional fuel oil pump shall be provided. The additional pump shall, when operating in parallel with one of the pumps in a), be suitable for and capable of delivering marine fuels with a sulphur content not exceeding 0,1% m/m and minimum viscosity of 2,0 cSt at the required capacity for normal operation of the propulsion machinery.

Where fuel oil pumps referred to in G.4.4 are not suitable for marine fuels with a sulphur content not exceeding 0,1% m/m and minimum viscosity of 2,0 cSt at the required capacity for normal operation of the propulsion machinery, two separate oil fuel pumps shall be provided, each capable and suitable for marine fuels with a sulphur content not exceeding 0,1% m/m and minimum viscosity of 2,0 cSt at the required capacity for normal operation of the propulsion machinery.

Note 1

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.

Note 2

Automatic start capability of standby pumps is required independent of the pump arrangement for vessels holding the class notation for unattended machinery space.

Note 3

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 12, B.9.

5. Plants with more than one main engine

For plants with more than one main 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 of 500 GT or above and on all passenger ships for plants with more than one engine, shut-off devices for isolating the fuel supply and over-production/recirculation lines to any engine from a common supply system are to 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 over-production/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 OT the filter equipment is to satisfy the requirements of Rules for Automations (Pt.1, Vol.VII), Sec. 2.

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 during cleaning of the 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 monitored.

7.6 Fuel 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.

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 For filter arrangement, see Section 2, G.3.

8. Purifiers

8.1 Manufacturers of purifiers for cleaning fuel and lubricating oil are to be approved by BKI.

8.2 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.

8.3 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 is to be installed in accordance with Section 9. Pumps, pipelines and fittings are subject to the following requirements.

9.1 Oil fired main boilers are to be equipped with at least two service pumps and two 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 are not to be longer than required for retracting of the burner for the purpose of routine maintenance. Only hose assemblies from approved hose assembly manufacturers are to be used.

10. Service tanks

10.1 On cargo ships of 500 GT or above and all passenger ships two fuel oil service tanks for each type of fuel used on board necessary for propulsion and essential systems are to be provided. Equivalent arrangement may be permitted.

10.2 Each service tank is to have a capacity of at least 8 h at maximum continuous rating of the propulsion plant and normal operating load at sea of the generator plant.

The requirements in the Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Section 11.SC 123 should also be observed.

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:

1) 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

2) one (1) Marine Diesel Oil (MDO) service tank for initial cold starting or repair work of engines or boilers.

Acceptable “equivalent arrangements [8]” shall comprise at least

1) 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

2) 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

3) 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.

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:

1) 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

2) two (2) MDO service tanks each of a capacity sufficient for at least 8 h operation of auxiliary engines.

Acceptable ”equivalent arrangements[8]” shall comprise at least:

1) one (1) HFO service tank with a capacity sufficient for at least 8 h operation of main engine(s) and auxiliary boiler(s), and

2) 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).

[8] Any fuel oil which requires post service tank heating to achieve the required injection viscosity is not regarded in this context as MDO.

10.5 The arrangements in 10.2 and 10.3 apply, provided the propulsion and vital systems which use two types of fuel support rapid fuel changeover and are capable of operating in all normal operating conditions at sea with both types of fuel (MDO and HFO).

11. Operation using heavy fuel oils

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 BKI's consent, 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 Section 10, B.5.

11.1.2 Heat tracing is to be arranged for pumps, filters and oil 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[9)]

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 equipment Heavy fuel oil/diesel oil blending and emulsifying equipment requires approval by BKI.

11.3 Service tanks

11.3.1 For the arrangement and equipment of service tanks, see Section 10, B.

11.3.2 The capacity of the service tanks is to be such that, should the 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 service tank is terminated in the settling tanks, suitable means are to 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 so arranged that faulty switching is excluded and to ensure reliable separation of the fuels.

Change-over valves which allow intermediate positions are not permitted.

11.4.2 The change-over devices are to be accessible and permanently marked. Their respective working position is to be clearly indicated.

11.4.3 Remote controlled change-over devices are to be provided with limit position indicators at the control platforms.

[9)] Recommendation for fuel oil treatment systems in the Guidance for Marine Industry (Pt.1, Vol.AC) Section 8 R-151 may be used as reference

11.5 Fuel supply through stand pipes

11.5.1 Where the capacity of stand pipes exceeds 500 ℓ, 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 (pressure less)

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 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 recirculating lines from the engines

— an automatic degasser or a gas blanket monitor with manual degasser

— a local gauge for the operating pressure

— 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 shall be protected against pressure peaks, e.g. by using adequate.dampers.

11.6 End preheaters

11.6.1 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 does not need preheating can be temporarily maintained.

11.6.2 A by-pass with shutoff valve shall 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 gauge for operating pressure

— an indicator for the operating temperature

11.8 The heavy fuel system is to be effectively insulated as necessary.

H. Lubricating Oil Systems

1. General requirements

1.1 Lubricating oil systems are to be so 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 for machinery which may be damaged in case of interruption of lubricating oil supply.

1.4 Lubricating oil treatment

1.4.1 Equipment necessary for adequate treatment of lubricating oil is to be provided (purifiers, automatic back-flushing filters, filters, free-jet centrifuges).

1.4.2 In the case of auxiliary engines running on heavy fuel 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 Rules for Electrical Installation (Pt.1, Vol.IV), Sec. 3 remain fully operational.

2. Lubricating oil systems

2.1 Lubricating oil circulating tanks and gravity tanks

2.1.1 For the capacity and location see Section 10, C.

2.1.2 For ships where a double bottom is required the minimum distance between shell and circulating tank shall be not less than 500 mm.

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 shall be protected against vibration through suitable supports.

2.1.5 Gravity tanks are to be fitted with an overflow pipe which leads to the circulating 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 ℓ 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 valves 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 are to 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 fitted in the delivery line of the lubricating oil pumps.

2.3.2 Mesh size and filter capacity are to be in accordance with the requirements of the manufacturer of the engine.

2.3.3 Uninterrupted supply of filtered lubricating oil has to be ensured under cleaning conditions of the 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 back-flushing 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 protection of the lubricating oil pumps simplex filters may be installed on the suction side of the pumps if they have a minimum mesh size of 100 μ.

2.3.8 For the arrangement of filters, see Section 2, G.3.

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 indicators

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.4.2.3.

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 BKI 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-speed ratio of

$$P/n_1 \ [\text{kW/min}^{-1}] \leq 3{,}0$$

n_1 = gear input revolution [min^{-1}]

3.3.3 The requirements under 3.1.2 are to be applied for multi-propeller plants and plants with more than one engine analogously.

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 operations) a complete spare pump is to be carried on board

3.4.2 Auxiliary turbines

Turbo generators and turbines used for driving essential auxiliaries such as boiler feed water 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. Seawater Cooling Systems

1. Sea suctions, sea chests

1.1 At least two 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 is 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 shutoff 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 2,0 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 air lines for clearing according to 1.5 may, with BKI's agreement, 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 as near as possible to midship 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 ES1 to ES4 the sea chest is to be arranged as follows:

- In calculating the volume of the sea chest the following value is to be applied as a guide:
- about 1,0 m^3 for every 750 kW of the ship's engine output including the output of auxiliary engines.
- The sea chest is to be of sufficient height to allow ice to accumulate above the inlet pipe.
- The free area of the strum holes is to be not less than four times the sectional area of the seawater inlet pipe.

2.1.2 As an alternative two smaller sea chests of a design as specified in 2.1.1 may be arranged.

2.1.3 All discharge valves are to 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 tanks with circulating cooling.

This system does not replace the requirements stated in 2.1.1.

2.4 For the fire pumps, see Section 12, E.1.3.6.

3. Sea valves

3.1 Sea valves are to be so arranged that they can be operated from above the floor plates.

3.2 Discharge pipes for seawater cooling systems are to be fitted with a shut-off valve at the shell.

4. Strainers

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 service.

Where cooling water is supplied by means of a scoop, strainers in the main seawater cooling line can be dispensed with.

5. Seawater cooling pumps

5.1 Diesel engine plants

5.1.1 Main propulsion plants are to be provided with main and stand-by cooling water pumps.

5.1.2 The main cooling water pump may be attached to the propulsion plant. It is to be ensured that the attached pump is of sufficient capacity for the cooling water required by main engines and auxiliary equipment over the whole speed range of the propulsion plant.

The drive of the stand-by cooling water pump is to be independent of the main engine.

5.1.3 Main and stand-by cooling water pumps are each to be of sufficient capacity to meet the maximum cooling water requirements of the plant.

Alternatively, three cooling water 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.

With this arrangement it is permissible 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.

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.P.1). 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 Plants with more than one main engine

For plants with more than one engine and with separate cooling water systems, complete spare pumps stored 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 water supply for auxiliary engines

Where a common cooling water pump is provided to serve more than one auxiliary engine, an independent stand-by cooling water pump with the same capacity is to be fitted. Independently operated cooling water 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 water requirement.

If each auxiliary engine is fitted with an attached cooling water pump, stand-by cooling water pumps need not to be provided.

6. Cooling water supply in dry dock

It is recommended that a supply of cooling water, e.g. from a water ballast tank, is to be available so that at least one diesel generator and, if necessary, the domestic refrigerating plant may run when the ship is in dry dock.

Cargo and container cooling systems are to conform to the requirements stated in Rules for Refrigerating Installations (Pt.1, Vol.VIII), Sec. I,1.4.

J. Fresh Water Cooling 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 exchangers 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 engine 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 requirements of Section 8.

2.2 The coolers of cooling water systems, engines and equipment are to be so 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 in the event of a failure of the heat exchanger it is possible by these means 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, box coolers

2.7.1 Arrangement and construction drawings of keel and box 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 is to 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 requirements for sea water cooling 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 emergency cooling from another system can be approved if the plant and the system are suitable for this purpose.

4.9 For plants with more than one main engine the requirements 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 requirements. Control devices whose failure may impair the functional reliability of the engine are to be equipped for manual operation.

6. Preheating of cooling water

Means are to be provided for preheating cooling fresh water. Exceptions are to be approved by BKI.

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 BKI Rules for Electrical Installations (Pt.1, Vol.IV) Sec. 13 have to be observed.

K. 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 For oil and water separators, see Section 2, M.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.

1.8 Pressure water tanks and other tanks connected to the compressed air system are to be considered as pressure vessels and are to comply with the requirements in Section 8 for 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 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. The fire closures may close automatically, if they are supplied with separated compressed air pipes.

2. Control air systems

2.1 Control air systems for essential consumers are to be provided with the necessary means of air treatment.

Pressure reducing valves in the control air system of main engines are to be redundant.

L. Exhaust Gas Lines

1. Pipe layout

1.1 Engine exhaust gas pipes are to be installed separately from each other, taking into account the structural fire protection. 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

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

For insulation of exhaust gas lines inside machinery spaces, see Section 12, B.4.1.

5. For special requirements for tankers refer to Section 15, B.9.3.

Engine exhaust gas lines are additionally subject to Section 2, G.7.

For special requirements for exhaust gas cleaning system see Section 2, N.

M. Bilge Systems

1. Bilge lines

1.1 Layout of bilge lines

1.1.1 Bilge lines and bilge suctions are to be so arranged that the bilges can be completely drained even under unfavourable trim conditions.

1.1.2 Bilge suctions are normally to be located on both sides of the ship. For compartments located fore and aft in the ship, one 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 thickness of bilge lines is to be in accordance with Table 11.5.

1.2 Pipes laid through tanks

1.2.1 Bilge pipes may not be led through tanks for lubricating oil, thermal oil, and drinking water or feed water.

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.

1.3 Bilge suctions and strums

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 such that they are accessible, with free flow and at a suitable distance from the tank top or the ship's bottom.

1.3.3 For the size and design of bilge wells see Rules for Hull, (Pt.1, Vol.II) Sec. 8, B.5.3.

1.3.4 Bilge alarms of main and auxiliary machinery spaces, see Section 1, E.5. and Rules for Automations (Pt.1, Vol.VII), Sec. 6, H.

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 shell.

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.

1.5 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 suction need only 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 reverse flow protecting devices.

1.6.4 The discharge lines of oily water separators are to be fitted with a reverse flow protecting valve at the ship's 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

— Main bilge pipes

$$d_H = 1,68\sqrt{(B + H) \cdot L} + 25 \quad [mm] \tag{4}$$

— Branch bilge pipes

$$d_z = 2,15\sqrt{(B + H) \cdot \ell} + 25 \quad [mm] \tag{5}$$

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 [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:

$$d_H = 3,0\sqrt{(B + H) \cdot \ell_1} + 35 \quad [mm] \tag{6}$$

ℓ_1 = total length of spaces between cofferdam or pump-room bulkhead and stern tube bulkhead [mm]

Other terms as in formulae (4) and (5).

Branch bilge pipes are to be dimensioned in accordance with 2.2 b). For bilge installations for spaces in the cargo area of tankers and bulk cargo/oil carriers see Section 15.

2.4 Minimum diameter

The inside diameter of main and branch bilge pipes is not to be less than 50 mm. For ships under 25 m length, the diameter may be reduced to 40 mm.

3. Bilge pumps

3.1 Capacity of bilge pumps

Each bilge pump must be capable of delivering:

$$Q = 5,75 \cdot 10^{-3} \cdot d_{H^2} \quad [m^3/h] \tag{7}$$

Q = minimum capacity $[m^3/h]$
d_H = calculated inside diameter of main bilge pipe [mm]

3.2 Where centrifugal pumps are used for bilge pumping, they are to 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 is not to 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 is to be available for firefighting and bilge pumping.

3.4.3 Fuel and oil pumps are not to 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 mechanically driven bilge pumps. On ships up to 2000 GT, one of these pumps may be attached to the main engine.

On ships of less than 100 GT, one mechanically 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 bilge pumps are to be provided. One pump may be coupled to the main propulsion plant. Where the criterion of service numeral according to SOLAS 74 is 30 [10] or more, an additional bilge pump is to be provided.

4. Bilge pumping for various spaces

4.1 Machinery spaces

4.1.1 On ships of more than 100 GT, the bilges of every main machinery space are to be capable of being pumped simultaneously as follows:

a) through the bilge suctions connected to the main bilge system

b) through one direct suction connected to the largest independent bilge pump

c) through an emergency bilge suction connected to the sea cooling water pump of the main propulsion plant or through another suitable emergency bilge system

4.1.2 If the ship's propulsion plant is located in several spaces, a direct suction in accordance with 4.1.1 b) is to be provided in each watertight compartment in addition to branch bilge suctions in accordance with 4.1.1 a).

When the direct suctions are in use, it is to be possible to pump simultaneously from the main bilge line by means of all the other bilge pumps.

The diameter of the direct suction may not be less than that of the main bilge pipe.

4.1.3 On steam ships the diameter of the emergency bilge suction is to be at least 2/3 of the diameter and on motor ships equal to the diameter of the suction line of the pump chosen according to 4.1.1c). Deviations from this requirement need the approval of BKI. The emergency bilge suction is to be connected to the cooling water pump suction line by a normally closed non-return valve with positive means of closing.

This valve is to be provided with a plate with the notice:

Emergency bilge valve!

To be opened in an emergency only!

Emergency bilge valves and cooling water inlet valves are to be capable of being operated from above the floor plates.

[10] See SOLAS 1974, Chapter II-1, Part C, Reg. 35-1, 3.2

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.

4.2 Shaft tunnel

A bilge suction is to be arranged at the aft end of the shaft tunnel. Where the shape of the bottom or the length of the tunnel requires, an 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 Rules for Electrical Installations (Pt.1, Vol.IV), Sec. 18, B.4.1.9.

4.3.2 Cargo holds having a length under 30 m may be provided with only one bilge suction on each side.

4.3.3 On ships with only one cargo hold, bilge wells are to be provided fore and aft.

4.3.4 For cargo holds for the transport of dangerous goods, see Section 12, P.7.

4.3.5 In all Ro/Ro cargo spaces below the bulkhead deck where a pressure water spraying system according to Section 12, L.2.3 is provided, the following is to be complied with:

— the drainage system is to 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 are to 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 located at each side of the protected space, uniformly distributed fore and aft. The distance between the single bilge wells shall not exceed 40 meters.

— 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
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 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 arrangements.

4.4.2 The drainage arrangements are to 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 to overboard, only when at a heel of the ship of 5°, the edge of the bulkhead deck or freeboard deck will not be immersed.

Drains from scuppers to overboard are to be fitted with reverse flow protecting devices according to Rules for Hull (Pt.1, Vol.II), Sec. 21.

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 is to 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 firefighting.

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 6,0 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/connections.

The change-over valves are to be so designed that an 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 is to 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 are to be either connected to the bilge system or are to be drained by means of hand pumps.

Spaces located above the aft peak may be drained to the shaft tunnel or to the engine room bilge, provided the drain line is fitted with a self-closing valve which is to be located at a highly visible and accessible position. The drain lines are to have a diameter of at least 40 mm.

4.9 Cofferdams, pipe tunnels and void spaces

Cofferdams, pipe tunnels and void spaces adjoining the ship's shell are to be connected to the bilge system.

For cofferdams, pipe tunnels and void spaces located above the deepest load water line equivalent means may be accepted by BKI after special agreement.

Where the aft peak is adjoining the engine room, it may be drained over a self-closing valve to the engine room bilge.

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 door 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 Rules for Hull (Pt.1, Vol.II), Sec. 6, H.7.

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 is to 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 is to 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 freeboard 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 as readily accessible.

4.13.3 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 is to have positive means of closure. The valve is to be operated from a position as stated in 4.13.2.

4.13.4 Local hand operation from above freeboard deck is required for the valve required in O.1.3.3 is to be operated from a position as stated in 4.13.2 if all requirements of 4.13 are met

4.13.5 It is to 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 are not to move from the demanded position.

4.13.6 Bilge wells are to comply with 1.3.1.

4.13.7 Dewatering and pumping arrangements are to be such that when they are in operation the following is to be available:

- The bilge system is to remain ready for use for any compartment.
- The immediate start of the firefighting pumps and supply of firefighting water is to remain available.
- The system for normal operation of electric power supply, propulsion and steering is to not be affected by operating the drainage and pumping system.

For water ingress detection systems see Rules for Electrical Installations (Pt.1, Vol.IV), Sec. 18.

4.13.8 The capacity of the dewatering system according 4.13.1 is to be calculated according following formula:

$$Q = 320\ A\ [m^3/h]$$

A is the free cross sectional area in m^2 of the largest air pipe or ventilation opening connecting the exposed deck with the space for which dewatering is required.

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 requirements for passenger vessels

5.1 Bilge pipe arrangement and bilge valves

5.1.1 The arrangement of bilge pipes:

— within 0,2B from the ship's side measured at the level of the subdivision load line

— in the double bottom less than 460 mm above the base line or

— below the horizontal level specified in Rules for Hull (Pt.1, Vol.II), Sec. 29, F.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 shell, damage to one part of the arrangement is not to 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 are to 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 is to 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 to be capable of being operated from above the bulkhead deck.

5.1.4 Shut-off and change-over valves which are to be capable of being operated from above the bulkhead deck are to be clearly marked, accessible and fitted with a position indicator at the control stand of the bilge system.

5.2 Bilge suctions

Bilge pumps in the machinery spaces are to be provided with direct bilge suctions in these spaces, but not more than two direct suctions need to be provided in any one space.

Bilge pumps located in other spaces are to have direct suctions to the space in which they are installed.

5.3 Arrangement of bilge pumps

5.3.1 Bilge pumps are to be installed in separate watertight compartments which are to be so arranged that they will probably not be flooded by the same damage.

Ships with a length of 91,5 m or over or having a criterion of service numeral according to SOLAS 74 of 305 or more are to have at least one bilge pump available in all flooding conditions for which the ship is designed to withstand. This requirement is satisfied if

— one of the required pumps is a submersible emergency bilge pump connected to its own bilge system and powered from a source located above the bulkhead deck or

— the pumps and their sources of power are distributed over the entire 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 are not to be located forward of the collision bulkhead.

5.4 Passenger vessels for limited range of service

The scope of bilge pumping for passenger vessels with limited range of service, e.g. navigation in sheltered waters, can be agreed with BKI.

6. Additional requirements for tankers

See Section 15, B.4.

7. Bilge testing

All bilge arrangements are to be tested under BKI's supervision.

N. Equipment for the Treatment and Storage of Bilge Water, Fuel / Oil Residues

1. Oily water separating equipment

1.1 Ships of 400 GT and above are to be fitted with an oily water separator or filtering equipment for the separation of oil/water mixtures.[11)][12)]

1.2 Ships of 10000 GT and above are to be fitted in addition to the equipment required in 1.1 with a 15 ppm alarm system.

1.3 A sampling device is to be arranged in a vertical section of 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 Recirculating facilities have to be provided to enable the oil filtering equipment to be tested with the overboard discharge closed.

2. Discharge of fuel/oil residues

2.1 A sludge tank is to be provided. For the fittings and mountings of sludge tanks, see Section 10, E.

2.2 A self-priming pump is to be provided for sludge discharge to reception facilities. The capacity of the pump is to be such that the sludge tank can be emptied in a reasonable time.

2.3 A separate discharge line is to be provided for discharge of fuel/oil residues to reception facilities

2.4 There shall be no interconnections between the sludge tank discharge piping and bilge water piping other than possible common piping leading to the standard discharge connection. Screw-down non-return valves arranged in lines connecting to common piping leading to the standard discharge connection are considered to fulfil this requirement

2.5 The oil residue (sludge) tank may be fitted with manual operated self closing drain valves with visual monitoring of the settled water (free air space) leading to the oily bilge water tank or bilge well.

2.6 Where incinerating plants are used for fuel and oil residues, compliance is required with Section 9 and with the Resolution MEPC.76 (40) "Standard Specification for Shipboard Incinerators".

[11)] 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 an 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 1978 as amended.

[12)] See also the requirements in the Guidance for Marine Industry (Pt.1, Vol.AC) Section 7 R-121

3. 15ppm Oily Bilge Water Separating Systems for Class Notation EP

Irrespective of the installation of a 15 ppm oily bilge water separating systems all requirements given in MARPOL Annex 1 Reg. 14 have to be fulfilled and need to be certified accordingly. The 15 ppm oily bilge water separating system may be part of the installation required by MARPOL.

The installation of 15ppm bilge water separating systems is optional, except where required by Class Notation **EP** (Environmental Passport) or by local legislation.

The bilge water separating system consists of a bilge water handling system and an oily water separator in combination with a 15 ppm alarm which actuates an automatic stopping device as described in the IMO 107(49).

3.1 Oily bilge water separator

3.1.1 The design and test procedure shall be in compliance with IMO Res. 107(49) under consideration of IMO MEPC.1/Circ.643. The oil content of the effluent of each test sample shall not exceed 5ppm.

3.1.2 The capacity of the oily bilge water separator is to be specified according to the following table.

Up to 400 GT	401 to 1600 GT	1601 to 4000 GT	4001 to 15000 GT	Above 15000 GT
0,25 m^3/h	0,5 m^3/h	1,0 m^3/h	2,5 m^3/h	5 m^3/h

3.2 15 ppm oil content alarm

3.2.1 The design and test procedure shall be in compliance with IMO Res. 107(49).

3.2.2 Additional calibration tests in the range from 2 ppm to 9 ppm oil content are to be carried out. Furthermore the response time is to be taken in case the input is changed from water to oil with a concentration of more than 15 ppm[9)].

3.2.3 An appropriate type test certificate issued by a flag state administrations or other classification societies may be accepted.

3.3 Oily bilge water tanks

3.3.1 An oily bilge water holding tank shall be provided. This tank should preferably be a deep tank arranged above the tank top which safeguards the separation of oil and water. Appropriate draining arrangements for the separated oil shall be provided at the oily bilge water holding tank.

3.3.2 Oil residues (sludge) and oily bilge water tanks shall be independent of each other.

3.3.3 A pre-treatment unit for oil separation shall be provided in accordance with the example of the Annex of the MEPC.1/Circ.642. The unit shall be placed between daily bilge pump and oily bilge water tank.

3.3.4 On ships using heavy fuel oil the oily bilge water tank shall be provided with heating arrangements.

3.3.5 The capacity of the oily bilge water tank shall be determined as follows:

Main engine rating [kW]	Capacity [m^3]
Up to 1000	4
Above 1000 up to 20000	P/250
Above 20000	40 + P/500

[9)] Refer to Transport Canada Standard TP 12301E

where:

P = main engine power [kW]

3.4 Oil residue (sludge) tanks

3.4.1 For storage of oil residues (sludge), see Section 10, E.

3.4.2 The capacity V [m3] of oil residues (sludge) tanks shall be determined as follows:

$$V = K \cdot C \cdot D$$

Where:

K = 0,015 for ships where heavy fuel oil is used and 0,005 where diesel oil or other fuel which does not need purification is used.

C = daily fuel oil consumption [m^3/d].

D = maximum duration of voyage, normally taken 30 days in absence of data [d].

3.4.3 Oil residue (sludge) tanks shall be located below the heavy fuel oil purifiers.

3.4.4 Oil residues (sludge) tanks shall be provided with access holes arranged in a way that cleaning of all parts of the tank is possible.

3.4.5 Oil residues (sludge) tanks shall be fitted with steaming - out lines for cleaning, if feasible.

3.5 Oily bilge water and sludge pumping and discharge

3.5.1 The oily bilge system and the main bilge system shall be separate of each other.

3.5.2 Suction lines of the oily bilge separator shall be provided to the oily bilge water tank. A suction connection to the oil residues (sludge) tank is not permitted.

3.5.3 The effluent from the 15 ppm bilge separator shall be capable of being recirculated to the oily bilge water tank or the pre-treatment unit.

3.5.4 The separated dirty water and exhausted control water of fuel purifiers shall be discharged into a particular tank. This tank shall be located above tank top for the purpose to facilitate the draining without needing a drain pump.

3.5.5 The oil residues discharge pump shall be suitable for high viscosity oil and shall be a self priming displacement pump.

3.5.6 The oil residues discharge pump shall have a capacity to discharge the calculated capacity of the oil residue (sludge) tank (see 3.4.2) within 4 hours.

O. 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 under all practical conditions

1.1.2 Ships having very wide double bottom tanks are also to be provided with suctions at the outer sides of the tanks. Where the length of the ballast water tanks exceeds 30 m, BKI may require suctions to be provided in the forward part of the tanks.

1.2 Pipes passing through tanks

Ballast water pipes are not to pass through drinking water, feed water, 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 are to 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 M.4.5 are applicable.

1.3.3 Where 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 has to be capable of being remotely operated from above the freeboard deck.

Where the fore peak is directly 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 Only one pipeline may be led through the collision bulkhead below the freeboard deck.

1.3.5 Where the fore-peak is divided to hold two different kinds of liquid, two pipelines may in exceptional cases be passed through the collision bulkhead below freeboard deck.

1.3.6 Ballast water tanks on ships with ice class **ES1** to **ES4** which are arranged above the ballast load line are to be equipped with means to prevent the water from freezing, see Rules for Hull (Pt.1, Vol.II), Sec. 15, A.2.3.

1.4 Anti-heeling arrangements

Anti-heeling arrangements, which may counteract heeling angles of more than 10° according to Rules for Hull (Pt.1, Vol.II), Sec. 1, E.3, are to be designed 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 is to automatically shut down in the case of power supply failure.
- The position ”closed” of the shut-off devices is to be indicated on the control stand by type approved end position indicators.
- Additionally, Rules for Electrical Installations (Pt.1, Vol.IV), Sec. 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 a 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

1.6.1 Scope and application

.1 Ballast water treatment plants are to be approved by a flag administration acc. to IMO Resolution MEPC.174(58), MEPC.169(57) respectively. The obligation to install a ballast water treatment plant depends on the ballast water capacity and keel laying date of the ship which processes ballast water such that it meets or exceeds Ballast Water Performance Standard in Regulation D-2 of the BWM Convention. Refer to International Convention For The Control And Management of Ship's Ballast Water and Sediments, 2004 – Regulation B-3.

.2 The requirements in this subsection are not applied to ship's ballast water systems including piping valves, pumps, etc. where BWMS is not fitted.

.3 This subsection is to be read in conjunction with Annex A - Installation of BWMS on-board ships.

1.6.2 Documents to be submitted

.1 Ballast water treatment systems (BWTS) includes ballast water equipment, all associated piping arrangements as specified by the manufacturer, control and monitoring equipment and sampling facilities and shall in addition to the provisions of 1.6.1.1 comply with the Rules in Section 8 and in this Section as well as in the Rules for Electrical Installations (Pt 1, Vol.IV), Sec. 9, D.8. The following documents shall be submitted once for each BWTS type for approval:

- A copy of the Type Approval Certificate of BWM system (issued by flag administration in accordance with (G8) MEPC 174(58) or MEPC 279(70)/BWMS Code MEPC 300(72)*)
- Ballast water management plan
- Arrangement of ballast piping including sampling points
- BWM System arrangement drawing including details of structural modifications, foundation details
- Wiring Diagram (including power, detailed wiring, control, safety, monitoring and alarm circuit)
- Arrangement of electric apparatus
- Electrical power balance
- Short circuit current analysis
- List of explosion-proof type electric equipment and arrangement (If applicable)
- Lightship calculation
- Other drawings considered necessary by BKI
- Note: In addition, on board test procedure is also to be submitted to the BKI survey location.

*BWMS installed on ships on or after 28 October 2020 shall be approved in accordance with MEPC 279(70) or BWMS Code MEPC 300(72)

If compliance with BKI Rules has already been ascertained as part of the flag state approval process in line with 1.6.1, documents for that BWTS type need not be submitted.

On manufacturer's application, BKI may issue an approval certificate confirming compliance with BKI Rules referenced above.

1.6.3 Definitions

.1 Ballast Water Management System (hereinafter referred to as 'BWMS') means any system which processes ballast water such that it meets or exceeds the Ballast Water Performance Standard in Regulation D-2 of the BWM Convention. The BWMS includes ballast water management equipment, all associated control equipment, monitoring equipment piping arrangements as specified by the manufaturer, control and monitoring equipment and sampling facilities. The categorization of BWMS technology is in given in Table 11.18. Applicability of the requirements for each BWMS technology is in accordance with Table 11.19

.2 Dangerous gas means any gas which may develop an atmosphere being hazardous to the crew and/or the ship due to flammability, explosivity, toxicity, asphyxiation, corrosivity or reactivity and for which due consideration of the hazards is required, e.g. hydrogen (H_2), hydrocarbon gas, oxygen (O_2), carbon dioxide (CO_2, carbon monoxide (CO), ozone (O_3), chlorine (Cl_2), and chlorine dioxide (ClO_2), etc.

.3 Dangerous liquid means any liquid that is identified as hazardous in the Material Safety Data Sheet or other documentation relating to this liquid.

.4 Hazardous area is defined in IEC 60092-502:1999 and means an area in which an explosive gas atmosphere is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of equipment electrical apparatus. When a gas atmosphere is present, the following hazards may also be present: toxicity, asphyxiation, corrosivity and reactivity.

.5 Non-hazardous area means an area which is not a hazardous area as defined in 4

Table 11.18: Categorization of BWMS technologies

BWM's technology category		**1**	**2a**	**3a**	**3b**	**3c**	**4**	**5**	**6**	**7a**	**7b**	**8**
Characteristics		In-line UV or UV + Advanced Oxidation Technology (AOT) or UV TiO2 or UV + Plasma	In-line Flocculation	In-line membrane separation and de-oxygenation (injection of N2 from a N2 Generator)	In-line de-oxygenation (injection of Inert Gas from Inert Gas Generator)	In-tank de-oxygenation with Inert Gas Generator	In-line full flow electrolysis	In-line side streamelectrolysis (2)	In-line (stored) chemical injection	In-line side-stream ozone injection without gas/liquid separation tank and without discharge treatment tank	In-line side-stream ozone injection with gas/liquid Separation tank and discharge water treatment tank	In-tank pasteurization and de-oxygenation with N_2 generator
Des-infection when ballasting	Making use of active substance		X			In-tank technology: No treatment when ballasting or de-ballasting	X	X	X	X	X	In-tank technology: No treatment when ballasting or de-ballasting
	Full flow of ballast water is passing through the BWMS	X	X	X	X		X				X	
	Only a small part of ballast water is passing through the BWMS to generate the active substance							X				
After treatment when deballasting	Full flow of ballast water is passing through the BWMS	X									X	
	Injection of neutralizer						X	X	X	X	X	
	Not required by the Type Approval Certificate issued by the Administration		X	X								
Example of dangerous gas as defined in 1.6.3.4			(1)	O_2 N_2	CO_2 CO		H_2 Cl_2	H_2 Cl_2	(1)		O_2 O_3 N_2	O_2 N_2

Note:

(1) To be investigated on a case by case basis based on the result of the IMO (GESAMP) MEPC report for Basic and Final approval in accordance with the G9 Guideline.

(2) In-line side stream electrolysis may also be applied in-tank in circulation mode (no treatment when ballasting or de-ballasting)

Taking into consideration future developments of BWMS technologies, some additional technologies may be considered in this Table 1 by identifying their characteristics in the same manner as for the above BWMS categories 1, 2, 3a, 3b, 3c. 4, 5, 6, 7a. 7b and 8.

Table 11.19: Applicability of the requirements for each BWMS technology

BWM's technology category	1	2a	3a	3b	3c	4	5	6	7a	7b	8
Requirements	In-line UV or UV + Advanced Oxidation Technology (AOT) or UV TiO2 or UV + Plasma	In-line Flocculation	In-line membrane separation and de-oxygenation (injection of N2 from a N^2 Generator)	In-line de-oxygenation (injection of Inert Gas from Inert Gas Generator)	In-tank de-oxygenation with Inert Gas Generator	In-line full flow electrolysis	In-line side streamelectrolysis (2)	In-line (stored) chemical injection	In-line side-stream ozone injection without gas/liquid separation tank and without discharge treatment tank	In-line side-stream ozone injection with gas/liquid Separation tank and discharge water treatment tank	In-tank pasteurization and de-oxygenation with N_2 generator
1.6.1 to 1.6.3	X	X	X	X	X	X	X	X	X	X	X
1.6.4.1.1 to 1.6.4.1.4	X	X	X	X	X	X	X	X	X	X	X
1.6.4.1.5			X	X	X						X
1.6.4.1.6	X	X	X	X	X	X	X	X	X	X	X
1.6.4.1.7			X	X	X						X
1.6.4.1.8				X						X	
1.6.4.1.9	X	X	X	X	X	X	X	X	X	X	X
Section 15 E.1.1.1				X	X				X	X	
Section 15 E.1.1.2						X	X	X			
Section 15 E.1.2	X	X	X	X		X	X	X	X	X	
Section 15 E.1.3	X	X	X	X	X	X	X	X	X	X	X
Section 15 E.1.4	X	X	X	X		X	X	X	X	X	
1.6.5.1 1)		X	X			X	X	X	X	X	X
1.6.5.1 2)			X	X	X				X	X	X
1.6.5.1 3)									X	X	
1.6.5.1 4)				X		X	X	X	X	X	
1.6.5.1 5)						X	X	X			
1.6.5.1 6)			X	X	X				X	X	X
1.6.5.2 1) - 1.6.5.2 4)		X	X	X	X	X	X	X	X	X	X
1.6.5.2 5)			X			X	X	X	X	X	X
1.6.5.2 6)			X						X	X	X
1.6.5.2 7)			X			X	X	X	X	X	X
1.6.5.3		X				X	X	X	X	X	
1.6.5.4						X	X	X	X	X	

1.6.4 Installations

.1 General requirements

.1.1 All valves, piping fittings and flanges are to comply with the relevant requirements of this Section and B.2.6. In addition, special consideration can be given to the material used for this service with the agreement of BKI.

.1.2 BWTS is to be provided with by-pass or override arrangement to effectively isolate it from any essential ship system to which it is connected. For new installation or retrofit to existing ships, under normal operating conditions of ballasting and de-ballasting given in the Ballast Water Management Plan (BWMP) the adequacy of the generating plant capacity installed on the vessel is to be demonstrated by an electrical load analysis.

For retrofit installation to exiting ships, a revised electrical load analysis with preferential trips of non-essential services can be accepted.

.1.3 The BWMS is to be operated in accordance with the requirements specified in the Type Approval Certificate (TAC) issued by the Flag Administration. BWMS should be operated within its Treatment Rated Capacity (TRC) as per the TAC. This may require limiting of ship's ballast pump flowrates.

The arrangement of the bypasses or overrides of the BWMS is to be consistent with the approved Operation Maintenance and Safety Manual by the Flag Administration's Type Approval.

In case the maximum capacity of the ballast pump(s) exceeds the maximum treatment rated Capacity (TRC) of the BWMS specified in the TAC issued by the Flag Administration, there should be a limitation on the BWMP giving a maximum allowable flow rate for operating the ballast pump(s) that shall not exceed the maximum TRC of the BWMS.

.1.4 BWMS should be subject to design review by BKI to verify the compliance of the BWMS's manufacturer package with the BKI Rules.

Manufacturers of the BWMS may apply for this design review at the type approval process.

In general, monitoring functions of BWMS belongs to system category I under the application of the Rules for Electrical Installations (Pt.1, Vol.IV) Section 10. However, in case a by-pass valve is integrated in the valve remote control system, the by-pass valve belongs to the system category II Ballast transfer remote control system.

The BWMS's components are required to be inspected and certified by the BKI the manufactory (BKI Certificate (BC) as defined in Section 2.D.2) including pressure vessels, piping class I or II, filters, switchboards, etc.

.1.5 Where a vacuum or overpressure may occur in the ballast piping or in the ballast tanks due to the height difference or injection of inert gas or nitrogen (N_2, a suitable protection device is to be provided, (i.e. P/V valves P/V breakers, P/V breather valves or pressure safety relief valve or high/low pressure alarms).

The pressure and vacuum settings of the protection device should not exceed the design pressure of the ballast piping (BWMS categories 3a and 3b) or ballast tank (BWMS categories 3a, 3b and 3c), as relevant.

For BWMS categories 3a, 3b and 3c, the inert gas or nitrogen product enriched air from the inert gas system and from the protection devices installed on the ballast tanks (i.e. P/V valves, P/V breakers or P/V breather valves) are to be discharged to a safe location[13)] (1) & (2) on the open deck.

[13)] Footnotes safe location(1) and safe location(2)
Safe location needs to address the specific types of discharges separately.
Signboards or similar warnings at the discharge areas are to be provided.
Safe location(1): inert gas or nitrogen product enriched air from:

- in-line (categories 3a and 3b) and in-tank (categories 3c and 8) de-oxygenation BWMS: the protection devices installed on the ballast tanks, nitrogen or inert gas generators, nitrogen buffer tank (if any); or
- in-line ozone injection BWMS (categories 7a and 7b): the oxygen generator;

safe locations on the open deck are:

- 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/outlets.

Safe location(2): oxygen-enriched air from:

- in-line and in-tank de-oxygenation BWMS (categories 3a and 8): the nitrogen generator; or
- in-line ozone injection BWMS (categories 7a and 7b): the protection devices or vents from oxygen generator, compressed oxygen vessel, the ozone generator and ozone destructor devices;

safe locations on the open deck are:

- outside of hazardous area;
- not within 3 m of any y source of ignition and from deck machinery, which may include anchor windlass and chain locker openings, and equipment which may constitute an ignition hazard; (continued to next page)

When the concerned ballast tanks are hazardous areas, an extension of hazardous area is to be considered at the outlet of the protection devices: with reference to IEC 60092-502:1999 §4.2.2.9 the areas on open deck, or semi-enclosed spaces on open deck, within 1.5 m of their outlets are to be categorized hazardous zone 1 and with reference to IEC 60092-502:1999 §4.2.3.1, an additional 1.5 m surrounding the 1.5 m hazardous zone 1 is to be categorized hazardous zone 2. Any source of ignition such as anchor windlass or opening into chain locker should be located outside the hazardous areas.

Where products covered by IEC 60092-502:1999 are stored on-board or generated during operation of the BWMS, the requirements of this standard shall be followed in order to:

- Define hazardous areas and acceptable electrical equipment, and
- Design ventilation systems.

.1.6 Electric and electronic components are not to be installed in a hazardous area unless they are of certified safe type for use in the area. Cable penetrations of decks and bulkheads are to be sealed when a pressure difference between the areas is to be maintained.

.1.7 Inert gas systems installed for de-oxygenation BWMS (categories 3a, 3b, 3c and 8) are to be designed in accordance with the following requirements:

1) FSS Code Ch 15 requirements
   - 2.1.2, 2.1.3
   - 2.2.1.3, 2.2.1.4, 2.2.2.1, 2.2.2.2, 2.2.2.3, 2.2.2.6, 2.2.4.1, 2.2.4.2, 2.2.4.3, 2.2.4.4, 2.2.4.5 except 2.2.4.5.1.3 and 2.2.4.5.3
   - 2.3.1.1.2, 2.3.1.2, 2.3.1.4.2, 2.3.1.5, 2.3.1.6, 2.3.2 except 2.3.2.2.1
   - 2.4.1.3, 2.4.1.4 and 2.4.2
   - For inert gas systems installed for in-tank de-oxygenation BWMS (category 8): 2.2.3.1, 2.2.3.2 except 2.2.3.2.6, 2.2.3.2.7 and 2.2.3.2.10

   In general, when applying FSS Code Ch.15 requirements to inert-gas based BWMS, the following modifications are to be considered:

   - The terms ”cargo tank” and ”cargo piping” are to be replaced by ”ballast water tank” or ”ballast water piping” as relevant.
   - The term ”cargo control room” is to be replaced by ”BWMS control station” as relevant
   - Requirements for slop tanks on combination carriers are to be disregarded
   - When applying FSS Code / 15.2.2.4.5.1.1, the acceptable oxygen content is to be specified by the manufacturer, 5% oxygen content need not necessarily be applied.

2) IACS UR F20 requirements F20.1.1.1, F20.1.1.3, F20.3.1, F20.3.3, F20.3.7, F20.3.8, F20.4.4, F20.4.5 and F20.4.6. In applying F20.4.6, the terms ”cargo tanks” and ”cargo piping” are to be understood as ”ballast tanks” and ”ballast piping” respectively. For de-oxygenation BWMS (categories 3a, 3b, 3c and 8), the requirements in 1) prevail.

.1.8 When cavitation is the BWMS treatment process (for example by use of pressure vacuum reactor working in combination with a vertical ballast water drop line) or part of the BWMS treatment process (for example by use of ”smart pipe” or ”special pipe” in BWMS category 7b or by use of ”venturi pipe” in BWMS technology 3b) or by use other means, the design and the wall thickness or grade of materials or inside coating or surface treatment of the part of the piping where the cavitation is taking place is to be specifically considered.

- 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.

.1.9 When it is required to have an automatic shutdown of the BWMS for safety reasons, this must be initiated by a safety system independent of the BWM control system.

.1.10 For the spaces, including hazardous areas, where toxicity, asphyxiation, corrosivity or reactivity is present, these hazards are to be taken into account and additional precautions for the ventilation of the spaces and protection of the crew are to be considered.

.1.11 Additional requirement for tankers shall be in accordance with Section 15.

.1.12 Additional requirements for tankers, see Section 15.E

1.6.5 Special requirements for BWMS categories 2, 3a, 3b, 3c, 4, 5, 6, 7a, 7b, and 8 generating dangerous gas or dealing with dangerous liquids

.1 Where the operating principle of the BWMS involves the generation of a dangerous gas, the following requirements are to be satisfied:

1) Gas detection equipment is to be fitted in the spaces where dangerous gas could be present, and an audible and visual alarm is to be activated both locally and at the BWMS control station in the event of leakage.

   i) The gas detectors should be located as close as possible to the BwMS components where the dangerous gas may accumulate.

   ii) For flammable gases and explosive atmosphere including but not limited to H2, the Construction, testing and performance of the gas detection devices is to be in accordance with IEC 60079-29-1:2016, IEC 60079-29-2:2015, IEC 60079- 29-3:2014 and/or IEC 60079-29-4:2009, as applicable.

   iii) Where other hazards are considered like toxicity, asphyxiation, corrosive and reactivity hazards, a recognized standard acceptable to the Society is to be selected with due consideration of the specific gases to be detected and due consideration of the performance of the detection device with regards to the specific atmosphere where it is used.

2) In spaces where inert gas generator systems are fitted (BWMS categories 3b and 3c) or nitrogen generators are fitted (BWMS categories 3a and 8), at least two oxygen sensors shall be positioned at appropriate locations (as required by Paragraph 2.2.4.5.4 of Chapter 15 of the FSS Code as amended by IMO resolutions up to MSC.410(97)) to alarm when the oxygen level falls below 19%. The alarms shall be both audible and visual and shall be activated:

   — inside the space;

   — at the entry into the space; and

   — inside the BWMS control station.

   For BWMS categories 7a and 7b, at least two oxygen sensors shall be positioned at appropriate locations in the following spaces:

   — spaces where ozone generators are fitted, or

   — spaces where ozone destructors are fitted, or

   — spaces where ozone piping is routed;

      i) to alarm when the oxygen level raises above 23 %. The alarms shall be both audible and visual and shall be activated at the following locations:
         — inside the space; and
         — at the entry into the space; and
         — inside the BWMS control station.

ii) Automatic shut-down of the BWMS is to be arranged when the oxygen level raisesabove 25%. Audible and visual alarms independent from those specified in the preceding paragraph are to be activated prior to this shut-down.

3) For BWMS categories 7a and 7b, at least one ozone sensor shall be provided at the vicinity of the discharge outlet to the open deck from the ozone destructors addressed in Footnote[14)] to alarm when the ozone concentration level raises above 0.1 ppm. The alarms shall be both audible and visual and shall be activated in the BWMS control room. In addition, at least two ozone sensors shall be positioned at appropriate location in the following spaces:

— spaces where ozone generators are fitted, or
— spaces where ozone destructors are fitted, or
— spaces where ozone piping is routed;

to alarm when the ozone concentration level raises above 0.1 ppm. The alarms shall be both audible and visual and shall be activated at the following locations:

— inside the space;
— at the entry into the space; and
— inside the BWMS control station.

Automatic shut-down of the BWMS is to be arranged when the ozone concentration measured from one of the two sensors inside the space raises above 0.2 ppm.

4) Inside double walled spaces or pipe ducts constructed for the purpose of .2,1) Note 1), sensors are to be provided for the detection of H_2 leakages (BWMS categories 4, 5 and 6 when relevant) or O_2 leakages (BWMS categories 7a and 7b) or O_3 leakages (BWMS categories 7a and 7b). The sensors are to activate an alarm at the high level settings and automatic shut-down of the BWMS at the high-high level settings described in above 1) to 3).

Note:

As an alternative to the sensor for the gas detection, monitored under-pressurization inside the double walled spaces or pipe ducts could be provided with an automatic alarm and shut-down of the BWMS in case of loss of the under-pressurization. The monitoring can be achieved either by monitoring the pressure inside the double walled spaces or pipe ducts or by monitoring the exhaust fan.

5) For in-line full flow electrolysis BWMS (category 4), in-line side-stream electrolysis BWMS (category 5) and in-line injection BWMS using chemical which is stored onboard (category 6): the hydrogen de-gas arrangement (when provided) is to be provided with redundant ventilation fans and redundant monitoring of the ventilation system.

In addition the ventilation fan shall be certified explosion proof and have spark arrestor to avoid ignition sources to enter the ventilation systems whereas remaining H_2 gas may be present in dangerous concentrations.

Audible and visual alarms and automatic shut-down of the BWMS are to be arranged for respectively high and high-high levels of H_2 concentration. The open end of the hydrogen by-product enriched gas relieving device is to be led to a safe location (3)[15)] on open deck.

6) The open end of inert gas or nitrogen gas enriched air (BWMS categories 3a, 3b, 3c and 8) or oxygen-enriched air (BWMS categories 3a, 7a, 7b and 8) are to be led to a safe location (1) & (2)[16)] on open deck.

[14)] Refer to footnote 17)
[15)] For safe location (3), refer to footnotes 17)
[16)] For safe location (1) and safe location (2) refer to footnote 13)

.2 Where the piping is conveying active substances, by-products or neutralizers that are containing dangerous gas or dangerous liquids as defined respectively in 1.6.3.3 and 1.6.3.4, the following requirements are to be satisfied:

Note:

1) *This requirement is applicable to the injection lines conveying the dangerous gas or dangerous liquids but not applicable to the ballast water lines where the dangerous gas or dangerous liquids are diluted.*

2) *The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guideline) could be used for assessing the hazards that could be expected from the media conveyed by the BWMS piping.*

1) Irrespective of design pressure and temperature, the piping is to be either of Class I (without special safeguard) or Class II (with special safeguard) as required by Table 11.1. The selected materials, the testing of the material, the welding, the non-destructive tests of the welding, the type of connections, the hydrostatic tests and the pressure tests after assembly on-board are to be as required in 11.D.2.5. Mechanical joints, where allowed, are to be selected in accordance with Table 11.15.

   Note:

   1) *For piping class II with special safeguards conveying dangerous gas like hydrogen (H_2), oxygen (O_2) or ozone (O_3), the special safeguards are to be either double walled pipes or pipe duct.*
   2) *For piping class II with special sofeguards conveying dangerous liquids, other special safeguards could be considered like shielding, screening, etc.*
   3) *Plastic pipes may be accepted after due assessment of the dangerous gas or dangerous liquids conveyed inside. When plastic pipes are accepted, the requirements of B.2.6 apply.*

2) The length of pipe and the number of connections are to be minimised.

3) Inside double walled space or pipe ducts constructed as the special safeguard for the purpose of 1) Note 1) are to be equipped with mechanical exhaust ventilation leading to a safe location (3)&(4)[17] on open deck.

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[17] Footnotes safe location(3) and safe location(4):

Safe location(3): hydrogen by-product enriched gas from:

— in-line full flow elect a oloatralue trolysis BWMS (category 4), in-line side-stream electrolysis BWMS (category 5) and in-line injection BWMS using chemical which is stored onboard (category 6): the hydrogen de-gas arrangement (when provided);

safe locations on the open deck are:

— not within 5 m of any source of ignition and from deck machinery, which may include anchor windlass and chain locker open nings, and equip ment which may constitute an ignition hazard;
— not within 3 m of areas traversed by personnel; and
— not within 5 m of air intakes from non-hazardous enclosed spaces.

The areas on open deck, or semi-enclosed spaces on open deck, within 3 m of the outlets are to be categorized hazardous zone 1 plus an additional 1,5 m surrounding the 3 m hazardous zone 1 is to be categorized hazardous zone 2.

Electrical apparatus located in the above hazardous areas zone 1 and zone 2 is to be suitable for at least IIC T1.

Safe location(4): For in-line ozone injection BWMS (categories 7a and 7b), vent outlet from O3 destructor device (ODS) can be considered as oxygen enriched air provided that:

— the ODS are duplicated; and
— the manufacturer justified that the quantity of consumable (activated carbon) used by the ODS is sufficient for the considered life cycle of the BwMs; and
— ozone detection is arranged in the vicinity of the discharge outlet from the vent outlet of the ODS to alarm the crew in in case the ODS is no ot working.

If one of the above 3 conditions is not fulfilled, the safe location from ODs on open deck are:

— outside of hazardous area;
— not within 3 m of any source of ignition;
— not within 6 m of areas traversed by personnel; and
— not within 6 m of air intakes for machinery (engines and boilers) and all ventilation inlets.

4) The routing of the piping system is to be kept away from any source of heating, ignition and any other source that could react hazardously with the dangerous gas or liquid conveyed inside. The pipes are to be suitably supported and protected from mechanical damage.

5) Pipes carrying acids are to be arranged so as to avoid any projection on crew in case of a leakage.

6) H_2 by-product enriched air vent pipes (BWMS categories 4, 5 and 6) or O_2 enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) or O_3 piping (BWMS categories 7a and 7b) shall not be routed through accommodation spaces, services spaces and control stations.

7) O_2 enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) shall not be routed through hazardous areas unless it is arranged inside double walled pipes or pipe ducts constructed as the special safeguard for the purpose of 3.3.2.1 Note 1) and provided with suitable gas detection as described in 3.3.1.4 and mechanical exhaust ventilation as described in 3).

8) The routing of H_2 by-product enriched air vent pipes (BWMS categories 4, 5 and 6) or O_2 enriched air vent pipes (BWMS categories 3a, 7a, 7b and 8) is to be as short and as straight as possible. When necessary, horizontal portions may be arranged with a minimum slope in accordance with the manufacturer's recommendation.

.3 For BWMS using chemical substances or dangerous gas which are stored on-board for either:

— storage or preparation of the active substances (BWMS categories 2 and 6), or

— storage or preparation of the neutralizers (BWMS categories 4, 5, 6, 7a and 7b), or

— recycling the wastes produced by the BWMS (BWMS category 2),

procedures are to be in accordance with the Material Safety Data Sheet and BWM.2/Circ.20 "Guidance to ensure safe handling and storage of chemicals and preparations used to treat ballast water and the development of safety procedures for risks to the ship and crew resulting from the treatment process", and the following measures are to be taken as appropriate:

1) The materials, inside coating used for the chemical storage tanks, piping and fittings are to be resistant to such chemicals substances.

2) Chemical substances (even if they are not defined as dangerous liquid in the sense of 1.6.3.4) and gas storage tanks are to be designed, constructed, tested, inspected, certified and maintained in accordance with:

   — for independent tanks permanently fixed onboard containing dangerous liquids (eg. sulfuric acid H_2SO_4) or dangerous gas (eg. oxygen O2): BKI Rules as applicable to pressure vessels
   — for independent tanks permanently fixed onboard not containing dangerous liquid (eg. sodium sulphite, sodium biosulphite or sodium thiosulfphate neutralizers) and not containing dangerous gas (eg. nitrogen N_2): BKI Rules or other industry standard recognized by BKI
   — for portable tanks: the IMDG Code or other industry standard recognized by BKI.

3) When the chemical substances are stored inside integral tanks, the ship's shell plating shall not form any boundary of the tank.

4) Dangerous liquids and dangerous gas storage tank air pipes are to be led to a safe location(1) & (2)[15) on open deck.

5) An operation manual containing chemical injection procedures, alarm systems, measures in case of emergency, etc. is to be kept onboard.

[15)] For safe location(1) and safe location(2), refer to footnotes to 1.6.4.1.5

6) Dangerous liquid storage tanks and their associated components like pumps and filters, are to be provided with spill trays or secondary containment system of sufficient volume to contain potential leakages from tank openings, gauge glasses, pumps, filters and piping fittings.
Further to the safety and/or pollution assessment of the concerned chemical substances, consideration should be provided for segregation of the drains from such spill trays (or secondary containment system) or piping systems from engine room bilge system or from cargo pump room bilge system, as applicable. When necessary, arrangement should be provided within the spill trays (or within the secondary containment system) for the detection of dangerous liquid or dangerous gas as defined respectively in 1.6.3.3 and 1.6.3.4.

Note:

The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guideline) could be used for this assessment.

.4 A risk assessment is to be conducted in a generic manner during the design review mentioned in 1.6.4.1.4 and submitted to the Classification Society for approval for the following BWMS categories:

— BWMS category 4: in all cases;

— BWMS category 5: in all cases;

— BWMS category 6: when one of the MSDS indicates that the chemical substance stored on-board is either flammable, toxic, corrosive or reactive;

— BWMS category 7a and 7b: in all cases.

Note:

The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guideline) could be used as a reference for this assessment.

1) The recommended risk assessment techniques for BWMS and other guidances are listed below but not limited to:

   — FMEA, FMECA, HAZID, HAZOP, etc.

   — ISO 31010 - Risk Assessment Techniques

   — IACS Recommendation Rec. 146

   — Guidance for Risk Evaluation for the Classification of Marine Related Facilities (Pt.4, Vol.A)

   — Reference Notes on Risk Assessment for the Marine and Offshore Oil and Gas Industries (Pt.4, Vol.1)

2) The risk assessment should ensure that the package supplied by the BWMS's manufacturer is intrinsically safe and/or provides mitigation measures to the hazards created by the BWMS which have been identified during the design review mentioned in 1.6.4.1.4 but that need to be implemented during the installation on-board.

1.7 Integration and installation of ballast water treatment systems on board

1.7.1 A ship related arrangement drawing and a piping diagram showing the integration of the BWTS into the ship's ballast piping system as well as the operating and technical manual shall be submitted for approval. If a BWTS uses active substances, additional arrangement drawings for operating compartments and storage rooms of these substances shall be submitted, including details of their equipment.

1.7.2 The rated capacity of BWTS shall not be less than the flow rate of the largest ballast pump. If the treated rated capacity (TRC) of ballast water specified by the manufacturer may be exceeded operationally, e.g. by parallel operation of several ballast pumps, appropriate references and restrictions shall be indicated in the ballast water management plan.

1.7.3 Proper installation and correct functioning of the ballast water management system shall be verified and confirmed by a BKI Surveyor.

2. Ballast pumps

The number and capacity of the pumps is to satisfy the ship's operational requirements.

3. Cross-flooding arrangements

3.1 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 are to 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 Rules for Hull (Pt.1, Vol.II), Sec. 36, H. and Rules for Electrical Installations (Pt. 1, Vol.IV), Sec. 7, H.). The cross-flooding arrangements are to ensure that in case of flooding equalization is achieved within 10 minutes.

3.2 Cross-flooding arrangements for equalizing of asymmetrical flooding in case of damage are to be submitted to BKI for approval.

4. Additional requirements for tankers

See Section 15, B.4.

5. Operational testing

The ballast arrangement is to be subjected to operational testing under BKI's supervision.

P. Thermal Oil Systems

Thermal oil systems are to be installed in accordance with Section 7.II.

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 draining the system.

1.3 The pumps are to be so mounted that any oil leakage can be safely disposed of.

1.4 For emergency shut-downs see Section 12, B.9.

2. Valves

2.1 Only valves made of ductile materials may be used.

2.2 Valves are to 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 11.1 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 Section 12, B.7.

3.8 Means of bleeding (of any air) are to be so arranged that oil/air mixtures will be drained safely. Bleeder screws 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 are to be equipped with air pipes and drains. For storage tanks see also Section 10, D.

4.2 The air pipes for the drainage tanks are to terminate above open deck. Air pipe closing devices see Q.1.3.

4.3 Drains are to be self-closing 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 BKI Surveyor.

Q. Air, Overflow and Sounding Pipes

1. General

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 11.5.

For special strength requirements regarding foredeck fittings, see Rules for Hull (Pt.1, Vol.II), Sec. 21, F.5.

1.1 Air and overflow pipes

1.2 Arrangement

1.2.1 All tanks, void spaces, etc. are to be fitted at their highest position with air pipes or overflow pipes. Air pipes normally are to terminate at the open deck.

1.2.2 Air and overflow pipes are to be laid vertically.

1.2.3 Air and overflow pipes passing through cargo holds are to be protected against damage.

1.2.4 For the height above deck of air/overflow pipes and the necessity of fitting brackets on air pipes, see Rules for Hull (Pt.1, Vol.II), Sec. 21, F.

The wall thickness of air pipes on the exposed deck is to be in accordance with Table 11.22a and Table 22b.

1.2.5 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 is to be ensured that no leaking oil can spread onto heated surfaces where it may ignite.

1.2.6 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.

1.2.7 On cargo ships of 500 GT 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 does not directly lead to the risk of ingress of sea or rain water.

1.2.8 Wherever possible, the air pipes of feed water and distillate tanks should not extend into the open deck.

1.2.9 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.

1.2.10 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.

1.2.11 On cargo ships of 500 GT 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 does not directly lead to the risk of ingress of sea or rainwater, see also Section 10, B.5.2.

1.2.12 Where fuel service 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.

1.2.13 The overflow pipes of changeable tanks must be capable of being separated from the fuel overflow system.

1.2.14 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, as far as practicable but at least so high above the deepest load waterline 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.

1.2.15 The air and overflow pipes of lubricating oil and fuel tanks are not to be led to a common line.

1.2.16 For the connection to a common line of air and overflow pipes on ships with the Character of Classification ✠ or ✠ see D.9.

1.2.17 For the cross-sectional area of air pipes and air/overflow pipes, see Table 11.20.

1.3 Number of air and overflow pipes

1.3.1 The number and arrangement of the air pipes is to be so performed that the tanks can be aerated and deaerated without exceeding the tank design pressure by over or under pressure.

1.3.2 Tanks which extend from side to side of the ship are to be fitted with an air/overflow pipe at each side. At the narrow ends of double bottom tanks in the forward and aft parts of the ship, only one air/over-flow pipe is sufficient.

Table 11.20: Cross-sectional areas of air and over-flow pipes

Tank filling systems		Cross-sectional areas of air and overflow pipes	
		AP	AOP
Filling mode	Without overflow	1/3 f per tank	—
	With Overflow	—	1,25 f per tank[1)]

Explanatory note:

AP = air pipe

AOP = air/overflow pipe

f = cross-sectional area of tank filling pipe

[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 pressure in the tanks in the event of overflow

1.4 Air pipe closing devices

Air/overflow pipes terminating above the open deck are to be fitted with type 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.

1.5 Overflow systems

1.5.1 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.

1.5.2 Fuel oil tanks

The requirements to be met by overflow systems of heavy oil tanks are specified in Guidance for the Construction, Equipment and Testing of Closed Fuel Overflow Systems (Pt.1, Vol.J).

1.5.3 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.

1.5.4 For the size of the air and overflow pipes, see Table 11.21.

1.5.5 The use of a fuel storage tank as overflow tank is permissible 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.

1.6 Determination of the pipe cross-sectional areas

1.6.1 For the cross-sectional areas of air and over-flow pipes, see Tables 11.20 and 11.21.

Air and overflow pipes are to have an outside diameter of at least 60,3 mm.

On ships ≥ 80 m in length in the forward quarter only air/ overflow pipes with an outer diameter ≥ 76,1 mm may be used, see also Rules for Hull (Pt.1, Vol. II) Sec. 21.

Table 11.21: 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
		AP	OP[2]	DP	
Filling	Stand-pipe	1/3 f	—	—	cross-sectional area of stand-pipe ≥ 1,25 F
	Relief valve	1/3 f [1]	min. 1,25 F	—	cross-sectional area of relief valve ≥ 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:

AP = air pipe
OP = overflow pipe
DP = drainage line
f = cross-sectional area of tank filling pipe
F = 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

1.6.2 The clear cross-sectional area of air pipes on passenger ships with cross-flooding arrangements is to be so large that the water can pass from one side of the ship to the other within 15 minutes, see also O.3.

1.7 The minimum wall thicknesses of air an overflow pipes are to be in accordance with Table 11.22a and 11.22b, whereby A, B and C are the groups for the minimum wall thicknesses.

1.8 The pipe materials 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 tanks are fitted with remote level indicators which are type approved by BKI 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 permissible in spaces which are accessible at all times.

All other sounding pipes are to be extended to the open deck. The sounding pipe openings are always to be accessible and fitted with watertight closures.

Table 11.22a: Classification of minimum wall thickness groups

<table>
<tr><th rowspan="4">Piping system or position of open pipe outlets</th><th colspan="9">Location</th></tr>
<tr><th rowspan="3">Tanks with same media</th><th rowspan="3">Tanks with dis-parate media</th><th colspan="3">Drain lines and scupper pipes</th><th colspan="2">Air, sounding and over-flow pipes</th><th rowspan="3">Cargo holds</th><th rowspan="3">Machine-ry spaces</th></tr>
<tr><th colspan="2">below freeboard deck or bulkhead deck</th><th rowspan="2">above freeboard deck</th><th rowspan="2">above weather deck</th><th rowspan="2">below weather deck</th></tr>
<tr><th>without shut-off on ship’s side</th><th>with shut-off on ship’s side</th></tr>
<tr><td>Air, over-flow and sounding pipes</td><td rowspan="4">A</td><td>C</td><td>—</td><td>—</td><td>—</td><td>C</td><td>A</td><td>A</td><td rowspan="4">A</td></tr>
<tr><td>Scupper pipes from open deck</td><td rowspan="3">B</td><td>—</td><td rowspan="3">A</td><td>A</td><td rowspan="3">—</td><td rowspan="3">—</td><td rowspan="3">B</td></tr>
<tr><td>Discharge and scup-per pipes leading directly overboard</td><td>B</td><td>—</td></tr>
<tr><td>Discharge pipes of pumps for sanitary systems</td><td>—</td><td>A</td></tr>
</table>

Table 11.22b: Minimum wall thickness of air, over flow, sounding and sanitary pipes

Outside pipe diameter d_a [mm]	Minimum wall thickness [mm]		
	A 1)	B 1)	C 1)
38 – 82,5	4,5	7,1	6,3
88,9	4,5	8	6,3
101,6 – 114,3	4,5	8	7,1
127 – 139,7	4,5	8,8	8
152,4	4,5	10	8,8
159 – 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) wall thickness groups, see Table 11.20a

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 independent from each other and are to be type approved by BKI[18)].

2.1.8 In cargo holds, fitted with non-weather tight hatch covers, 2 level alarms are to be provided in each cargo hold, irrespective if sounding pipes are fitted. The level alarms are to be independent from each other and are to be type approved by BKI.

2.1.9 Sounding pipes passing through cargo holds are to be laid in protected spaces or they are to be protected against damage.

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 Section 10, B.3.3.7.

2.2.2 Sounding pipes are not to be located in the vicinity of oil firing equipment, machine components with high surface temperatures or electrical equipment

2.2.3 Sounding pipes are not to 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 are to have an inside diameter of at least 32 mm.

2.3.2 The 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.

2.3.3 The minimum wall thicknesses of sounding pipes are to be in accordance with Tables 11.22a and 11.22b.

2.3.4 For pipe materials see B.

R. Drinking Water Systems [18)]

1. Drinking water tanks

1.1 For the design and arrangement of drinking water tanks, see Rules for Hull (Pt.1, Vol.II) Sec. 12.

1.2 On ships with ice class **ES1** 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 of insects by a fine mesh screen.

Air pipe closing devices, see Q.1.3.

2.3 Sounding pipes are to terminate sufficiently high above deck.

[18)] National Regulations, where existing, are to be considered.

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 backflow.

4. Pressure water tanks/calorifiers

For design, equipment, installation and testing of pressure water tanks and calorifiers, Section 8, 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 ship's own evaporator unit is used for the drinking water supply, the treatment of the distillate has to comply with current regulations of national health authorities.

S. Sewage 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:

1) a sewage treatment plant approved according to Resolution MEPC. 159(55) or
2) 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
3) a sewage collecting tank

1.2 A pipeline for the discharge of sewage to a reception facility is to be arranged. The pipeline is to be provided with a standard discharge connection.

1.3 The holding tank shall have means to indicate visually the content. A sounding pipe alone does not fulfil the above requirement .

2. Arrangement

2.1 For scuppers and overboard discharges see Rules for Hull (Pt.1, Vol.II) Sec. 21.E.

2.2 The minimum wall thicknesses of sanitary pipes leading directly outboard below free board and bulkhead decks are specified in Tables 11.22a and 11.22b.

2.3 For discharge lines above freeboard deck/ bulkhead deck the following pipes may be used:

1) steel pipes according to Table 11.6, Group N
2) pipes having smaller thicknesses when specially protected against corrosion, on special approval
3) special types of pipes according to recognized standards, e.g. socket pipes, on 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 type approved by BKI.

2.6 If sanitary discharge pipes are led through cargo holds, they are to be protected against damage by cargo.

2.7 Sewage tanks 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 Q.1.3.

2.7.2 Sewage tanks 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 ship's side, the thickness of the pipe is to be according to Table 11.22b, 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[19)].

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° heel. 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 at the shell plating. In this case the reverse-flow protection device need not to be of screw-down type.

2.7.6 Ballast and bilge pumps are not to be used for emptying sewage tanks.

3. Additional rules for ships with Character of Classification ✠ or ✠̲

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.

3.2 If this condition cannot be fulfilled, e.g. when:

1) watertight compartments are connected with each other through internal openings of the sanitary discharge lines, or

2) sanitary discharge lines from several water tight compartments are led to a common drain tank, or

3) 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 devices at the watertight bulkheads.

The operation of the shut-off devices is to be possible from an always accessible position above the bulk-head deck on passenger ships and above the unsuitable leak water line on other ships. The position of the shut-off devices is to be monitored at the remote control position.

[19)]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 requirements.

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, discharge lines of sanitary collecting tanks are 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, 2.7.4 and 2.7.5 are to be applied.

T. Hose Assemblies and Compensators

1. Scope

1.1 The following requirements are applicable for hose assemblies and compensators made of non-metallic and metallic materials intended for a permanent connection between a fixed piping system and items of machinery. The requirements may also be applied to temporary connected flexible hoses or hoses of portable equipment.

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, fire extinguishing, compressed air, auxiliary steam[20] (pipe Class III) 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 of Diesel engines. Furthermore it is not permitted to use hose assemblies and compensators in high pressure fuel injection piping systems of combustion engines.

1.3 Compensators made of non-metallic materials are not approved for the use in cargo lines of tankers.

1.4 These requirements for hose assemblies and compensators are not applicable to hoses intended to be used in fixed fire extinguishing systems.

2. Definitions

Hose assemblies are short length consist of metallic or non-metallic hoses completed with prefabricated end fittings ready for installation.

Hose assemblies and compensator for essential services or containing either flammable or toxic media are not to exceed 1,5 m in length.

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 characteristics.

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 respectively nominal pressure of hose assemblies and compensators made of non-metallic materials

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.

[20] Metallic hose assemblies and compensators only

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 2,0 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 respectively the nominal pressure.

2.4.3 For metallic hose assemblies and compensators the test pressure is 1,5 times the maximum allowable working pressure respectively the nominal pressure.

2.5 Burst pressure

For non-metallic as well as metallic hose assemblies and compensators the burst pressure is to be at least 4 times the maximum allowable working pressure or the nominal pressure. Excepted here of are non-metallic hose assemblies and compensators with a maximum allowable working pressure or 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 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 or nominal pressure.

3. Requirements

3.1 Compensators and hoses assemblies (hose and hose end fitting) used in the systems mentioned in T.1.1.1 are to be of approved type[21)]. Compensator and hoses are to be designed and constructed in accordance with recognised National or International standards acceptable to the BKI.

3.2 Manufacturers of hose assemblies and compensators[22)] are to be recognized by BKI. For production of hose assemblies and compensators intended to be installed in mass produces engines with a piston diameter up to 300 mm the procedure specified in the Guidance for The Approval and Type Approval of Materials and Equipment for Marines Use (Pt.1, Vol. W) may be applied

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.

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. Hose assemblies and compensator constructed of non-metallic materials intended for installation in piping systems for flammable media (e.g. fuel, lubricating oil, hydraulic oil etc) and sea water systems where failure may result in flooding (e.g. bilge, ballast etc), are to be of fire-resistant type13 except in cases where such hoses are installed on open decks, as defined in Regulation 9.2.3.3.2.2(10) of SOLAS Chapter II-2 as amended by IMO resolutions up to MSC.421(98) and not used for fuel oil lines. Fire resistance is to be demonstrated by testing to ISO 15540:2016 and ISO 15541:2016.

[21)] See Guidance for The Approval and Type Approval of Materials and Equipment for Marines Use (Pt.1, Vol. W).

[22)] See Guidance for The Approval and Type Approval of Materials and Equipment for Marines Use (Pt.1, Vol. W) for Hose Assemblies and Compensators.

3.6 Hoses and compensator constructed of rubber materials and intended for use in bilge, ballast, compressed air, oil fuel, lubricating, hydraulic and thermal oil systems are to incorporate a single, double or more, closely woven integral wire braid or other suitable material reinforcement.

Hoses and compensator 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 and compensator are to be used in oil supply lines to burners, the hoses are to have external wire braid protection in addition to the reinforcement mentioned above. Flexible hoses and compensator for use in steam systems are to be of metallic construction.

3.7 Hoses and compensator 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.2.5 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.

3.8 The use of hose clamps and similar types of end attachments is not acceptable for flexible hoses and compensator in piping systems for steam, flammable media, starting air systems or for sea water systems where failure may result in flooding. In other piping systems, the use of hose clamps may be accepted where the working pressure is less than 5 bar and provided there are double clamps at each end connection.

3.9 Hose assemblies and compensator 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 5 are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.

3.10 Hose assemblies and compensator are to be selected for the intended location and application taking into consideration ambient conditions, compatibility with fluids under working pressure and temperature conditions consistent with the manufacturer's instructions and any requirements of BKI.

4. Installations

4.1 Hose assemblies and compensators are only to be used at locations where they are required for compensation of relative movements. The number of hose assemblies and compensators is to be kept to minimum. They are to be kept as short as possible under consideration of the installation instructions of the hose manufacturer with particular attention to the following:

- Orientation
- End connection support (where necessary)
- Avoidance of hose contact that could cause rubbing and abrasion
- Minimum bend radius

4.2 Non-metallic hose assemblies and compensators are to be located at visible and accessible positions.

4.3 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 ends with double clips.

4.4 Non-metallic hose assemblies and compensators are installed in the vicinity of hot components they shall be provided with type approved heat protection sleeves. In case of flammable fluids the heat-protection sleeve is to be applied such that in case of a hose or end fitting leakage oil spray on hot surfaces will not occur.

4.5 Hose assemblies and compensators conveying flammable liquids that are in close proximity of heated surfaces are to be screened or protected analogously to G.3.4.

4.6 Hose assembly and compensators are not to be installed where they may be subjected to torsion deformation (twisting) under normal operating conditions.

5. Test

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 BKI. For testing of hose assemblies and compensators intended to be installed in mass produced engines with a piston diameter up to 300 mm the procedure specified in the Guidance for The Approval and Type Approval of Materials and Equipment for Marines Use (Pt.1, Vol. W) may be applied.

5.2 For compensators intended to be used in exhaust gas pipes the pressure test according 5.1 may be omitted.

6. Marking of hose assemblies and compensators

Hose assemblies and compensators are to be permanently marked to ensure traceability to the hose assembly manufacturer, production date and product type. Where a flexible hose assembly and compensator is made up of items from different manufacturers, the components are to be clearly identified and traceable to evidence of prototype testing. The scope of marking should be as follows:

1) manufacturer sign
2) date of manufacture (month/year)
3) product type according to type approval certificate
4) nominal diameter
5) maximum allowable working pressure or nominal pressure
6) maximum allowable working temperature

Alternatively:

1) BKI Test Certificate Number
2) maximum allowable working pressure

7. Ship cargo hoses

7.1 Ship cargo hoses for cargo-handling on chemical tankers and gas tankers are to be type approved [19).]

Mounting of end fittings is to be carried out only by approved manufacturers [20)].

7.2 Ship cargo hoses are to be subjected to final inspection at the manufacturer under supervision of a BKI Surveyor as follows:

1) visual inspection
2) hydrostatic pressure test with 1,5 times the maximum allowable working pressure or 1,5 times the nominal pressure. The nominal pressure is to be at least 10 bar.
3) measuring of the electrical resistance between the end fittings. The resistance is not to exceed 1kΩ and in case of repeat test not bigger than 1 x 10^6 Ω

7.3 Cargo hoses on gas tankers are additionally subject to the Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol.IX) Sec. 5 & 7.

7.4 Cargo hoses on chemical tankers are additionally subject to the Rules for Ships Carrying Dangerous Chemical in Bulk (Pt.1, Vo.X) Sec. 5 & 7.

7.5 Marking

Ship cargo hose assemblies are to be permanently marked to ensure traceability to the hose assembly manufacturer, production date and product type. The scope shall be as follows:

1) manufacturer's mark
2) BKI Test Certificate number
3) test pressure
4) month – BKI stamp - year
5) nominal d

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Section 12 Fire Protection and Fire Extinguishing Equipment

A. General

1. Scope

1.1 The requirements 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 Fire fighting ships to which the Notation "**FF**" is to be allocated are also subject to the Guidance on Fire Fighting Ship (Pt.4, Vol.C).

2. Documents for approval

Diagrammatic plans, drawings and documents covering the following are to be submitted. To facilitate a smooth and efficient approval process, the drawings could be submitted in electronic format.

- 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 12.3
- CO_2 or alternative gas fire extinguishing system with arrangement drawing, operating diagram, CO_2 room, tripping devices, alarm diagram, calculation, form BKI, 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

— 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. References to further Rules

3.1 Structural fire protection, Rules for Hull (Pt.1, Vol.II), Sec.22.

3.2 Ships Carrying Liquefied Gases in Bulk, Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol. IX).

3.3 Ships Carrying dangerous chemicals in bulk, Rules for Ships Carrying Dangerous Chemicals in Bulk (Pt.1, Vol.X).

3.4 Pressure vessels Section 8

3.5 Oil fired equipment Section 9

3.6 Fuel and oil storage Section 10

3.7 Pipes, valves, fittings and pumps Section 11

3.8 Machinery for ships with ice class Section 11.I.2

3.9 Additional fire protection and fire extinguishing equipment in automated plant, Rules for Automations (Pt.1, Vol. VII).

3.10 Electrical plant,Rules for Electrical Installations (Pt.1, Vol. IV).

3.11 Equipment of fire fighting ships, Guidance on Fire Fighting Ship (Pt.4, Vol.C).

3.12 Fire Prevention in Machinery Spaces of Ships in Service – Guidance to Owners, Guidance for Marine industry (Pt.1, Vol.AC) Section 1 R-18.

3.13 Fire-extinguishing arrangements in machinery spaces, Guidance for Code and Convention Interpretations (Pt.1, Vol.Y) Section 9, SC-30.

4. Alternative design and arrangements

The fire safety design and arrangements may differ from the prescriptive regulations 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 is to 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 is to 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 normally is not to 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 are to be non-combustible. Where there is a danger that oil may penetrate insulating materials, these are to 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.

1.7 The following requirements apply to closable ventilation louvers and ventilator closing appliances serving emergency generator rooms, where fitted:

1.7.1 Ventilation louvers and closing appliances may either be hand-operated or power- operated (hydraulic/pneumatic/electric) and are to be operable under a fire condition.

1.7.2 Hand-operated ventilation louvers and closing appliances are to be kept open during normal operation of the vessel. Corresponding instruction plates are to be provided at the location where hand-operation is provided.

1.7.3 Power-operated ventilation louvers and closing appliances shall be of a fail-to-open type. Closed power-operated ventilation louvers and closing appliances are acceptable during normal operation of the vessel.

Power-operated ventilation louvers and closing appliances shall open automatically whenever the emergency generator is starting / in operation.

1.7.4 It shall be possible to close ventilation openings by a manual operation from a clearly marked safe position outside the space where the closing operation can be easily confirmed. The louver status (open / closed) shall be indicated at this position. Such closing shall not be possible from any other remote position.

[1)] Reference is made to the “Guidelines on Alternative Design and Arrangements for Fire Safety” adopted by IMO by MSC/Circ. 1002.

2. Fuel oil purifiers

2.1 Enclosed space

Fuel oil purifiers for heated fuel oil should preferably be installed in a separate room. This room is to be enclosed by steel divisions, be fitted with a self-closing steel door and be provided with the following:

- separate mechanical ventilation[2)]
- 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 is to be capable being actuated together with the fire extinguishing system of the machinery space.

If the fuel oil purifiers are arranged in separate machinery space of Category A, this space shall be provided with 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 giving particular consideration to arrangement, shielding/ containment of leaks and to adequate ventilation[2)].

3. Arrangement of boiler plants

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 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 is to be such that oil or fuel cannot penetrate into the insulating material.

Metal cladding or 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 is to be such that it will not crack or deteriorate when subject to vibration.

5. Fuel and lubricating oil tanks

The requirements of Section 10 are to be observed.

[2)] See Guidance for Ventilation System on Board Seagoing Ships (Pt.1, Vol.A)

6. Protection against fuel and oil leakages

6.1 Suitable means of collecting are to be fitted below hydraulic valves and cylinders as well as below potential leakage points in lubricating oil and fuel oil systems.

Where oil leakages are liable to be frequent, e.g. with oil burners, separators, drains and valves of service tanks, the collectors are to be drained to an oil drain tank.

Leakage oil drains may not be part of an overflow system.

6.2 The arrangement of piping systems and their components intended for combustible liquids are to 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, pre-heaters etc. containing combustible liquids are not to be placed directly above heat sources such as boilers, steam lines, exhaust gas manifolds and silencers or items of which have to be insulated in accordance with B.4.1 and are also not to be placed above electrical switchgear.

6.4 Fuel injection pipes of diesel engines are to be shielded or so installed that any fuel leaking out can be safely drained away, see also Section 2, G.2.2 and Section 11.G.3.3

6.5 All parts of the fuel oil system containing heated oil under pressure exceeding 1,8 Bar is, as far as practicable, to be arranged such that defects and leakage can readily be observed. The machinery spaces in way of such parts of the fuel oil system are to be adequately illuminated.

7. Bulkhead penetrations

Pipe penetrations through class A or B divisions are to be capable to withstand the temperature for which the divisions were designed.

Where steam, exhaust gas and thermal oil lines pass through bulkheads, the bulkhead is to be suitably insulated to protect it against excessive heating.

8. Means of closure

Means are to be provided for the airtight sealing of boiler rooms and machinery spaces. The air ducts to these spaces are to be fitted with fire dampers 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 shut-off devices

Steam-driven fuel pumps, lubricating oil 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 operated shut-off devices.

The controls for remote operation of the valve for the emergency generator fuel tank have to be in separate location from the controls for remote operation of valves for tanks located in machinery spaces.

The location and grouping of the shut-off 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 watertight doors and skylight in the machinery space area
- actuation of the machinery space fire extinguishing system.

On passenger ships, all controls indicated in 8, 9, 10 and 10.1 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 shut-off of machinery aggregates and auxiliary systems indicated in 9. and 10. is not permitted, see also Rules for Electrical Installations (Pt.1, Vol. IV), Sec. 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 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 Rules for Electrical Installations (Pt.1, Vol.IV), Sec. 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 effecting at least 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 Rules for Electrical Installations (Pt.1, Vol.IV), Sec. 16.

11.5 Design

[3)] For definition see Table 12.1, Note.4

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. These requirements 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 shall 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 the mechanical exhaust ventilators has to comply with Section 15, B.5.3. For the type of protection of electrical motors and other electrical equipment located in the exhaust air stream, see Rules for Electrical Installations (Pt.1, Vol.IV) Sec. 16, H.

11.5.4 Reference is made to the ventilation requirements in Guidance for Ventilation System on Board Seagoing Ships (Pt.1, Vol.A).

11.6 Monitoring
The failure of a fan has to 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 C is to be provided for the cargo spaces and vehicle decks.

11.7.3 For the fire extinguishing equipment see F.2.2, F.2.3.6 and Table 12.1.

11.8 Electrical equipment is to comply with the requirements in Rules for Electrical Installations (Pt.1, Vol.IV), Sec. 16.

12. Ro-ro spaces in passenger ships not intended for the carriage of vehicles with fuel in their tanks

12.1 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, with the exception of 11.5.3, 11.7.1 and 11.8, as well as the requirements of Section 11.M.4.4 are to be applied.

12.2 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 are to be observed with the exception that a sample extraction smoke detection system is not permitted and that additionally the as well as the requirements of Section 11.M.4.4 are to be applied.

13. Fire resistance of components in fixed fire-extinguishing systems

Unless otherwise specified in this Section, piping, pipe fittings and related components except gaskets of fixed fire-extinguishing systems shall be designed inside the protected spaces to withstand a temperature of 925 °C.

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 Rules for Electrical Installations (Pt.1, Vol.IV), Sec. 9, D.3.

[4)] Reference is made to Guidance for Code and Convention Interpretations (Pt.1, Vol.Y) Sec.11.243

2. Fire detection in passenger ships

2.1 In passengers ships carrying not more than 36 passengers, a fire detection and alarm system in accordance with Rules for Electrical Installations (Pt.1, Vol.IV), Sec. 9, D. is to be provided in all accommodation- and service spaces and, if considered necessary by BKI, in control stations[5)].

Spaces where there is no substantial fire risk are excluded from this requirement.

2.2 Instead of a fire detection and alarm system in accordance with 2.1, an approved automatic pressure water spraying system[6)] in accordance with L.1 or an approved equivalent pressure water spraying system may be provided. In this case, additionally an approved fire detection and alarm system in accordance with Rules for Electrical Installations (Pt.1, Vol.IV), Sec. 9, D. is to be installed in corridors, stairways and escape routes within the accommodation areas. 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.

In this case however, deviating from Rules for Electrical Installations (Pt.1, Vol.IV), Sec. 9, D.3.1.11 and L.1.7.2, all decks within this public space may be monitored or protected by common fire detection or spraying section.

2.4 In passenger ships carrying more than 36 passengers, an approved automatic pressure water spraying system[7)] in accordance with L.1 or an equivalent approved pressure water spraying system is to be provided in all accommodation and service spaces including corridors and stairways, and in control stations.

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 Rules for Electrical Installations (Pt.1, Vol.IV), Sec. 9.

In spaces having little or no fire risk, e.g. void spaces, public toilets, CO_2 room 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 are to 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 12.1) 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.

2.7 Special category spaces without a permanent patrol system are to be equipped with 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.

[5)] For definition see SOLAS II-2, Reg.3.

[6)] See IMO-Resolution A.800(19)' "Revised Guidelines for Approval of Sprinkler Systems Equivalent to that referred to SOLAS Regulation II-2/12" as amended by Res. MSC.265(84).

[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.

2.8 The cabin balconies are to be provided with a fire detection and alarm system in accordance with Rules for Electrical Installations (Pt.1, Vol.IV) Sec. 9, D., if the furniture and furnishings on such balconies are not of restricted fire risk[7)8)].

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 an approved equivalent pressure water spraying system[7)] is to be provided for accommodation and service spaces. Corridors, stairways and escape routes within the accommodation spaces are subject to 3.1 above.

Spaces where there is no fire risk, 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.

4. Fire detection and alarm systems for machinery spaces

4.1 Machinery spaces of category A[9)] ships with Class Notation **OT** or **OT-S** 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 power, 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.

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 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 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 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.

[8)] This requirement applies to passenger ships with keel laying date on or after 1st July 2008. Passenger ships with keel laying date before 1st July 2008 shall comply with this requirement by the first survey after 1st July 2008

[9)] For definition see Rules for Hull (Pt.1, Vol.II) Sec. 22, E.4.6 [6] (applicable to all ships in the scope of this section) provided for upper and lower cargo hold spaces.

6. Design of fire detection and fire alarm systems

6.1 For the design and installation of fire detection and alarm systems, see Rules for Electrical Installations (Pt.1, Vol.IV) Sec. 9, D.3 and additionally C.6.2 and L.1 of this Section.

The requirement in the Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Sec.11 SC 271 is also to be applied.

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 (see Guidance for Code and Convention Interpretations (Pt.1, Vol.Y) Sec.11, SC.260).

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 air-flow 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.

D. Scope of Fire Extinguishing Equipment

1. General

1.1 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.

1.2 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 12.1. The design of this equipment is described in E to Q.

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 located 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.

1.3 Approval of fire extinguishing appliances and equipment Approvals of Administrations or Classification Societies are generally accepted for fire-fighting equipment and components such as fire extinguishers, fire hoses, foam concentrates, etc. unless BKI approved equipment is expressly required in the Rules of this Section.

2. Protection of the cargo area of tankers

2.1 The cargo areas and the cargo pump rooms of tankers are to be equipped with a fixed fire extinguishing system in accordance with Table 12.1.

2.2 Tankers equipped with a crude oil washing system and tankers of 20000 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 15. D.

3. Open top container cargo spaces

Fire extinguishing arrangements for open top container cargo spaces have to be agreed upon with BKI[10)].

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 Guidelines for the Use of Gas as Fuel for Ships (Pt.1, Vol.1).

10) See IMO MSC/Circ. 608/Rev.1 "Interim Guidelines for Open Top Containerships".

Table 12.1: Fixed Fire Extinguishing System

Spaces and areas to be protected	Type of vessel: Cargo ships ≥ 500 GT	Type of vessel: 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]	See [1]	for all ships
	CO_2, high expansion foam or pressure water spraying system [1,2]	
Machinery spaces containing internal combustion engine not for used propelling the ship	≥ 375 kW	≥ 375 kW
	CO_2, high expansion foam or pressure water spraying system [2]	
Machinery spaces containing steam engines	≥ 375 kW	≥ 375 kW
	CO_2, high expansion foam or pressure water spraying 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 (FWBLAFFS) [3]	
Fuel oil purifiers in acc. with B.2.	Fixed local fire extinguishing arrangement Low expansion foam-, pressure water spraying or 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 Sect. 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	
Accommodation, service spaces and control station, include corridor 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 [6]
Galley range exhaust ducks 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	—	Fixed water-based fire fighting system
Cargo Spaces: 2. For motor vehicles with fuel in their tanks	CO_2, high-expansion foam- or fixed water-based fire-fighting system	
Cargo Spaces: 3. For dangerous good	for all ships CO_2 fire-extinguishing system [4,5,8]	
Cargo Spaces: 4. On ro-ro ships a) closed	CO_2, high-expansion foam- or fixed water-based fire-fighting system	—
Cargo Spaces: 4. On ro-ro ships b) open or not capable of being sealed	Fixed water-based fire-fighting system	—
Cargo Spaces: 5. Cargo spaces not include in 1-4	≥ 2000 GT [6] CO_2, or inert gas system	≥ 1000 GT CO_2 or inert gas or high-expansion foam system

Table 12.1: Fixed Fire Extinguishing System *(continued)*

Spaces and areas to be protected	Type of vessel	
	Cargo ships ≥ 500 GT	Passenger ships
Cargo area and cargo tanks	Tankers acc. to D.2: Low-expansion foam system and inert gas system Chemical tankers acc. to Rules for Ships Carrying Dangerous Chemical in bulk (Pt.1, Vol.X) Section 11: Low-expansion foam, dry powder, pressure water spraying and inert gas system. Ships for the carriage of liquefied gases acc. To Rules for Ship Carrying Liquefied Gas in Bulk (Pt.1, Vol. IX), Section 11: Pressure water spraying, dry powder system [8] and inert gas systems.	—
Cargo pump spaces	Tanker and chemical tankers: CO_2, high expansion foam or water mist system [2]	—
Cargo pump and compressor rooms:	Ships for the carriage of liquefied gases: CO_2 system [2]	—

[1] Also applies to <500 GT in the case of ships with class notation **OT** and in the case of chemical tankers.
[2] Approved systems using gases other than CO_2 may be applied. Refer to 1.
[3] Applies to passenger ships of 500 GT and above and cargo ships of 2000 GT and above.
[4] Special category spaces are closed vehicle decks on passenger ships to which the passengers have access.
[5] Pressure water spraying system in ro-ro spaces (open or not capable of being sealed), in open top container cargo spaces (Refer to. D.3) and in special category spaces.
[6] May be dispensed with on request where only coal, ore, grain, unseasoned timber, non-combustible cargo or cargo representing a low fire risk are carried. Reference is made to MSC.1/Circ.1395/Rev.1.
[7] May be dispensed with, if the furniture and furnishing are only of restricted fire risk, see L.4.
[8] Details see J.3.
[9] For ships of less than 500 GT the requirement may be dispensed with subject to acceptance by the Administration.
[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/mm^2. Oil fuel transfer pumps are not considered as oil fuel units. (MSC.1/Circ.1203)

E. General Water Fire Extinguishing Equipment (Fire and Deck wash 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, and 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 On 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 12.2.

1.2.2 Where fire pumps with different capacities are installed, no pumps is to supply less than 80% of the total required capacity divided by the specified number of fire pumps.

1.2.3 Each fire pumps is to 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, as applicable, are also be complied with.

The capacity of a fire pump is not to be less than 25 m^3/h.

On cargo ships of less than 100 GT the fire pump is to 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 m^3/h on cargo ships.

1.2.5 For emergency fire pumps, see 1.4.

1.2.6 The pressure head of every fire pump is to be so chosen that the requirement of 2.3.4 is met. On cargo ships of less than 300 GT, instead of the pressure given in Table 12.3 every nozzle is under the conditions of 2.3.4 be capable of delivering a water jet of at least 12 m length horizontally.

Table 12.2: 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
Minimum capacity V (m^3/h) of one fire pump [1]					
[2] $5,1 \cdot 10^{-3} \cdot d^2_H$	$3,8 \cdot 10^{-3} \cdot d^2_H$	[2] $7,65 \cdot 10^{-3} \cdot d^2_H$	$5,75 \cdot 10^{-3} \cdot d^2_H$	$3,8.10^{-3} \cdot d^2_H$	

[1] d_H (mm) = theoretical diameter of the bilge main (see Section 11, M. formula 4.)

[2] Applicable to passenger ships with a criterion numeral of 30 or over in accordance with SOLAS 1974 as amended, Chapter II-1, Part B, Regulation 6.

1.3 Drive and arrangement of pumps

1.3.1 Each fire pump is to 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 be detached from the main engine (e.g. by means of a clutch coupling or reversing gear).

1.3.4 Fire pump and their power source may not be located forward of the collision bulkhead. In cargo ships, BKI may on request, permit exception to this requirement

On cargo ships of 2000 GT and over and on passenger ships, above 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 are to be of self-priming type or are to 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, suction from the de-iced seawater cooling system is to be provided for at least one of 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 fire-fighting 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 shut-off and a non-return device.

1.3.10 On passenger ships of 1000 GT and over, 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 less than 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 "**OT**", 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 shut-off valves from the sea water inlet to the fire main are to be capable of being controlled from the above-named positions. Alternatively, locally-operated valves may be used, these are to be permanently kept open and provided with appropriate sign, 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 has to 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.

1.4 Emergency fire pumps

1.4.1 The emergency fire pumps are to 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 m^3/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 m^3/h for cargo ships of less than 2000 GT.

The emergency fire pump is to be of self-priming type.

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 12.3; 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.

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 has to be sufficient for at least 18 hours 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 hours without refilling. This period may be reduced to 3 hours for cargo ships off less than 5000 GT.

1.4.5 The space where the emergency fire pump and its power source are installed is not to be directly adjacent to machinery spaces of category A[9)] or to the space where the main fire pumps are installed. Where this is not feasible, the division between the rooms is to be formed by not more than one bulk-head[11)]. Recesses have to be restricted to a minimum, and doors between the spaces are to be designed as air-locks. 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. See Rules for Hull (Pt.1, Vol.II) Sec. 22.

When a single access to the emergency fire pump room is through another space adjoining a machinery space of category A[9)] 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 the spaces containing the main fire pumps

[11)] The requirements in Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Sec.11 SC 245 should also be observed

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 ($NPSH_a$)[12)].

Upon installation on board, a performance test is to be carried out to verify the required capacity. As far as practicable, the test is to be conducted at lightest seagoing 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 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 according to Section 11. Table 11.22 b, Column B, but not less than 11 mm, all welded and be insulated equivalent to A-60 standard (see Guidance for Code and Convention Interpretations (Pt.1, Vol.Y) Sec.11, SC.245).

The sea suction may also be located in machinery spaces of category A if otherwise not practicable. In this case the suction piping is to be as short as possible and the valve is to 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 is to 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 11, I.1.4 and Section 11, 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 (see Guidance for Code and Convention Interpretations (Pt.1, Vol.Y) Sec.11, SC.163).

1.4.10 The ventilation system of the space in which the emergency fire pump is installed is to be so designed that smoke cannot 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 the case of a diesel as power source for the emergency fire pump, it is to be capable of being started by hand cracking 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.

If starting by hand-cracking is impracticable an alternative independent means of power starting is to be provided. This means is to 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 are to be as shown in Fig.12.1

[12)] Reference is made to the Guidance for Design, Construction and Testing of Pumps (Pt.1, Vol.V) and IMO MSC.1/Circ.1388, "Unified Interpretation of Chapter 12 of the International Code for Fire Safety Systems (FSS Code)".

It has to be possible to use the shore connection on either side of the ship.

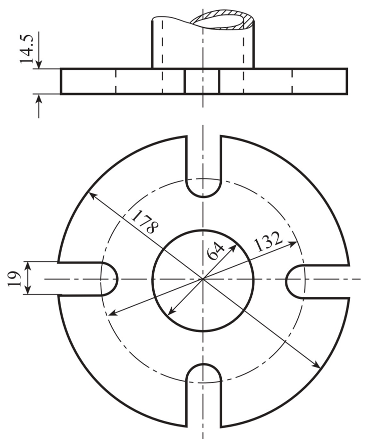


Figure 12.1: International shore connection

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 is to be possible by means of shut-off valves to isolate the sections of the fire main within category A machinery spaces[11)] where the main fire pumps are located from the rest of the fire main. The shut-off valves are to be located in a readily accessible position outside the category A machinery spaces.

With the shut-off valves closed, it is to 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[13)].

Alternatively, to the steel casing the piping may be thick-walled according to Section 11. Table 11.22 b, Column B, but not less than 11 mm, all welded and be insulated equivalent to A-60 standard.

2.2.2 On passenger ships of 4000 GT and over, the fire main must be constructed as a ring system equipped with appropriately sited isolating valves.

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 a location close to the main fire pumps or the open deck. The shut-off devices are to be fitted with warning signs instructing personnel to close them after use.

Alternatively, the fore mentioned 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 in a protected position at the poop front and on the tank deck at intervals of not more than 40 m[14)].

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.

[13)] The requirement in Guidance for Code and Convention Interpretation (Pt.1, Vol.Y), Sec.11, SC 121 should also be observed
[14)] Refer to IMO MSC.1/Circ.1456.

2.3 Fire main design

2.3.1 The following formula should be used as guidance for the sizing of the fire main:

$$d_F = 0{,}8 \cdot d_H$$

d_F = internal diameter of fire main

d_H = theoretical diameter of main. bilge pipe.in accordance with Section 11, M.2.

d_{Fmin} = 50 mm

For pipe thicknesses see Section 11, Table 11.5 (Seawater lines).

2.3.2 On passenger ships the diameter dF need not to exceed d_{Fmax} = 175 mm, on cargo ships d_{Fmax} = 130 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 the discharge pressure at the nozzles is to be less than the values shown in Table 12.3 when water is drawn simultaneously from any two adjacent hydrants. On liquefied gas tankers this requirement is to be met at a minimum pressure at the nozzles of 0,50 N/mm^2 (refer to Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol.IX) Sec. 11, 11.2.1).

Table 12.3: Pressure at nozzles

Type of vessels	GT	Pressure at nozzle [N/mm^2]
Cargo ships	< 6.000	0,25
	≥ 6.000	0,27
Passenger ships	< 4.000	0,30
	≥ 4.000	0,40

2.4 Hydrants

2.4.1 Hydrants are to be so positioned that water from two nozzles simultaneously, one of which is to 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 has to be possible to reach any part with water from two nozzles simultaneously, each from single length of hose.

In passenger ships any part of accommodation, service and machinery spaces are to be capable of being reached with water from at least two nozzles, one of which is to be from a single length of hose, when all watertight doors and all doors in main vertical zone bulkheads are closed.

2.4.2 Deck hydrants are to be arranged such that they remain accessible when carrying deck cargo. Hydrants are to be located near the accesses to spaces. In the case of cargo spaces for the transport of dangerous goods, the additional requirements of P and Q, as applicable, 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 E.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 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 part of the escape route (e.g. the shaft tunnel).

2.5 Fire hoses

2.5.1 Fire hoses are 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

- 15 m in machinery spaces
- 20 m in other spaces and open decks
- 25 m for open decks on ships with a maximum breadth in excess of 30 m

Every hose is to 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.

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 are to 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 ship's 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 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 P and Q, as applicable, are to be equipped with 3 additional hoses and nozzles.

2.6 Nozzles

2.6.1 Only dual-purpose spray and jet nozzles with a shut-off are to be provided.

2.6.2 The nozzle sizes are to be 12, 16 and 19 mm or as near thereto as possible.

In accommodation and service spaces, a nozzle size of 12 mm is sufficient.

For machinery spaces and exterior locations, the nozzle size is to be such as to obtain the maximum discharge possible from two nozzles at the stipulated pressure from the smallest available fire pump. However, a nozzle size greater than 19 mm need not be used.

F. Portable and Mobile Fire Extinguishers, Portable Foam Applicators and Water Fog Applicators

1. Extinguishing media and weights of charge, fire classes and spare charges

1.1 The extinguishing medium for fire extinguisher is to be suitable for the potential fire classes, see Table 12.4.

Table 12.4: 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 (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

Toxic extinguishing media and extinguishing media liable to generate toxic gases may not be used.

CO_2 fire extinguisher may not be located in accommodation areas and water fire extinguishers not in machinery spaces.

1.2 Fire extinguishers are to 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 proven.

1.3 The charge in portable dry powder and gas extinguishers shall be at least 5 kg and the con-tent of foam and water extinguishers is not to be less than 9 litres.

The total weight of a portable fire extinguisher ready for use is not exceeding 23 kg.

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 136 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 are to 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[15].

1.7.2 The nozzle/branch pipe and inductor have 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.

[15] Refer to IMO MSC.1/Circ.1312

2. Number and location

2.1 General

2.1 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.

2.2 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.

2.2 Portable fire extinguishers

The minimum number and distribution of portable fire extinguishers shall be selected according to Table 12.5 under consideration of the fire hazards in the respective space[16)]. The classes of portable fire extinguishers indicated in that table are given only for reference.

2.3 Mobile fire extinguisher, portable foam applicators and water fog application

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[9)] containing internal combustion machinery[17)]

The following is to be provided:

- a sufficient number of portable fire extinguishers or equivalent which are to be so located that no point in the space is more than 10 m walking distance from an extinguisher and that there are at least two such extinguishers in each such space. For smaller spaces of cargo ships the Administration may consider relaxing this requirement.n the space is more than 10 m walking distance from an extinguisher
- mobile fire extinguishers of 50 kg dry powder or 45 litres foam or equivalent, sufficient in number to enable foam or its equivalent to be directed onto any part of the fuel and lubricating oil pressure systems, gearing and other fire hazards.
- at least one portable air foam applicator unit complying with the provisions of the Fire Safety Systems Code

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.

[16)] Reference is made to IMO Res. A.951(23) “Improved Guidelines for Marine Portable Fire Extinguishers”.

[17)] Refer to Unified interpretation of SOLAS chapter II-2 on the number and arrangement of portable fire extinguishers on board ships (MSC.1/Circ.1275 and Corr.1).

Table 12.5: Minimum numbers and distribution of portable fire extinguishers in the various types of spaces

	Type of spaces	Minimum number of extinguisher	Class(es) of extinguisher(s)
Accommodation space	Public spaces	1 per 250 m of deck area or fraction thereof	A
	Corridors	Travel distance to extinguishers should not exceed 25 m within each deck and main vertical zone	A
	Stairways	0	
	Lavatories, cabins, offices, pantry containing no coking appliances	0	
	Hospital	1	A
Service spaces	Laundry, drying rooms, pantry 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, specie 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 12, M.1	
Control Stations	Control station (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

Table 12.5: Minimum numbers and distribution of portable fire extinguishers in the various types of spaces *(continued)*

	Type of spaces	Minimum number of extinguisher	Class(es) of extinguisher(s)
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
	Weather 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 12, O.1	B

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 is extinguisher 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 12, P.9. fire Two portable 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 for their 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

2.3.2 Machinery spaces of category A[9)] containing oil fired boilers or oil fuel units[1)]

At least is to be provided:

- There shall be at least two mobile 50 kg dry powder 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 mobile 135 litres foam extinguisher or equivalent in each boiler room. The extinguishers are to 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 by sub section 12.L.3, an approved foam-type extinguisher of at least 135 L capacity is not required.

- In each firing space there shall be a receptacle containing at least 0,1 m^3 sand or sawdust impregnated with soda or one additional portable extinguisher alternatively.

- There shall be in each boiler room or at an entrance outside of the boiler room at least one portable foam applicator unit complying with the provisions of the Fire Safety Systems Code.

For machinery space of category A containing combined of internal combustion machinery and oil fired boiler or oil fuel unit, see requirements in Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Section 9 SC-30.

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 into 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 12.1.

2.3.4 Machinery spaces of category A10 in passenger ships

In addition to the firefighting 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 not be equipped with mobile fire extinguisher and a portable foam applicator unit, unless a fixed fire extinguishing system is not provided in such spaces.

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 applicators is to be available.

G. High-Pressure CO_2 Fire Extinguishing Systems

1. Calculation of the necessary quantity of CO_2

The calculation of the necessary quantity of CO_2 is to be based on a gas volume of 0,56 m^3 per kg of CO_2.

If two or more individually floodable spaces are connected to the CO_2 system, the total CO_2 quantity available need not be more than the largest quantity required for one of these spaces.

Adjacent spaces with independent ventilation systems not separated by at least A-0 class divisions shall 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 or other oil-fired equipment, for purifier spaces according to B.2.1 and for cargo pump rooms is to be sufficient to give a minimum volume of free gas equal to the larger of the following:

— 40% of the gross volume of the largest machinery space so protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 40% or less of the horizontal area of the space concerned taken midway between the tank top and the lowest part of the casing; or
— 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 may be reduced to 35% and 30% respectively.

1.1.3 For cargo pump spaces on chemical tankers, and for compartment and cargo pump spaces on liquefied 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 according to 35% of the gross volume of the space.

1.1.5 Where two or more spaces containing boilers or internal combustion machinery are not entirely separated, they are to be considered as a single space for the purpose of determining the quantity of CO_2 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 CO_2 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 CO_2 for the cargo space is to be increased in accordance with one of the following formulae, as appropriate:

$$CO_{2\,30\%}^{INC} = 60 \cdot A_T \cdot \sqrt{\frac{B}{2}}$$

$$CO_{2\,45\%}^{INC} = 4 \cdot A_T \cdot \sqrt{\frac{B}{2}}$$

$CO_{2\,30\%}^{INC}$	=	Increase of CO_2 quantity for cargo spaces not intended for carriage of motor vehicles with fuel in their tanks for their tanks for their own propulsion [kg]
$CO_{2\,45\%}^{INC}$	=	Increase of CO_2 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 [m^2].
B	=	breadth of cargo space protected by the CO_2 system [m^2].

The non-weathertight gaps are not to 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 representing a low fire risk, application may be made to the national authorities for exemption from this requirement.

1.2.4 For the cargo spaces of ships intended for the transport of motor vehicles with filled fuel tanks and for closed ro-ro spaces, the available quantity of CO_2 is to 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 rooms be connected to the CO_2 fire extinguishing system.

1.2.6 Where cargo spaces connected to a CO_2 system are temporarily used as spaces for the transport of as cargo tanks, means are to be provided for sealing off the relevant connecting lines during such periods by the use of spectacle flanges.

1.3 Protection of space against over-/ underpressure

It is to be safeguarded that flooding of space with CO_2 cannot cause an unacceptable over or under pressure in the space concerned. If necessary, suitable means of pressure relief are to be provided.

2. CO_2 cylinders

2.1 Design and equipment

2.1.1 In respect of their material, manufacture, type and testing, CO_2 cylinders must comply with the requirements of Section 8, G.

2.1.2 CO_2 cylinders may normally only be filled with liquid CO_2 in a ratio of 2 kg CO_2 to every 3 litre of cylinder capacity. Subject to the shipping route concerned, special consideration may be given to a higher filling ratio (3 kg CO_2 to every 4 litres capacity).

2.1.3 Cylinder intended for flooding boiler rooms, machinery spaces as well as cargo pump and compressor rooms are to be equipped with quick-opening valve 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 CO_2 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 CO_2.

For the cargo spaces indicated in G.4.14 CO_2 cylinders with quick-opening valves suitable for group release are to be provided for flooding of these spaces within the times required in G.4.14.

2.1.4 Cylinder valves are to be approved by a recognized institution and be fitted with an overpressure relief device.

2.1.5 Siphons are to be securely connected to the cylinder valve.

2.2 Disposition

2.2.1 CO_2 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 manifold.

If hoses are used to connect the cylinders to the manifold, they are to be type approved.

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 CO_2 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 CO_2 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 CO_2 cylinders

3.1 Rooms for CO_2 cylinders may not be located forward of the collision bulkhead and are to, wherever possible, be situated on the open deck. Access is to be possible from the open deck. CO_2 cylinder rooms below the open deck are to have a stairway or ladder leading directly to the open deck. The CO_2 cylinder room is not to 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 are to 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 CO_2 in the cylinders, independent of the ambient temperatures. These means are to be so arranged that 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 are to be lockable. The doors of cylinder rooms are to open outwards.

Bulkheads and decks including doors another means of closing any opening therein which form the boundaries between CO_2 storage rooms and adjacent enclosed spaces are to be gas tight.

Cylinder rooms are to be exclusively used for installation of CO_2 cylinders and associated system components.

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 boundary of the cylinder room is to conform to the insulation valves prescribed for control stations (see Rules for Hull (Pt.1, Vol.II) Sec. 22).

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 CO_2 protected cargo hold(s) to reach the cylinder room, e.g. if the cylinder room is located forward of CO_2 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 spaces. The capability to release different quantities of CO_2 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 Rules for Materials (Pt.1, Vol.V).

4.2 The manifold from the cylinders 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 according to the requirements for pipe class I (see Section 11). 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 requirements regarding remarking are to be observed when processing the pipes.

4.3 Pipework 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 pipework is to be protected against external corrosion. Distribution lines serving spaces other than machinery spaces are to be galvanized internally.

4.5 Welded or flanged pipe connections are to be provided. 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 CO_2 protected spaces

4.6 Bends or suitable compensators are to be provided to accommodate the thermal expansion of the pipelines. Hoses for connecting the CO_2 cylinders to the manifold are to be type-approved and hose lines are to be fabricated by manufacturers approved by BKI, see Section 11.T.

4.7 Distribution piping for quick-flooding is to be designed in such that icing due to expansion of the extinguishing gas cannot occur. Reference values are shown in Table 12.6. System flow calculations shall be performed using a recognized calculation technique (e.g. NFPA calculation program).

Table 12.6: Design of quick flooding lines

Nominal Diameter DN		Weight of CO_2 for machinery and boiler spaces	Weight of CO_2 for cargo holds for motor vehicles
[mm]	[inches]	[kg]	[kg]
15	½	45	400
20	¾	100	800
25	1	135	1200
32	1 ¼	275	2500
40	1 ½	450	3700
50	2	1100	7200
65	2 ½	1500	11500
80	3	2000	20000
90	3 ½	3250	
100	4	4750	
110	4 ½	6810	
125	5	9500	
150	6	15250	

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 minimum pipe thicknesses are shown in Table 12.7.

4.9 A compressed air connection with a non-return valve and a shut-off valve is to be fitted at a suitable point. The compressed air connection is to 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 CO_2 pipes may pass through accommodation spaces providing that they are thick-walled according to Section 11, Table 11.6 Group D (for pipes with an outer diameter of less than 38 mm, the minimum wall thickness is to be 5,0 mm), joined only by welding and not fitted with drains or other openings within such spaces.

CO_2 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 are to be fitted with a pressure relief valve and the outlet of the valve is to be led to the open deck.

Table 12.7: Design of quick flooding lines

Da [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	4,0
82,5 – 88,9	5,6	4,0
101,6	6,3	4,0
108,0 – 114,3	7,2	4,5
127,0	8,0	4,5
133,0 – 139,7	8,0	5,0
152,4 – 168,3	8,8	5,6

4.12 CO_2 pipes also used as smoke sampling pipes are to be self-draining.

4.13 CO_2 pipes passing through ballast water tanks are to be joined only by welding and be thick-walled according to Section 11, Table 11.6 Group D (for pipes with an outer diameter of less than 38 mm, the minimum wall thickness is to be 5,0 mm).

4.14 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 2/3 of the required CO_2 can be discharged into the space within 10 min.

For solid bulk cargo spaces, the fixed piping system shall be such that at least 2/3 of the required gas can be discharged into the space within 20 min.

The system controls shall be arranged to allow 1/3, 2/3 or the entire quantity of CO_2 to be discharged based on the loading condition of the hold.

5. Release devices

5.1 Release of the system is to be actuated manually. Automatic actuation is not acceptable.

5.2 Release of the CO_2 cylinders, whether individually or in groups, and opening of the distribution valve are to be actuated independently of each other. For spaces, for which CO_2 cylinders with quick-opening valves for group release are required (refer to G.2.1.3), two separate controls are to be provided for releasing CO_2 into the protected space. One control is to be used for opening the distribution valve of the piping which conveys CO_2 into the protected space and a second control is to be used to discharge CO_2 from its storage cylinders. Positive means are to be provided so that these controls can only be operated in that order[18)].

5.3 Remotely operated cylinder actuating devices and distribution valves are to be capable of local manual operation.

5.4 The controls for flooding of machinery spaces, closed ro-ro spaces, cargo spaces for the transport of reefer containers, paint lockers and the like and of cargo pump and compressor spaces are to be readily accessible, simple to operate and be located 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 release controls for reefer container cargo holds are to be arranged in an easily accessible location within the accommodation area, e.g. in the fire control station.

[18)] Reference is made to IACS Unified Interpretation SC 252 and MSC.1/Circ.1487.

5.5 The emergency release from the CO_2 room has to ensure the group release of the CO_2 cylinders for spaces requiring quick-flooding release (see G.2.1.3).

Small spaces located in close vicinity of the CO_2 room, e.g. paint store, may be flooded from the CO_2 room, in which case a separate release box may be dispensed with.

5.6 The key for the release box is to be kept in a clearly visible position next to the release box in a locked case with a glass panel.

5.7 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 small space (e.g. galley range exhaust duct) requires only one cylinder with a maximum content of 6 kg CO_2, an additional shut-off downstream of the cylinder valve may be omitted.

5.8 Distribution valves are to be protected against unauthorized and unintentional actuation and fitted with signs indicating the space to which the associated CO_2 lines lead.

5.9 Distribution valves are to be made of a seawater-resistant material. The valve position 'open' or 'closed' is to be visible.

6. CO_2 discharge nozzles

6.1 The number and arrangement of the nozzles provided is to ensure even distribution of the CO_2. The discharge nozzles shall be made of steel or equivalent material.

6.2 Boiler rooms and machinery spaces

The nozzles are to be arranged preferably in the lower part of the machinery space and in the bilges, taking into account the room configuration. At least eight nozzles are to be provided, not less than two of which are to be located in the bilges.

Nozzles are to 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 CO_2 system is connected with a sample extraction smoke detection system, 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 Rules for Electrical Installations (Pt.1, Vol.IV) Sec. 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 is to be provided which are to be independent of the discharge CO_2. The audible warning is to 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.

The pre-discharge alarms are to be automatically actuated a suitable time before flooding occurs. As adequate is to be considered the period of time necessary to evacuate the space to be flooded but not less than 20 seconds. The system is to be designed such that flooding is not possible before this period of time has elapsed.

The automatic actuation of the CO_2 alarm in the protected space may be realized by e.g., opening the door of the release station.

The alarm has to 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 systems, any danger to persons is to 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 ro-ro cargo spaces, spaces for the transport of reefer containers and other spaces where personnel can be expected to enter and where the access is therefore facilitated by doors or man way hatches.

In conventional cargo spaces audible/visual alarms are not required.

In small spaces, e.g. paint stores, the alarms may be dispensed with if the CO_2 system can be released either from a place next to the access door outside of this space or from the CO_2 room provided this room is located in close vicinity to the protected space.

7.4 The power supply to electrical alarm systems has to be guaranteed in the event of failure of the ship's 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: Rules for Electrical Installations (Pt.1, Vol.IV) Sec. 15.

8. General arrangement plan

In the wheelhouse and in the CO_2 rooms arrangement plans are to be displayed showing the disposition of the entire CO_2 system. The plan shall 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 CO_2 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 shut off and the space has been sealed."

9.1.2 At the distribution stations and in the CO_2 room:

"Before flooding with CO_2 shut off ventilation and close air intakes. Open distribution valves first, then the cylinder valves!"

9.1.3 In the CO_2 room and at entrances to spaces which can be flooded:

"WARNING!"

"In case of alarm or release of CO_2 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 CO_2 cylinder room:

"This space is to be used only for the storage of CO_2 cylinders for the fire extinguishing system. The temperature of the space is to be monitored."

9.1.5 At the release station for the CO_2 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 subjected to hydraulic pressure test in the presence of a BKI Surveyor 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 have to 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 BKI 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.

10.4 A functional test of the alarm equipment is to be carried out

H. Low-Pressure CO_2 Fire-Extinguishing Systems

1. Calculation of the necessary quantity of CO_2

Calculation of the necessary quantity of CO_2 is subject to the provisions set out in G.1.

2. CO_2 containers

2.1 Design and construction

2.1.1 The rated CO_2 supply is to be stored in pressure vessels at a pressure of 18 to 22 bar.

2.1.2 With regard to their material, manufacture, construction, equipment and testing, the containers must comply with the requirements contained in Section 8.

2.1.3 The containers may be filled with liquid CO_2 up to a maximum of 95% of their volumetric capacity calculated at 18 bar.

The vapor space has to 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 signalling 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, one of which has to provide permanent monitoring of the liquid level. A liquid level of 10% or more below the set level is to trip a visual/audible alarm.

Where more than one space is protected by the CO_2 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 CO_2 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 shut-off valves on the inlet side. The shut-off valves are to 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 is to be at least 10% above the cut-in pressure of the refrigerating units.

The capacity of each relief valve is to be so 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 Rules for Ships Carrying Liquefied Gases in Bulk (Pt. 1, Vol.IX) Sec. 8.

The blow-off line is to discharge into the open air.

2.2.4 Insulation

Containers and piping which are normally filled with CO_2 are to be insulated in such that after failure of the refrigeration, when setting pressure of the of the relief valves is not reached before a period of 24 hours, assuming a container pressure equal to the cut-in pressure of the refrigerating units and ambient temperature of 45 °C.

The insulating material has to be at least not readily ignitable and be sufficiently robust. Protection against steam penetration and damage from outside is to be provided. See also Rules for Refrigerating Installations (Pt. 1, Vol.VIII) Sec. 1, L.

3. Refrigerating plant

3.1 At least two complete, mutually independent, automatically refrigerating sets are to be provided. The capacity of the refrigerating sets is to be such that the required CO_2 temperature can be maintained under conditions of continues operation during 24 hours with an ambient temperature of up to 45 °C and a seawater temperature of up to 32 °C.

3.2 The failure of a refrigerating unit is to cause the standby unit to start up automatically. Manual switch over has to be possible.

3.3 Separate electrical supply is to be provided from the main busbar

3.4 At least two circulating pumps are to 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 systems.

3.5 The supply of cooling water has to be available from two sea chests, wherever possible from either side of the ship.

4. Location and disposition

CO_2 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 are to be located in the same room where the pressure vessels are stored.

5. Piping, valves and fittings

Unless otherwise specified in 5.1 to 5.3, the requirements in G.4., G5.and G 6. Apply analogously together with Section 11, 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 CO_2 does not occur until it leaves the nozzles.

The piping system is to be designed in such a way that the CO_2 pressure at the nozzles should not be less than 1 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 CO_2 fire extinguishing system”.

7. Release

7.1 The automatic release of CO_2 flooding is not permitted.

7.2 If devices are fitted for automatically gauging the rated quantity of CO_2, provision is also to be made for manual control.

G.5.2 also applies.

7.3 If the system serves more than one space, means for control of discharge quantities of CO_2 are to 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 CO_2 cylinder room and to the valve groups for the flooding of individual spaces with CO_2:

- name of space and gross volume [m^3]
- necessary volume of CO_2
- number of nozzles for the space
- flooding time [min] (i.e. the time the flooding valves have to 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 a pressure of 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 and G.10.3 apply wherever relevant.

I. Gas Fire-Extinguishing Systems using Gases other than CO_2 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 CO_2 are subject to special approval by BKI.

1.2 System using extinguishing gases other than CO_2 are to be approved in accordance with a standard acceptable to BKI[19)].

1.3 The systems 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.

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[20)] 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 clean agents, the system is to be designed for a discharge of 95% of the design concentration in not more than 10 seconds.

For systems using inert gases, the discharge time is to not exceed 120 seconds for 85% of the design concentration.

1.5 For cargo pump rooms where flammable liquids other than oil or petroleum products are handled, the system may be used only if the design concentration for the individual cargo has been established in accordance with the approval standard[23)] and is documented in the approval certificate.

2. Calculation of the supply of extinguishing gas

2.1 The supply of extinguishing gas is to 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.

[19)] 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.1/Circ.1267. Type approvals already conducted in accordance with guidelines contained in MSC/Circ.848 remain valid until 1 July 2012.

[20)] Refer to document IMO FP 44/INF.2 – "Physiologically based pharmacokinetic model to establish safe exposure criteria for halocarbon fire extinguishing agents."

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 are to be subtracted from the gross volume. This includes, but is not necessarily limited to:

— internal combustion engines

— reduction gear

— boilers

— heat exchangers

— tanks and piping trunks

— exhaust gas pipes, boilers and silencers

2.3 The volume of free air contained in air receivers located in a protected space is to 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 are to comply in respect of their material, construction, manufacture and testing with the relevant BKI Rules on pressure vessels.

3.2 The filling ratio is not to 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 are to 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.

4. Storage of containers

4.1 Centralized systems

Gas containers in centralized systems are to be stored in a storage space complying with the requirements for CO_2 storage spaces (see 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 requirements may be executed as modular systems with gas containers, and containers with the propellant if any, permitted to be stored within the protected space providing the conditions of 4.2.2 through 4.2.9 are complied with.

4.2.2 Inside a protected space, the gas containers are to 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 are to 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 has to 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 is to 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 are to be designed with bottle(s) located outside the protected space, in a dedicated room complying with the requirements for CO_2 storage spaces (see G.3).

4.2.3 Duplicate sources of power located outside the protected space are to 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 are to be monitored for fault conditions and loss of power. Visual and audible alarms are to be provided to indicate this.

4.2.5 Pneumatic, electric or hydraulic power circuits connecting the containers are to be duplicated. The sources of pneumatic or hydraulic pressure are to be monitored for loss of pressure. Visual and audible alarms are to be provided to indicate this.

4.2.6 Within the protected space, electrical circuits essential for the release of the system are to be heat-resistant according to IEC 60331 or other equivalent standard, e.g. mineral-insulated cable or equivalent.

Piping systems essential for the release of systems designed to be operated hydraulically or pneumatically are to be of steel or other equivalent heat resistant material.

4.2.7 Not more than two discharge nozzles are to be fitted to any container.

4.2.8 The containers are to be monitored for decrease in pressure due to leakage or discharge. Visual and audible alarms in the protected space and on the navigating bridge are to be provided to indicate this.

4.2.9 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 (Rules for Material (Pt.1, Vol.V) Sec. 7) and to be designed according to the working pressure of the system.

5.2 Welded or flanged pipe connections are to be provided. 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 is to be made of stainless steel or be galvanized.

5.4 Flexible hoses may be used for the connections of containers to a manifold in centralized systems or to a rigid discharge pipe in modular systems. Hoses are not to 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 are to be installed. The arrangement of nozzles is to 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 are to be arranged such as to avoid personnel being endangered by the discharging gas.

5.6 The piping system is to be designed to meet the requirements stipulated in 1.4. System flow calculations are to be performed using a recognized calculation technique (e.g. NFPA calculation program).

5.7 In piping sections where valve arrangement introduces sections of closed piping (manifolds with distribution valves), such sections are to be fitted with a pressure relief valve and the outlet of the valve is to be led to the open deck.

6. Release arrangements and alarms

6.1 The systems 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 are to be arranged near to the entrance of the protected space and are to be readily accessible also in case of a fire in the related space. Release stations are to be marked with the name of the space they are serving.

6.2 Centralized systems are to be provided with additional means of releasing the system from the storage space.

6.3 If the protected space is provided with a system containing a halocarbon clean agent as fire extinguishing agent, the mechanical ventilation of the protected space is to be stopped automatically before the discharge of the extinguishing gas.

6.4 Audible and visual alarms are to be provided in the protected space and additional visual alarms at each access to the space.

6.5 The alarm is to be actuated automatically by opening of the release station door. For installations with a design concentration in excess of the NOAEL (see 1.3), 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 seconds.

6.6 Audible alarms are to be of horn or siren sound. They are to 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.

6.7 Electrical alarm systems are to have power supply from the main and emergency source of power.

6.8 For the use of electrical alarm systems in gas dangerous zones refer to the relevant Section of the Rules for Electrical Installations (Pt.1, Vol.IV).

6.9 Where pneumatically operated alarms are used the permanent supply of compressed air is to be safeguard 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 is to be given to 7.2 through 7.4.

7.2 A minimum agent holding time of 15 min is to 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 are not to 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 Hydrogen Chloride (HCl) below 5 ppm at that location. The concentrations of other products are to be kept below values considered hazardous for the required durations 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 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 additional warning 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 instruction is to be provided on the ship. The manual is to 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 BKI 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

Prior to commencing of the installation, the following documents are to be submitted in electrical format [1] to BKI Head Office 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 (centralized 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 maximum 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 maximum 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 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 BKI[21)].

2. Aerosol fire extinguishing systems

Systems using an aerosol as fire extinguishing medium are to be type approved by BKI in accordance with an international standard[22)].

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 BKI in accordance with an international standard[23)].

K. Foam Fire Extinguishing Systems

1. Foam concentrates

1.1 Only approved[24)] foam concentrates may be used.

1.2 Distinction is made between low- and high expansion foam.

In the case of low-expansion foam, produced by adding 3 - 6% foam concentrated, the foam expansion ratio (i.e. the ratio of the volume of foam produced to the mixture of water and foam concentrate supplied) is not to 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 BKI.

Foam concentrates intended for use in the cargo area of chemical tankers are to be alcohol-resistant if this is required by the List of Products, Rules for Ships Carrying Dangerous Chemical in Bulk (Pt.1, Vol.X), Sec. 17 and Sec. 11, 11.3.

Tankers for the carriage of alcohols and other flammable polar liquids are to 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 for Ships Carrying Dangerous Chemical in Bulk (Pt.1, Vol.X), Sec. 17 and Sec. 11, 11.3.

2.2 Deck foam systems on tankers carrying:

- 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

21) See FSS Code, Chapter 5, 2.3

22) Refer to IMO MSC.1/Circ.1270, "Revised Guidelines for the Approval of Fixed Aerosol Fire-Extinguishing Systems Equivalentto Fixed Gas Fire-Extinguishing Systems, as Referred to in SOLAS 74, for Machinery Spaces."

23) 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".

24) See IMO MSC.1/Circ.1312 and MSC/Circ.670. Approval certificates issued in accordance with MSC/Circ.582 and MSC/Circ.799 remain valid until 1 July 2012.

— 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).

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 BKI type approved[25)].

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[26)].

4. Low-expansion foam systems for boiler rooms and machinery spaces

Low-expansion foam systems do not substitute the fire extinguishing systems prescribed in Table 12.1

4.1 Capacity of the system

The system is to be so designed that the largest area over which fuel can spread can be covered within five minutes with a 150 mm thick blanket of foam.

4.2 Foam distribution

4.2.1 The foam solution is to be conveyed through fixed pipelines 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)[27)]

1.1 Pressure water tanks

1.1.1 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 shut off and is protected against damage, and with a pressure gauge. The requirements specified in Section 8 are also applicable.

[25)] Reference is made to IMO circular MSC.1/Circ.1384, “Guidelines for the Testing and Approval of Fixed High-Expansion Foam Systems”, which supersedes circular MSC.1/Circ.1271, except that the evidences from fire and component tests previously provided in accordance with MSC.1/Circ.1271 remain valid for the approval of new systems.

[26)] Refer to Res. MSC.327(90) and (see Guidance for Code and Convention Interpretations (Pt.1, Vol.Y) Sec.11, SC.262).

[27)] Pressure water spraying systems deviating from these requirements may be used if approved as equivalent by BKI. See IMO Resolution A.800(19), "Revised Guidelines for Approval of Sprinkler Systems Equivalent to that Referred to in SOLAS Regulation II-2/12 ", as amended by Res. MSC.265 (84). Existing type approvals issued to confirm compliance with Res. A.800(19) remain valid until 1 July 2015.

1.1.2 The volume of the pressure water tank is to be equivalent to at least twice the specified pump capacity per minute.

The tank is to 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.

1.1.3 Means are to be provided for replenishing the air cushion in the pressure water tank.

Note:

Instead of a pressure tank, approved water mist system [31)] may be provided with an equivalent bottle battery consisting of water and gas cylinders.

1.2 Pressure water spraying pump

1.2.1 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 is to start up automatically before the fresh water charge in the pressure water tank has been exhausted. Suitable means of testing are to be provided.

1.2.2 The capacity of the pump is to be sufficient to cover an area of at least 280 m^2 at the pressure required for the spray nozzles. At a rate of application of at least 5 litre/m^2 and per minute, this is equivalent to a minimum delivery rate of 1400 litre/min.

Note:

The minimum flow rate of 5 litre/m^2/min is not applicable to approved water mist system[31)]

1.2.3 The pump is to be equipped with a direct sea suction. The shut-off 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.

1.3 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 non-freezing space.

1.4 Water supply

1.4.1 The system is to be completely charged with fresh water when not in operation.

In addition to the water supply as per 1.2 the system is also to be connected to the fire main via a screw-down non-return valve.

1.4.2 The system is to be kept permanently under pressure and is to 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 still is to be at least 1,75 bar.

1.4.3 Control stations, where water may cause damage to essential equipment, may be fitted with a dry pipe system or pre-action system[28)].

[28)] See definitions for “dry pipe system“ and “preaction system“, as indicated in IMO Res. A.800(19).

1.5 Power supply

At least two mutually independent power sources are to be provided for supplying the pump and the automatic indicating and alarm systems. Each source is to be sufficient to power the system (Rules for Electrical Installations (Pt.1, Vol.IV) Sec. 7)

1.6 Piping, valves and fittings

1.6.1 Lines between sea chest, pump, water tank, shore connection and alarm valve are to comply with the dimensional requirements set out in Section 11, Table 11.5. Lines are to be effectively protected against corrosion.

1.6.2 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.

1.6.3 Each sprinkler section is to be capable of being isolated by one section valve only. The section valves are to be arranged readily accessible outside 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 unauthorized persons.

Any stop valves in the system from the sea water inlet up to the section valves are to be secured in operating position.

1.6.4 A test valve is to be arranged downstream of each section valve. The flow of the test valve is to correspond to the smallest sprinkler in the pertinent section.

1.6.5 Small sections where the possibility of freezing exists during operation of the ship in cold climates may be of the dry type[29)].

Saunas are to be fitted with a dry pipe system.

1.7 Sprinklers

1.7.1 The sprinklers are to be grouped into sections. Each section may not comprise more than 200 sprinklers.

1.7.2 On passengers ships, a sprinkler section may extend only over one main vertical zone or one watertight compartment and may not include more than two vertically adjacent decks.

1.7.3 The sprinklers are to be so arranged in the upper deck area that a water volume of not less than 5 litre/m^2 and per minute is sprayed over the area to be protected.

> ***Note:***
>
> *The minimum flow rate of 5 litre/m^2/min is not applicable to approved water mist system*[31)]

Inside accommodation and service spaces the sprinklers are to 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

1.7.4 The sprinklers are to be made of corrosion resistant material. Sprinklers of galvanized steel are not allowed.

[29)] Definition of “dry pipe system” see IMO Res. A.800(19), Annex, paragraph 2.3

1.7.5 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

1.8 Indicating and alarm systems

1.8.1 Each sprinkler section is to 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 is to be indicated. The indicating panels are to be centralized on the navigation bridge. In addition to this, visible and audible alarms from the indicating panels are to be located in a position other than on the navigation bridge, so as to ensure that an alarm is immediately received by the crew.

Designs of alarm systems see Rules for Electrical Installations (Pt.1, Vol.IV) Sec. 9.

1.8.2 A gauge indicating the pressure in the system is to be provided at each section valve according to 1.6.3 as well as at the centralized indication panel(s) on the navigating bridge.

1.9 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 have to 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 approved by BKI on the basis of an internationally recognized standard[30)].

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 BKI on the basis of an internationally recognized standard[34)].

The requirement in Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Section 11.SC 218 and Section 11.SC 219 should also be observed.

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 litre/min per m^2 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 purposes may be incorporated into the water spraying system.

2.2.3 The nozzles may be installed below the heated surfaces instead. A prerequisite for his 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 heated surfaces.

[30)] Refer to IMO circular 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 WaterMist Fire-Extinguishing Systems". Reference is made to the Unified Interpretation stated in MSC.1/Circ.1458.

2.2.4 The piping system for water supply and distribution is to 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 shut-off 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 Fixed water-based fire-fighting systems for vehicle spaces, special category spaces 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[31)].

Water spray systems shall be designed acc. to sections 3 and 4 of MSC.1/Circ.1430. The water spray nozzles shall be approved as per item 3.11 of these guidelines.

Water mist systems shall be BKI type approved and be designed acc. to sections 3 and 5 of MSC.1/Circ.1430.

2.3.2 A pressure gauge is to be provided on the valve manifold.

Each distribution valve has to be clearly marked as to the section served.

Instructions for maintenance and operation are to be displayed in the valve (drencher control) room.

2.3.3 In case of manually activated systems, the water supply pump is to be capable of being started from the distribution valve group. All the shutoff valves located between the seawater inlet and the distribution valves are to be capable of being opened from the distribution valve group, unless they are secured in the open position.

2.3.4 Drainage and pumping arrangements are to be designed in compliance with Section 11.M.4.3.5 and M.4.4, as applicable.

The system has to be fitted with a sufficient number of drainage valves.

2.4 Pressure water spraying systems for the cargo area of tankers

These are subject to the Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol.IX) Sec. 11.3.

3. Fixed local application fire-fighting systems [32)]

3.1 The following is to be applied to category A machinery spaces[10)] above 500 m^3 in gross volume of passenger ships of 500 GT and above and cargo ships of 2000 GT and above.

[31)] Refer to IMO circular MSC.1/Circ.1430 “Revised Guidelines for the Design and Approval of Fixed Water-Based Fire-Fighting Systems for Ro-Ro Spaces and Special Category Spaces”, which supersedes circular MSC.1/Circ.1272, except that the evidences from fire and component tests previously provided in accordance with MSC.1/Circ.1272 remain valid for the approval of new systems.

[32)] These requirements apply to ships with keel laying date on or after 1 July 2002

3.2 In addition to the main fire extinguishing system, fire hazard areas as listed in 3.3 are to be protected by fixed local application fire-fighting systems, which are to be type approved by BKI in accordance with international regulations[33)].

On ships with Class Notation **OT** or **OT-S** these systems are to have both automatic and manual release capabilities.

In case of continuously manned machinery spaces, these systems are only required to have manual release capability.

3.3 The fixed local application fire-fighting systems are to protect areas such as the following without the need for engine shut-down, personnel evacuation, or sealing of the spaces:

— fire hazard portions of internal combustion machinery used for the ship's main propulsion and power generation and other purposes

— oil fired equipment, such as incinerators, boilers, inert gas generators and thermal oil heaters

— 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 manifolds 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 is to be located outside the protected areas. The system shall be available for immediate use and capable of continuously supplying the extinguishing medium for at least 20 minutes. The capacity of the pump is to 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 Rules for Electrical Installations (Pt.1, Vol.IV) Sec. 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 is to reflect the arrangement successfully tested in accordance with MSC/Circ. 913or MSC.1/Circ.1387, respectively.

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.

[33)]Existing fixed water-based local application fire-fighting systems approved and installed based on MSC/Circ.913 should be permitted to remain in service as long as they are serviceable. The requirement in the Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Section 11.SC217 should also be observed

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.

Where the clear distance between neighbouring engines is less than two-meter, simultaneous operation of two adjacent sections has to be ensured and any stored extinguishing medium has to be sufficient for their simultaneous coverage.

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 manoeuvrability 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 are to be located at easily accessible positions inside and outside the protected space. The controls inside the space are not to 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 is to 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 are to be provided as recommended by the manufacturer. The operating instructions are to be displayed at each operating station.

3.13 Nozzles and piping are not to prevent access to engines or other machinery for routine maintenance. In machinery spaces fitted with overhead hoists or other moving equipment, nozzles and piping are not to 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 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 ½ 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 ½ 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 exceed½ 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 high expansion 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.

3.16 The requirement in the Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Section 11.SC198 should also be observed.

4. Pressure water-spraying system for cabin balconies of passenger ship

4.1 The cabin balconies of passenger ships are to be provided with an approved pressure water spraying system[34] if the furniture and furnishings on such balconies are not of restricted fire risk [8)9)].

5. Combined water mist systems for multi-area 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 BKI type approved [27) 30) 31) 33) 34) 35)].

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 CO_2, dry powder, water or an equivalent extinguishing medium and capable of being operated from outside the room is to be provided.

1.1.1 If CO_2 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/m^3 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 litre/m^2/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 m^2, which do not give access to accommodation spaces, portable CO_2 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 bestow 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 are to 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 after clarification with BKI.

[34] 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”.

3. Deep-fat cooking equipment[36)]

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 BKI[35)].
- 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
- control 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 12.8.

2. On passenger ships the sprinklers are to be supplied from the sprinkler system of the ship.

3. On cargo ships the sprinkler system may be connected to the fresh water hydrophore system, provided the hydrophore pump is capable of meeting the demand of the required number of sprinklers

Table 12.8: Required fire safety systems

Spaces	Automatic pressure water spraying system (sprinkler), see 2. and 3.	Fixed fire extinguishing system (CO_2, high expansion foam, pressure water spraying or equivalent)	Fixed fire detection
Combined incinerator and waste storage space		X	X
Incinerator space		X	X
Waste storage space	X		

O. Fire Extinguishing Equipment for Helicopter Landing Decks

1. In terms of the associated fire risk and the scope of required firefighting equipment, distinction is made between:

- helidecks (purpose-built helicopter landing platforms for routine helicopter operations). For further helideck requirements, see Guidance for the Class Notation Helicopter Deck and Facilities (HELIL & HELIL (SRF)) (Pt.7, Vol.A).
- helicopter landing areas (on-deck areas designated for occasional or emergency landing of helicopters)

[35)] Re ISO 15371"Ships and marine technology - Fire-extinguishing systems for protection of galley cooking equipment", ISO 15371:2000 "Fire-extinguishing systems for protection of galley deep-fat cooking equipment – fire tests" may be used.

2. In close proximity to the helideck or helicopter landing area, following fire-fighting appliances and accessories are to be provided and stored near the means of its access:

— at least two dry powder extinguishers having a total capacity of not less than 45 kg

— CO_2 extinguishers of a total capacity of not less than 18 kg or equivalent

— at least two nozzles of dual-purpose type and hoses sufficient to reach any part of the helideck;

— two fireman's outfits in addition to those required by SOLAS 74 or national regulations,

— at least the following equipment, stored in a manner that provides for immediate use and protection from the elements:

  — adjustable wrench
  — blanket, fire resistant
  — hook, grab or salving
  — hacksaw, heavy duty completes with 6 spare blades
  — ladder
  — life line 5 mm diameter x 15 m in length
  — pliers, side cutting
  — set of assorted screwdrivers
  — harness knife completes with sheath
  — cutters bolt 600 mm

3. In addition to the equipment indicated in 2, helidecks are to be provided with fixed fire-fighting arrangements consisting of at least:

— two foam monitors of equal size or deck integrated foam nozzles

— two hose reel foam stations

The minimum foam solution discharge rate shall be determined by multiplying the required coverage area by 6 litre/m^2/min. The min. capacity of each monitor shall be 500 litre/min, the minimum capacity of each hose reel shall be 400 litre/min.

The foam concentrate shall be of approved type[36)] and be sufficient in quantity to allow operation of all connected foam discharge devices for at least 5 min.

Manual release stations at each monitor and hose reel are to be provided. In addition, a central release station shall be arranged at a protected location.

Note:

Above requirements only cover the main particulars. The details of the equipment to be provided are governed by MSC.1/Circ.1431, the guidelines of which are to be observed.

4. In addition to the equipment indicated in 2, helicopter landing areas are to be provided with at least two portable foam applicators or two hose reel foam stations, each capable of delivering a minimum foam solution discharge rate in accordance with Table 12.9.

The foam concentrate shall be of approved type38 and be sufficient in quantity to allow operation of all connected foam discharge devices for at least 10 min.

36) The foam concentrate is to be certified acc. to "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, Level "B" foam" or acc. to the Revised Guidelines for the performance and testing criteria and surveys of foam concentrates for fixed fire-extinguishing systems (MSC.1/Circ.1312).

Table 12.9: Required foam quantity

Category	Helicopter overall length	Discharge rate foam solution [liter/min]
H1	< 15 m	250
H2	> 15 m ... < 24 m	500
H3	> 24 m ... < 35 m	800

Note:

Above requirements only cover the main particulars. The details of the equipment to be provided are governed by MSC.1/Circ.1431, the guidelines of which are to be observed.

5. Drainage facilities in way of helidecks or helicopter landing areas are to 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. Equipment for the Transport of Dangerous Goods

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 12.10a for conventional cargo spaces
— Table 12.10b for container cargo spaces
— Table 12.10c for closed ro-ro spaces
— Table 12.10d for open ro-ro spaces
— Table 12.10e for shipborne barges
— Table 12.10f 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.

1.1.4 The requirements for open top container cargo spaces are to be agreed upon with BKI.

1.2 Documents to be submitted

Diagrammatic plans, drawings and documents covering the following are to be submitted to BKI.

— 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 VI, Part A, "General provisions"

1.3.3 SOLAS, Chapter VII, Part A, "Carriage of dangerous goods in packaged form"

1.3.4 IMO International Maritime Dangerous Goods (IMDG) Code

1.3.5 Medical First Aid Guide for Use in Accidents Involving Dangerous Goods (MFAG)

1.3.6 IMO MSC/Circ.608/Rev.1, "Interim Guidelines for Open Top Containerships"

1.3.7 Guidance for Code and Convention Interpretations (Pt.1, Vol.Y) Sec.11 SC109, SC110, and SC111, "Open top container holds – Water supplies – Ventilation – Bilge pumping"

1.3.8 IEC 60079, "Electrical apparatus for explosive atmospheres"

1.4 Certification

On request the "Document of Compliance for the Carriage of Dangerous goods" according to SOLAS, Chapter II-2, Regulation 19.4 may be issued after successful survey. These vessels will be assigned the Notation DG.

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 closed up test.

Class 3 23 °C ≤ FP ≤ 60 °C :

Flammable liquids having a flashpoint between 23 °C and 60 °C closed up test.

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 close-cup test.

Class 6.1 liquids 23 °C ≤ FP ≤ 60 °C :

Toxic liquids having a flashpoint between 23 °C and 60 °C close-cup test.

Class 6.1 liquids FP > 60 °C :

Toxic liquids having a flashpoint above 60 °C closed-cup test.

Class 6.1 solids :

Toxic solids.

Class 8 liquids FP < 23 °C :

Corrosive liquids having a flashpoint below 23 °C closed-cup test.

Class 8 liquids 23 °C ≤ FP ≤ 60 °C :

Corrosive liquids having a flashpoint between 23 °C and 60 °C closed-cup test.

Class 8 liquids FP > 60 °C :

Corrosive liquids having a flashpoint above 60 °C closed-cup test.

Class 8 solids :

Corrosive solids.

Class 9 goods evolving flammable vapour exclusively :

Miscellaneous dangerous substances and articles and environmentally hazardous substances evolving flammable vapour.

Class 9 other than evolving flammable vapour :

Miscellaneous dangerous substances and articles and environmentally hazardous substances 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. Fixed fire extinguishing system

2.1 Fixed gas fire extinguishing system

All cargo holds are to be equipped with a fixed CO_2 fire-extinguishing system complying with the requirements of G or H.

2.2 Fixed pressure water-spaying 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 CO_2 fire-extinguishing system.

Drainage and pumping arrangements are to be designed in compliance with Section 11, M.4.3.5 and M.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.

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 2.3).

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.

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/m^2 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 volume of 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 also 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 is to 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 the side shell 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. Source of Ignition

The degree of explosion protection for the individual classes is specified in column "Sources of ignition" of Tables 12.10a to 12.10f 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 12.10a to 12.10f.

4.1.2 For the design of the electrical equipment and classification of the dangerous areas, Rules for Electrical (Pt.1, Vol.IV), Sec. 17.

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 15, 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 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 **Class 1** goods the adjacent cargo spaces, with the exception of open ro-ro spaces, are also to be monitored 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 Guidance for Ventilation System on Board Seagoing Ships (Pt.1, Vol.A).

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.

The requirements in the Guidance for Code and Convention Interpretations (Pt.1, Vol.Y) Section 11, SC-288 shall also 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 system 36 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 number ..... .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 m^3/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 m^3/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 Rules for Electrical Installations (Pt.1, Vol.IV), Sec. 17, E.2

Requirements in 6.3 are to be applied when the ventilation rate is reduced.

7.4.5 Section 11, M 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.

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. Protective clothing and breathing apparatus

8.1 Full protective clothing

Four sets of protective clothing appropriate to the properties of the cargo are to be provided.

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.

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.

In case that a cargo space is located partly above a machinery space of category A and the deck above the machinery space is not insulated to A-60 standard, the goods are prohibited in the whole of that cargo space. If the uninsulated deck above the machinery space is a weather deck, the goods are prohibited only for the portion of the deck located above the machinery space.

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 cargo spaces

11.1 A separation, suitable to minimize the passage of dangerous vapours and liquids, is to be provided between a closed ro-ro cargo space and adjacent open ro-ro space. Where such separation is not provided the ro-ro cargo space is to be considered to be a closed ro-ro cargo space over its entire length and the special requirements for closed ro-ro spaces apply.

11.2 A separation, suitable to minimize the passage of dangerous vapours and liquids, is to be provided between a closed ro-ro cargo space and adjacent weather deck. Where such separation is not provided the arrangements of the closed ro-ro cargo space are to be in accordance with those required for the dangerous goods carried on the adjacent weather deck.

Table 12.10a: Requirements for the carriage of dangerous goods in packaged form in conventional cargo spaces

Class	Requirements									
	Fixed gas fire-extinguisher system	Water supplies	Water cooling	Source of ignition	Detection system	Ventilation	Bilge pumping	Personnel protection	Portable fire-extinguisher	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
1.4 S	P.2.1	P.3.1 P.3.2			P.5.1 P.5.2					
2.1 Hydrogen and Hydrogen mixtures	P.2.1	P.3.1 P.3.2		P.4 IIC T4	P.5.1	P.6.1 P.6.2		P.8		P.10.1 P.10.2
2.1 other than Hydrogen and Hydrogen mixtures	P.2.1	P.3.1 P.3.2		P.4 IIB T4	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	P.5.1	P.6.1 P.6.2	P.7	P.8	P.9	P.10.1 P.10.2
3 23 °C $\leq$ FP $\leq$ 60 °C	P.2.1	P.3.1 P.3.2			P.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	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 $\leq$ FP $\leq$ 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 FP > 60 °C	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.6.2 [2]		P.8		
8 Liquids FP < 23 °C	P.2.1	P.3.1 P.3.2		P.4 IIB T4	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 $\leq$ FP $\leq$ 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 FP > 60 °C	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 Goods evolving flammable vapors	P.2.1	P.3.1 P.3.2		P.4 IIB T4		P.6.1 P.6.2		P.8		
9 other than goods evolving flammable vapor	P.2.1	P.3.1 P.3.2				P.6.1 P.6.2 [2]		P.8		

[1] Under the provision of the IMDG Code, as amended, stowage of class 2.3, class 4.3 liquids having a flashpoint less than 23 °C as listed in the IMDG Code a class 5.2 under deck is prohibited
[2] When "mechanically-ventilated spaces" are required by IMGD Code, as amended.
[3] Only applicable to dangerous goods having a subsidiary risk class 6.1.
[4] When "protected from sources of heat" is required by the IMDG Code, as amended.

Table 12.10b: Requirements for the carriage of dangerous goods in packaged form in container cargo spaces

Class		Requirements								
		Fixed gas fire-extinguisher system	Water supplies	Water cooling	Source 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
1.4	S	P.2.1	P.3.1 P.3.2			P.5.1 P.5.2				
2.1	Hydrogen and Hydrogen mixtures	P.2.1	P.3.1 P.3.2		P.4 IIC T4	P.5.1	P.6.1 P.6.3		P.8	P.10.2
2.1	other than Hydrogen and Hydrogen mixtures	P.2.1	P.3.1 P.3.2		P.4 IIB T4	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	P.5.1	P.6.1 P.6.3	P.7	P.8	P.10.2
3	23 °C $\leq$ FP $\leq$ 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.6.3 [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	P.5.1	P.6.1 P.6.3	P.7	P.8	P.10.2
6.1	Liquids 23 °C $\leq$ FP $\leq$ 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.10.2.1
6.1	Liquids FP > 60 °C	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	P.5.1	P.6.1 P.6.3	P.7	P.8	P.10.2.1
8	Liquids 23 °C $\leq$ FP $\leq$ 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 FP > 60 °C	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	Goods evolving flammable vapors	P.2.1	P.3.1 P.3.2		P.4 IIB T4		P.6.1 P.6.3		P.8	
9	other than goods evolving flammable vapor	P.2.1	P.3.1 P.3.2				P.6.1 P.6.3 [2]		P.8	

[1] Under the provision of the IMDG Code, as amended, stowage of class 2.3, class 4.3 liquids having a flashpoint less than 23 °C as listed in the IMDG Code a class 5.2 under deck is prohibited
[2] When "mechanically-ventilated spaces" are required by IMDG Code, as amended.
[3] For solid not applicable to closed freight containers.
[4] Only applicable to dangerous goods having a subsidiary risk class 6.1.
[5] When "protected from sources of heat" is required by the IMDG Code, as amended.
[6] For reduced ventilation air rate, the requirements in 6.3 and the Guidance for Code and Convention Interpretations (Pt.1, Vol.Y) Section 11.SC-288 is applied

Table 12.10c: Requirements for the carriage of dangerous goods in packaged form in closed ro-ro spaces

Class		Requirements										
		Fire-extinguisher system	Water supplies	Water cooling	Source of ignition	Detection system	Ventilation	Bilge pumping	Personnel protection	Portable fire-extinguisher	Machinery space boundaries	Separator of roro space [5]
1.1	to 1.6	P.2	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
1.4	S	P.2	P.3.1 P.3.2			P.5.1 P.5.2						P.11
2.1	Hydrogen and Hydrogen mixtures	P.2	P.3.1 P.3.2		P.4 IIC T4	P.5.1	P.6.1 P.6.2		P.8		P.10.1 P.10.2	P.11
2.1	other than Hydrogen and Hydrogen mixtures	P.2	P.3.1 P.3.2		P.4 IIB T4	P.5.1	P.6.1 P.6.2		P.8		P.10.1 P.10.2	P.11
2.2		P.2	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	P.3.1 P.3.2		P.4 IIB T4	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 $\leq$ FP $\leq$ 60 °C	P.2	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	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	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	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	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	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	P.3.1 P.3.2		P.4 IIB T4	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 $\leq$ FP $\leq$ 60 °C	P.2	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 FP > 60 °C	P.2	P.3.1 P.3.2			P.5.1		P.7	P.8			P.11
6.1	Solids	P.2	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	P.3.1 P.3.2		P.4 IIB T4	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 $\leq$ FP $\leq$ 60 °C	P.2	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 FP > 60 °C	P.2	P.3.1 P.3.2			P.5.1		P.7 [3]	P.8			P.11
8	Solids	P.2	P.3.1 P.3.2			P.5.1			P.8			P.11
9	Goods evolving flammable vapors	P.2	P.3.1 P.3.2		P.4 IIB T4		P.6.1 P.6.2		P.8			P.11
9	other than goods evolving flammable vapor	P.2	P.3.1 P.3.2				P.6.1 P.6.2 [2]		P.8			P.11

[1] Under the provision of the IMDG Code, as amended, stowage of class 2.3, class 4.3 liquids having a flashpoint less than 23 °C as listed in the IMDG Code a class 5.2 under deck is prohibited

[2] When "mechanically-ventilated spaces" are required by IMGD Code, as amended.

[3] Only applicable to dangerous goods having a subsidiary risk class 6.1.

[4] When "protected from sources of heat" is required by the IMDG Code, as amended.

[5] Only applicable for ship with keel-laying on or after 1 July 1998.

Table 12.10d: Requirements for the carriage of dangerous goods in packaged form in open ro-ro spaces

Class		Requirements							
		Fixed pressure water fire-extinguisher system	Water supplies	Water cooling	Source of ignition	Detection system	Personnel protection	Portable fire-extinguisher	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
1.4	S	P.2.2	P.3.1 P.3.2			P.5.2	P.8		
2.1	Hydrogen and Hydrogen mixtures	P.2.2	P.3.1 P.3.2		P.4 IIC T4		P.8		P.10.1 P.10.2
2.1	other than Hydrogen and Hydrogen mixtures	P.2.2	P.3.1 P.3.2		P.4 IIB T4		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		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		P.8	P.9	P.10.1 P.10.2
3	23 °C $\leq$ FP $\leq$ 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 [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.2.1	P.3.1 P.3.2		P.4 IIB T4		P.8	P.9	P.10.1 P.10.2
6.1	Liquids 23 °C $\leq$ FP $\leq$ 60 °C	P.2.2	P.3.1 P.3.2				P.8	P.9	P.10.1 P.10.2
6.1	Liquids FP > 60 °C	P.2.1	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		P.8	P.9	P.10.1 P.10.2
8	Liquids 23 °C $\leq$ FP $\leq$ 60 °C	P.2.2	P.3.1 P.3.2				P.8	P.9	P.10.1 P.10.2
8	Liquids FP > 60 °C	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	Goods evolving flammable vapors	P.2.2	P.3.1 P.3.2		P.4 IIB T4		P.8		
9	other than goods evolving flammable vapor	P.2.2	P.3.1 P.3.2				P.8		

[1] When "away from source 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 12.10e: Requirements for the carriage of dangerous goods in packaged form in shipborne barge

Class		Requirements					
		Fixed gas fire-extinguisher system	Water supplies	Water cooling	Source of ignition [2]	Detection system [2]	Ventilation [2]
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	
1.4	S	P.2.1	P.3.1 P.3.2			P.5.1	
2.1	Hydrogen and Hydrogen mixtures	P.2.1	P.3.1 P.3.2		P.4 IIC T4	P.5.1	P.6.1 P.6.2
2.1	other than Hydrogen and Hydrogen mixtures	P.2.1	P.3.1 P.3.2		P.4 IIB T4	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	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 [2,3]
5.2	[1]						
6.1	Liquids FP < 23 °C	P.2.1	P.3.1 P.3.2		P.4 IIB T4	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.6.3
6.1	Liquids FP > 60 °C	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	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 FP > 60 °C	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	Goods evolving flammable vapors	P.2.1	P.3.1 P.3.2		P.4 IIB T4		P.6.1 P.6.2
9	other than goods evolving flammable vapor	P.2.1	P.3.1 P.3.2				P.6.1 P.6.2 [3]

[1] Under the provision of the IMDG Code, as amended, stowage of class 2.3, class 4.3 liquids having a flashpoint less than 23 °C as listed in the IMDG Code a class 5.2 under deck is prohibited

[2] In the special case where the barge is capable of containing flammable vapours or alternatively if they are capable of discharging flammable vapours to as 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.

[3] When "mechanically-ventilated spaces" are required by IMGD Code, as amended.

Table 12.10f: Requirements for the carriage of dangerous goods in packaged form on the weather deck

Class		Requirements					
		Fixed fire-extinguisher system	Water supplies	Detection system	Personnel protection	Portable fire-extinguisher	Machinery space boundaries
1.1	to 1.6	P.2.2	P.3.1 P.3.2	P.5.2			P.10.3
1.4	S	P.2.2	P.3.1 P.3.2	P.5.2	P.8		
2.1	Hydrogen and Hydrogen mixtures	P.2.2	P.3.1 P.3.2		P.8		P.10.1 P.10.2
2.1	other than Hydrogen and Hydrogen mixtures	P.2.2	P.3.1 P.3.2		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.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.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.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.2.1	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.2.2	P.3.1 P.3.2		P.8	P.9	P.10.1 P.10.2
6.1	Liquids FP > 60 °C	P.2.1	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.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 FP > 60 °C	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	Goods evolving flammable vapors	P.2.2	P.3.1 P.3.2		P.8		
9	other than goods evolving flammable vapor	P.2.2	P.3.1 P.3.2		P.8		

[1] When ”protected from sources of heat” is required by the IMDG Code, as amended.

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 12.11 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 References to other rules

1.2.1 SOLAS, Chapter II-2, Regulation 19, “Carriage of dangerous goods”

1.2.2 SOLAS, Chapter VI, Part A, “General provisions” and Part B, “Special provisions of solid bulk cargoes”

1.2.3 SOLAS, Chapter VII, Part A-1, “Carriage of dangerous goods in solid form in bulk”

1.2.4 ICLL, Annex B, Annex I, Chapter II, Regulation 19, “Ventilators”, (3)

1.2.5 IMO International Maritime Dangerous Goods (IMDG) Code

1.2.6 IMO International Maritime Solid Bulk Cargoes (IMSBC) Code

1.2.7 Medical First Aid Guide for Use in Accidents Involving Dangerous Goods (MFAG)

1.2.8 IMO MSC.1/Circ.1395/Rev.1, “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”.

1.2.9 IEC 60079, “Electrical apparatus for explosive atmospheres”

1.3 Certification

On request the following Certificates may be issued after successful survey:

- The “Document of Compliance for the Carriage of Dangerous Goods” is issued according to SOLAS, Chapter II-2, Regulation 19.4. These vessels will be assigned the Notation DG.
- The “Document of Compliance for the Carriage of Solid Bulk Cargoes” is issued in accordance with the requirements of the IMSBC Code. These vessels will be assigned the Notation DBC.

Note:

For requirements and certification of dangerous goods in packaged form see P.

1.4 Identification and classification

1.4.1 Identification of solid bulk cargoes

1.4.1.1 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.

1.4.1.2 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 1.5.2.

— Group C consists of cargoes which are neither liable to liquefy (Group A) nor to possess chemical hazards (Group B).

1.4.2 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 phyrophoric materials, which, in contact with air without energy supply, are liable to self-heating.

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 2.7.7.2.1 to 2.7.7.2.6 of the IMDG Code.

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.

1.5 Documentation

All vessels intended for the carriage of solid bulk cargoes are to be provided with following documentation:

1.5.1 The IMSBC Code, as amended.

1.5.2 The MFAG. To be provided for cargoes of Group B only.

1.5.3 The approved Loading Manual (see Rules for Hull (Pt.1, Vol.II) Sec. 5, A.4).

1.5.4 The approved Stability Information (see Rules for Hull (Pt.1, Vol.II) Sec. 28, D).

1.5.5 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 CO_2 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

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.1. 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.1, 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 12.3).

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 applied by a single length of hose each, two may be supplied by two coupled hose lengths each.

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 12.11. 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 12.11.

4.1.2 For the design of the electrical equipment and classification of the dangerous areas, see Rules for Electrical Installations (Pt.1, Vol.IV) Sec. 17.

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 15, 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 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.

For the construction and design requirements see Guidance for Ventilation System on Board Seagoing Ships (Pt.1, Vol.A).

6.2 Natural ventilation

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.

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 (see also Guidance for Ventilation System on Board Seagoing Ships (Pt.1, Vol.A)).

Continuous ventilation or ventilation at all times, 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 a computer based 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 no..... 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.

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 bulk-head, 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 Gastightness

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.

14. Fuel tanks

14.1 Tightness

Prior to loading, fuel tanks situated under the cargo spaces shall be pressure tested to ensure that there is no leakage of manholes and piping systems leading to the tanks.

14.2 Sources of heat

14.2.1 Stowage adjacent to sources of heat, including fuel tanks which may require heating is not permitted.

14.2.2 Stowage adjacent to sources of heat and to fuel tanks heated to more than 55 °C is not permitted.

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.

Means are to be provided to monitor and to control the temperature so that it does not exceed 50 °C (see also, Section 10, B.5.1 and B.5.5)

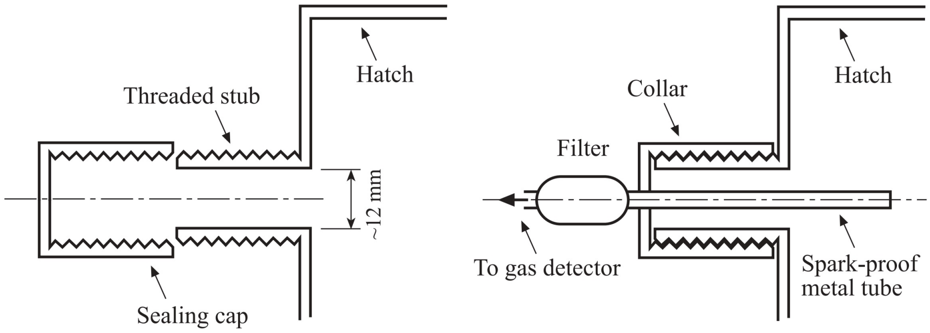


Figure 12.2: Gas Sampling Point

Table 12.11: 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	Bilge pumping	Personnel protection	No smoking signs	Machinery space boundaries	Other boundaries	Gas sampling points	Weathertightness	Fuel tanks
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				
ALUMINIA HYDRATE	MHB	Q.2.2.1									Q.8.1.1 Q.8.2.1						
ALUMINIUM NITRATE UN 1438	5.1	Q.2.2	Q.3					Q.6.1 Q.6.2			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.7.1 Q.7.2 Q.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.7.2 Q.7.2 Q.7.3	Q.8.1.1 Q.8.2.1	Q.9	Q.10.2				
AMMONIUM NITRATE UN 1942	5.1	Q.2.2	Q.3	Q.4 T3	Q.5.1.2			Q.6.1 Q.6.2			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.6.1 Q.6.2			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.6.1 Q.6.2			Q.8.1.2 Q.8.2.2	Q.9	Q.10.1			Q.13	Q.14.2.3
AMRPHOUS SODIUM SILICATE LUMPS	MHB (CR)	Q.2.2.1															
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															
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.6.1 Q.6.2			Q.8.1.2 Q.8.2.2						
CASTOR BEANS UN 2969	9	Q.2.1	Q.3					Q.6.1 Q.6.2			Q.8.1.2 Q.8.2.2						

Table 12.11: Requirements of the carriage of solid dangerous goods in bulk *(continued)*

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	Bilge pumping	Personnel protection	No smoking signs	Machinery space boundaries	Other boundaries	Gas sampling points	Weathertightness	Fuel tanks
CHARCOAL	MHB	Q.2.1									Q.8.1.1						
CLINKER ASH, WET	MHB	Q.2.2.1									Q.8.1.1						
COAL	MHB	Q.2.1		Q.4 IIC, 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.2.1									Q.8.1.1						
COPRA (dry) UN 1363	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.14.2.1
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.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) (By product 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 CUT-TINGS UN 2793	4.2	Q.2.1	Q.3		Q.5.1.1			Q.6.1 Q.6.2			Q.8.1.2 Q.8.2.2	Q.9	Q.10.1				
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.8.1.2 Q.8.2.2						
FLUORSPAR	MHB	Q.2.2.1									Q.8.1.1						

Table 12.11: Requirements of the carriage of solid dangerous goods in bulk *(continued)*

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	Bilge pumping	Personnel protection	No smoking signs	Machinery space boundaries	Other boundaries	Gas sampling points	Weathertightness	Fuel tanks
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.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						
METAL SULPHIDE CONCENTRATES	MHB	Q.2.1				Q.5.2.5 Q.5.2.7					Q.8.1.1 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.8.1.2 Q.8.2.2						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						
RADIOACTIVE MATERIAL, LOW SPECIFIC ACTIVITY (LSA-I) UN 2912	7	Q.2.2.1									Q.8.1.1 Q.8.2.1						

Table 12.11: Requirements of the carriage of solid dangerous goods in bulk *(continued)*

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	Bilge pumping	Personnel protection	No smoking signs	Machinery space boundaries	Other boundaries	Gas sampling points	Weathertightness	Fuel tanks
RADIOACTIVE MATERIAL, SURFACE CONTAMINATED OBJECTS (SCO-I) UN 2913	7	Q.2.2.1									Q.8.1.1 Q.8.2.1						
SAWDUST	MHB	Q.2.1						Q.6.1 Q.6.2									
SEED CAKE, containing vegetable oil UN 1386 (a)[2)]	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				
SEED CAKE, containing vegetable oil UN 1386 (b) mechanically expelled seeds[2)]	4.2	Q.2.1	Q.3	Q.4 IIA T3	Q.5.1.2			Q.6.1 Q.6.2	Q.6.7.1		Q.8.1.2 Q.8.2.2	Q.9	Q.10.1				
SEED CAKE, containing vegetable oil UN 1386 (b) solvent extracted seeds[2)]	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				
SEED CAKE UN 2217[2)]	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.5.2.5, .6		Q.6.1 Q.6.3			Q.8.2.1	Q.9				Q.13	
SODIUM NITRATE 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 POTAS- SIUM 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 ANF PLASTICS	MHB	Q.2.1		Q.4 T3 IP55		Q.5.2.5					Q.8.1.1	Q.9					
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				Q.14.2.1
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						
WOODCHIPS having a moisture content of 15 % or more	MHB	Q.2.2.1				Q.5.2.5 Q.5.2.10		Q.6.1 Q.6.2			Q.8.2.1						

Table 12.11: Requirements of the carriage of solid dangerous goods in bulk *(continued)*

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	Bilge pumping	Personnel protection	No smoking signs	Machinery space boundaries	Other boundaries	Gas sampling points	Weathertightness	Fuel tanks
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.4 IIB T4, IP55		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.2.2.1		Q.4 T3, IP55		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.2.1		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				

[1] The additional requirements for DIRECT REDUCED IRON (B) and (C) are to be agreed upon with BKI.

[2] The requiremets in Guidance for Recommendations (Pt.1, Vol.AC) Sec.11, SC250 should also be observed

Section 13 Machinery for Ships with Ice Classes

A. General

1. Notations affixed to the Character of Classification

The machinery of ships strengthened for navigation in ice is designated after the Character of Classification ✠ **SM** by the additional Notation **ES, ES1, ES2, ES3 or ES4**, provided that the requirements contained in this Section and the relevant structural requirements set out in Rules for Hull (Pt.1, Vol.II), Section 15 together with the supplements thereto are satisfied. The reinforcements necessary for the Class Notation **ES** may also be applied to the machinery alone.

2. Compliance with the "Finnish-Swedish Ice Class Rules"

The requirements for ice classes **ES, ES1, ES2, ES3 and ES4**contained in this Section are equivalent to the relevant Finnish-Swedish ice class requirements for the corresponding ice classes, as set out in Table 13.1.

Table 13.1: Corresponding ice classes

BKI ice class	ES	ES1	ES3	ES4
Finnish-Swedish Ice Class	IC	IB	IA	IA super

B. Necessary Propulsion Power

The necessary propulsion power shall be as stated in Rules for Hull (Pt.1, Vol.II), Section 15.

The rated output of the main engines in accordance with Section 2, A.3. has to 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 **ES4, ES3, ES2, ES1** and IA Super, IA, IB and IC respectively. Topics not covered by the following regulations have to be handled according regulations for ships without ice class.

The given loads are the expected ice loads for the whole 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. The regulations also apply to azimuthing and fixed thrusters for main propulsion, considering loads resulting from propeller-ice inter-action. 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) or load case when ice block hits on the propeller hub of a pulling propeller. Ice loads resulting from ice impacts on the body of thrusters have to be estimated, but ice load formulae are not available.

Bow propellers, Voith Schneider Propellers, jet propulsors and other special designs require a special consideration.

Table 13.2: Definition of loads

Symbol	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 0,7R chord line. See Fig. 13.1.	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 0,7R chord line. See Fig. 13.1.	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.	In 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 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 in the rules.
T_f	The maximum lifetime thrust on 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 in the rules.
Q_{max}	The maximum ice-induced torque resulting from propeller/ice interaction on propeller, including hydrodynamic loads.	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 plastic hinge is caused to the root area. The force is acting on 0.8R. 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 cause damage to other components
Q_r	Maximum response torque along the propeller shaft line, taking into account the dynamic behavior of the shaft line for ice excitation (torsional vibration) and hydrodynamic mean torque on propeller	Design torque for propeller shaft line components
T_r	Maximum response torque along the propeller shaft line, taking into account the dynamic behavior of the shaft line for ice excitation (axial vibration) and hydrodynamic mean torque on propeller	Design torque for propeller shaft line components

2. Symbols

c	=	chord length of blade section [m]
$c_{0.7}$	=	chord length of blade section at 0.7R propeller radius [m]
CP	=	controllable pitch
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 ship's service life [kN]
F_{ex}	=	ultimate blade load resulting in plastic bending deformation of the blade [kN]
F_f	=	maximum forward blade force for the ship's service life [F_f]
F_{ice}	=	ice load [kN]
$(F_{ice})_{max}$	=	maximum ice load for the ship's service life [kN]
FP	=	fixed pitch
h_0	=	depth of the propeller centreline from lower ice waterline LWL [m]
H_{ice}	=	thickness of maximum design ice block entering to propeller [m]
K	=	shape parameter for Weibull distribution
LWL	=	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 [s^{-1}]
n_n	=	nominal propeller rotational speed at MCR in free running condition [s^{-1}]
N_{class}	=	reference number of impacts per propeller rotational speed per ice class
N_{ice}	=	total number of ice loads on propeller blade for the ship's service life
N_R	=	reference number of load for 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]
$P_{0,7n}$	=	propeller pitch at 0,7R radius at MCR in free running condition [m]
Q	=	Torque [kNm]
$Q_{e\ max}$	=	maximum engine torque [kNm]
Q_{max}	=	maximum torque on the propeller resulting from propeller-ice interaction [kNm]
Q_{motor}	=	electric motor peak torque [kNm]
Q_n	=	nominal torque at MCR in free running condition [kNm]
Q_r	=	maximum response torque along the propeller shaft line [kNm]
$Q_{s\ max}$	=	maximum spindle torque of the blade for the ship's service life [kNm]
R	=	propeller radius R = D/2 [m]
R	=	blade section radius [m]
T	=	propeller thrust [kN]

T_b	=	maximum backward propeller ice thrust for the ship's service life [kN]
T_f	=	maximum forward propeller ice thrust for the ship's service life [kN]
T_n	=	propeller thrust at MCR in free running condition [kN]
T_r	=	maximum response thrust along the shaft line [kN]
t	=	maximum blade section thickness [m]
Z	=	number of propeller blades
α_i	=	duration of propeller blade/ice interaction expressed in rotation angle [deg]
γ	=	the reduction factor for fatigue; scatter and test specimen size effect
γ_v	=	the reduction factor for fatigue; variable amplitude loading effect
γ_m	=	the reduction factor for fatigue; mean stress effect
ρ	=	a reduction factor for fatigue correlating the maximum stress amplitude to the equivalent fatigue stress for 10^8 stress cycles
$\sigma_{0,2}$	=	proof yield strength [MPa]
σ_{exp}	=	mean fatigue strength of the blade material at 10^8 cycles to failure in sea water [MPa]
σ_{fat}	=	equivalent fatigue ice load stress amplitude for 10^8 stress cycles [MPa]
σ_{fl}	=	characteristic fatigue strength for blade material [MPa]
σ_r	=	resulting Von Mises stress [MPa]
σ_{ref}	=	reference stress [MPa] $\sigma_{ref} = 0{,}6 \cdot \sigma_{0,2} + 0{,}4 \cdot \sigma_u$
σ_{ref}	=	reference stress [MPa] $\sigma_{ref1} = 0{,}6 \cdot \sigma_u$ or $\sigma_{ref2} = 0{,}6 \cdot \sigma_{0,2} + 0{,}4 \cdot \sigma_u$ whichever is less
σ_{ST}	=	maximum stress resulting from F_b or F_f [MPa]
σ_u	=	ultimate tensile strength of blade material [MPa]
$(\sigma_{ice})_{max}$	=	maximum ice load stress amplitude [MPa]
$(\sigma_{ice})_{hmax}$	=	principal stress caused by maximum backward propeller ice load [MPa]
$(\sigma_{ice})_{fmax}$	=	principal stress caused by the maximum forward propeller ice load [MPa]

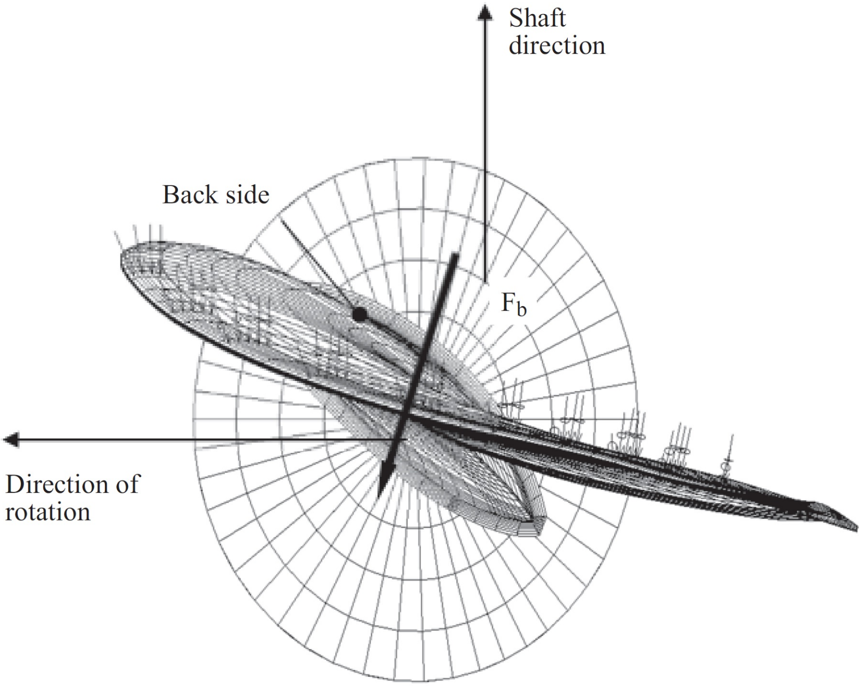


Figure 13.1: Direction of the backward blade force resultant F_b taken perpendicular to chord line at radius 0,7R. Ice contact pressure at leading edge is shown with small arrows.

3. Design ice conditions

In estimating the ice loads of the propeller for ice classes, different types of operation as given in Table 13.3 were taken into account. For the estimation of design ice loads, a maximum ice block size is determined. The maximum design ice block entering the propeller is a rectangular ice block with the dimensions H_{ice} . $2H_{ice}$. $3H_{ice}$. The thickness of the ice block (H_{ice}) is given in Table 13.4.

Table 13.3: Ice loads of the propeller for ice classes

Ice class	Operation of the ship
ES4 (IA Super)	Operation in ice channels and in level ice The ship may proceed by ramming
ES3, **ES2**, **ES1**(IA, IB, IC)	Operation in ice channels

Table 13.4: Thickness of the ice block for ice classes

	ES4 (IA Super)	ES3 (IA)	ES2 (IB)	ES1 (IC)
Thickness of the design maximum ice block entering the propeller (H_{ice})	1,75 m	1,5 m	1,2 m	1,0 m

4. Materials

4.1 Materials exposed to sea water

Materials of components exposed to sea water, such as propeller blades, propeller hubs, and thruster body, shall have an elongation of not less than 15% and shall comply with the respective requirements in, Rules for Materials (Pt,1, Vol.V). A Charpy V impact test shall be carried out for materials other than bronze and austenitic steel. An average impact energy value of 20 J taken from three tests is to be obtained. All tests have to be performed at minus 10 °C.

4.2 Materials exposed to sea water temperature

Materials exposed to sea water temperature shall be of ductile material and comply with Rules for Materials (Pt,1, Vol.V). An average Charpy V impact energy value of 20 J taken from three tests is to be obtained, if no higher values are required in the Rules for Materials (Pt,1, Vol.V). All tests have to be performed at minus 10 °C. This requirement applies to components such as blade bolts, CP mechanisms, shaft bolts, strut-pod connecting bolts, etc. This does not apply to surface hardened components, such as bearings and gear teeth.

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 values of the parameters in the formulae in this section shall be given in the units shown in the symbol list (2.).

If the propeller is not fully submerged when the ship is in ballast condition, the propulsion system shall be designed according to ice class **ES3** for ice classes **ES2** and **ES1**.

In no case it can be accepted that scantling dimensions determined according to the following paragraphs are less than those determined by applying the Rules without ice strengthening.

5.1 Design loads on propeller blades

F_b is the maximum force experienced during the lifetime of the 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 the 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, not acting simultaneously. Hence, they are to be applied to one blade separately.

5.1.1 Maximum backward blade force F_b for propellers

$$F_b = K_f \cdot [n \cdot D]^{0,7} \cdot \left[\frac{EAR}{Z}\right]^{0,3} \cdot D^2 \qquad [kN] \quad \text{when } D \leq D_{limit} \qquad (1)$$

$$F_b = K_f \cdot [n \cdot D]^{0,7} \cdot \left[\frac{EAR}{Z}\right]^{0,3} \cdot D^x \cdot {H_{ice}}^{1,4} \qquad [kN] \quad \text{when } D > D_{limit} \qquad (2)$$

where:

$x = 1,0$, $D_{limit} = 0,85 \cdot {H_{ice}}^{1,4}$ [m] for open propeller

$x = 0,6$, $D_{limit} = 4 \cdot H_{ice}$ [m] for ducted propeller

Table 13.5:

K_f	Open propeller	Ducted propeller
$D \le D_{limit}$	27	9,5
$D > D_{limit}$	23	66

n is the nominal rotational speed [1/s] (at MCR in free running condition) for a CP propeller and 85 % of the nominal rotational speed (at MCR in free running condition) for an FP propeller.

5.1.2 Maximum forward blade force F_f for propellers

$$F_f = K_f \cdot \left[\frac{EAR}{Z}\right] \cdot D^2 \quad [kN] \quad \text{when } D \le D_{limit} \tag{3}$$

$$F_f = K_f \cdot \left[\frac{EAR}{Z}\right] \cdot D \cdot \frac{1}{\left(1 - \frac{d}{D}\right)} \cdot H_{ice} \quad [kN] \quad \text{when } D > D_{limit} \tag{4}$$

where:

$$D_{limit} = \frac{2}{\left(1 - \frac{d}{D}\right)} \cdot H_{ice} \quad [m] \quad \text{for open and ducted propeller}$$

Table 13.6:

K_f	Open propeller	Ducted propeller
$D \le D_{limit}$	250	250
$D > D_{limit}$	500	500

5.1.3 Loaded area on the blade for open propellers

Load cases 1-4 have to be covered, as given in Table 13.7 below, for CP and FP propellers. In order to obtain blade ice loads for a reversing propeller, load case 5 also has to be covered for FP propellers.

5.1.4 Loaded area on the blade for ducted propellers

Load cases 1 and 3 have to be covered as given in Table 13.8 for all propellers, and an additional load case (load case 5) for an FP propeller, to cover ice loads when the propeller is reversed.

5.1.5 Maximum blade spindle torque Q_{smax} for open and ducted propellers

The spindle torque Q_{smax} around the axis of the blade fitting shall be determined both for the maximum backward blade force F_b and forward blade force F_f, which are applied as in Table Table 13.7 and Table Table 13.8. If the above method gives a value which is less than the default value given by the formula below, the default value shall be used.

$$\text{Default value } Q_{max} = 0,25 \cdot F \cdot c_{0,7} \quad [kNm] \tag{5}$$

Where:

$c_{0,7}$ = is the length of the blade section at 0,7R radius

F = is either F_b or F_f , whichever has the greater absolute value

5.1.6 Load distributions for fatigue analysis

The Weibull-type distribution (probability that Fice exceeds a portion of $(F_{ice})_{max}$), as given in Fig. 13.2 is used for the fatigue design of the blade.

$$P\left(\frac{F_{ice}}{(F_{ice})_{max}} \geq \frac{F}{(F_{ice})_{max}}\right) = e^{\left(-\left(\frac{F}{(F_{ice})_{max}}\right)^{k} \cdot \ln(N_{ice})\right)} \tag{6}$$

where:

k = is the shape parameter of the spectrum,

= 0,75 shall be used for the ice force distribution of an open propeller

= 1,0 for that of a ducted propeller blade.

N_{ice} = is the number of load cycles in the spectrum, see 5.1.7

F_{ice} = is the random variable for ice loads on the blade, $0 \leq F_{ice} \leq (F_{ice})_{max}$.

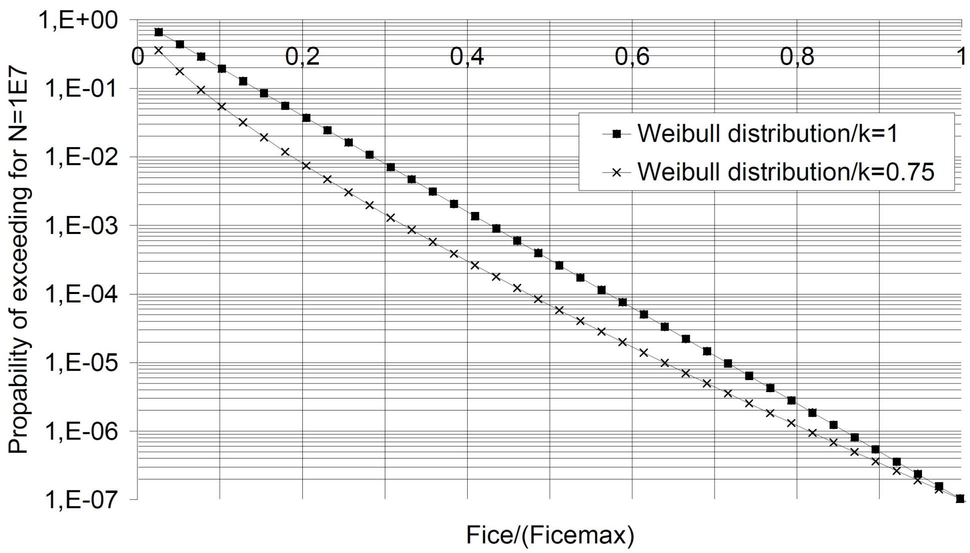


Figure 13.2: The Weibull-type distribution (probability that F_{ice} exceeds a portion of $(F_{ice})_{max}$) for fatigue design.

5.1.7 Number of ice loads for fatigue analysis

The number of load cycles per propeller blade in the load spectrum shall be determined according to the formula:

$$N_{ice} = k_1 \cdot k_2 \cdot k_3 \cdot k_4 \cdot N_{class} \cdot n \tag{7}$$

where:

Table 13.7: Reference number of loads for ice classes N_{class}

Class	ES 4	ES 3	ES 2	ES 1
N_{class}	$9 \cdot 10^6$	$6 \cdot 10^6$	$3{,}4 \cdot 10^6$	$2{,}1 \cdot 10^6$

Table 13.8: Propeller location factor k_1

Position	Centre propeller	Wing propeller	Pulling propeller (wing and center)
k_1	1	2	3

Table 13.9: Propeller location factor k_2

type	open	ducted
k_2	1	1,1

Table 13.10: Propeller location factor k_3

type	Fixed	azimuthing
k_3	1	1,2

The submersion factor k_4 is determined from the equation

$$k4 = \begin{cases} 0{,}8 - f & \text{when } f < 0 \\ 0{,}8 - 0{,}4 \cdot f & \text{when } 0 \leq f \leq 1 \\ 0{,}6 - 0{,}2 \cdot f & \text{when } 1 < f \leq 2{,}5 \\ 0{,}1 & \text{when } F > 2{,}5 \end{cases} \quad (8)$$

Where the immersion function f is:

$$f = \frac{h_o - H_{ice}}{D/2} \quad (9)$$

Where h_0 is the depth of the propeller centreline at the lower ice waterline (LIWL) of the ship.

If h_0 is not known, h_0 = D/2.

For vessels with the additional notation Icebreaker, the above stated number of load cycles N_{Zice} shall be multiplied by a factor of 3.

For components that are subject to loads resulting from propeller/ice interaction with all the propeller blades, the number of load cycles is to be multiplied by the number of propeller blades ($N_{Zice} = N_{ice} \cdot Z$)

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:

$$T_f = 1{,}1 \cdot F_f \quad (10)$$

$$T_b = 1{,}1 \cdot F_b \quad (11)$$

However, the load models within this Section do not include propeller/ice interaction loads where an ice block hits the propeller hub of a pulling propeller.

Table 13.11: Load case for open propellers

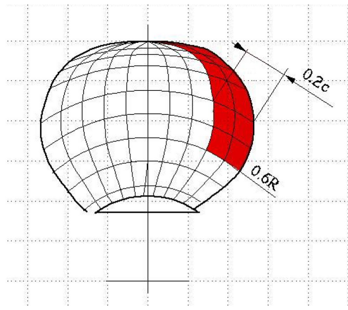
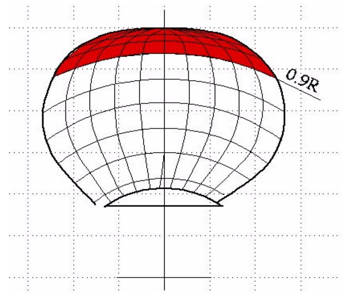
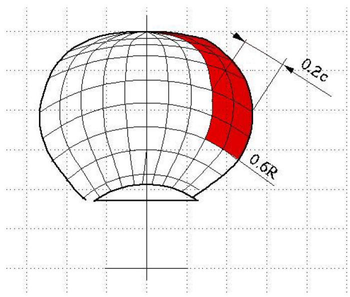
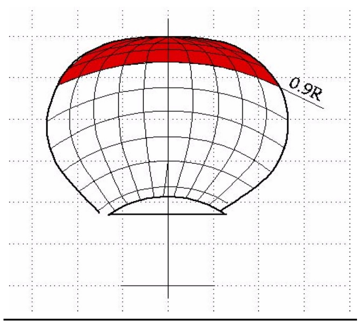
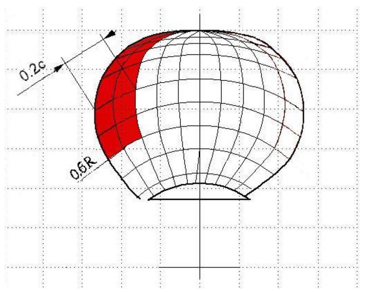
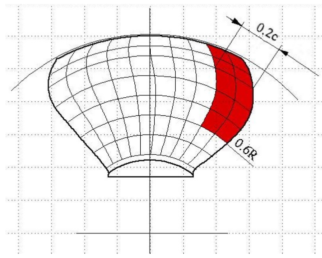
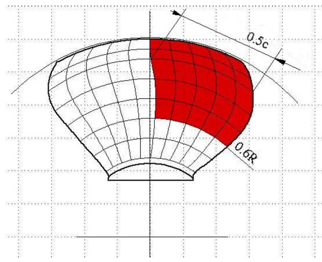
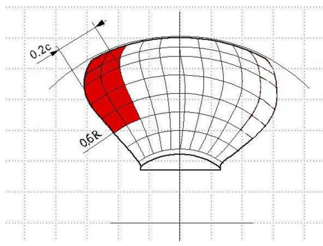
	Force	Loaded area	Right-handed propeller blade seen from behind
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0,6R to tip and from the leading edge to 0,2 times the chord length	
Load case 2	50 % of F_b	Uniform pressure applied on the back of the blade (suction side) on the propeller tip area outside 0,9R radius	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) on 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 propeller face (pressure side) on the propeller tip area outside 0,9R radius	
Load case 5	60% of F_f or F_b whichever is greater	Uniform pressure applied on propeller face (pressure side) to an area from from 0,6R to the tip and from the trailing edge to 0,2 times the chord length	

Table 13.12: Load case for ducted propellers

	Force	Loaded area	Right-handed propeller blade seen from behind
Load case 1	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0,6R to 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) on 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 blade face (pressure side) on area from 0,6R to the tip and from the leading edge to 0,2 times the chord length	

5.2.2 Design thrust along the propulsion shaft line T_r for open and ducted propellers

The design thrust along the propeller shaft line is to be calculated with the formulae below. The greater value of the forward and backward direction loads shall be taken as the design load for both directions. The factors 2,2 and 1,5 take into account the dynamic magnification resulting from axial vibration.

In a forward direction

$$T_r = T + 2,2 \cdot T_f \quad [\text{kN}] \tag{12}$$

In a backward direction

$$T_r = 1,5 \cdot T_b \quad [\text{kN}] \tag{13}$$

If the hydrodynamic bollard thrust, T, is not known, T is to be taken as follows:

Table 13.13: T value based on the type of Propeller

Propeller type	T
CP propellers (open)	$1,25 \cdot T_n$
CP propellers (ducted)	$1,1 \cdot T_n$
FP propellers driven by turbine or electric motor	T_n
FP propellers driven by diesel engine (open)	$0,85 \cdot T_n$
FP propellers driven by diesel (ducted)	$0,75 \cdot T_n$

Here, T_n is the nominal propeller thrust at MCR in free running open water condition.

5.3 Torsional design loads

5.3.1 Design torque along propeller shaft line Q_r

If there is not any relevant first blade order torsional resonance within the designed operating rotational speed range extended 20% above the maximum and 20% below the minimum operating speeds, the following estimation of the maximum torque can be used to calculate the design torque along the propeller shaft line.

$$Q_r = Q_{e\,max} + Q_{max} \cdot \frac{1}{I_t} \qquad [\text{kNm}] \tag{14}$$

For directly coupled two stroke Diesel engines without flexible coupling, the following equation is to be applied

$$Q_r = Q_{e\,max} + Q_{vib} + Q_{max} \cdot \frac{1}{I_t} \qquad [\text{kNm}] \tag{15}$$

where:

I = equivalent mass moment of inertia of all parts on engine side of component under consideration

It = 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 not known, it shall be taken as follows:

Table 13.14: Guidelines for the determination of maximum motor torque

Propeller type	$Q_{e\,max}$
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	$0{,}75 \cdot Q_n$

Here, Q_{motor} is the electric motor peak torque.

If there is a first blade order torsional resonance within the designed operating rotational speed range extended 20% above the maximum and 20% below the minimum operating speeds, the design torque (Q_r) of the shaft component shall be determined by means of torsional vibration analysis of entire propulsion line n the time domain or alternatively in the frequency domain. It is then assumed that the plant is sufficiently designed to avoid harmful operation in barred speed range.

5.3.2 Design ice torque on propeller Q_{max} for open and ducted propellers

Q_{max} is the maximum torque on a propeller resulting from ice/propeller interaction.

$$Q_{max} = K_Q \cdot \left[1 - \frac{d}{D}\right] \cdot \left[\frac{P_{0,7}}{D}\right]^{0,16} \cdot (n \cdot D)^{0,17} \cdot D^3 \qquad [\text{kN}], \text{ when } D < D_{limit} \tag{15}$$

$$Q_{max} = 1.9 \cdot K_Q \cdot \left[1 - \frac{d}{D}\right] \cdot \left[\frac{P_{0,7}}{D}\right]^{0,16} \cdot (n \cdot D)^{0,17} \cdot D^{1,9} \cdot H_{ice}^{1,1} \ [kN], \text{ when } D \geq D_{limit} \qquad (16)$$

where:

$D_{limit} = 1,8 \cdot H_{ice}$ [m] for open and ducted propeller

Table 13.15:

K_Q	Open Propeller	Ducted Propeller
D < D_{limit} for PC1 - PC5	14,7	10,4
D < D_{limit} for PC6 - PC7	10,9	7,7

n is the rotational propeller speed in bollard condition. If not known, n is to be taken as follows:

Table 13.16: Guidance for rotational speeds to calculate torsional loads

Propeller type	Rational speed n
CP propellers	n_n
FP propellers driven by turbine or electric motor	n_n
FP propellers driven by diesel engine	$0,85 \cdot n_n$

Here, n_n is the nominal rotational speed at MCR in free running condition [1/s].

For CP propellers, the propeller pitch, $P_{0,7}$ shall correspond to MCR in bollard condition. If not known, $P_{0,7}$ is to be taken as $0,7 \cdot P_{0,7n}$, where $P_{0,7n}$ is the propeller pitch at MCR in free running condition.

5.3.3 Alternative determination of Q_{max}

As an alternative, so far detailed data are not available e.g. in an early design stage, the maximum ice torque can be determined using the following formulae:

$$Q_{max} = m_{ice} \cdot D^2 \quad [kNm] \qquad (17)$$

Where D is the propeller diameter in [m] and magnification factor m_{ice} has to be chosen according to the following table for open propellers:

Table 13.17:

Ice Class	Magnification factor m_{ice} for FPP	Magnification fact m_{ice} for CPP
ES1	24	19
ES2	30	26
ES3	32	30
ES4	42	36

The magnification factor for ducted propellers may be reduced by 30 %.

5.3.4 Ice torque excitation Q (φ) for open and ducted propeller

.1 Excitation for the time domain calculation

The propeller ice torque excitation for shaft line transient torsional vibration analysis shall be described by a sequence of blade impacts which are of a half sine shape; see Fig. 13.3.

The torque resulting from a single blade ice impact as a function of the propeller rotation angle is then defined as:

$$Q(\varphi) = C_q \cdot Q_{max} \cdot \sin\left(\varphi\left(\frac{180}{\alpha_i}\right)\right), \quad \text{when } \varphi = 0 \ldots\alpha_i \text{ plus integer revolutions} \tag{18}$$

$$Q(\varphi) = 0, \quad \text{when } \varphi = \alpha_i \ldots 360 \text{ plus integer revolutions}$$

Where the C_q and α_i parameters are given in the table below. α_i is duration of propeller blade/ice interaction expressed in propeller rotation angle. φ is rotation angle starting when the first impact occurs.

Table 13.18: 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
Case 1	Single ice block	0,75	90	90	72	60
Case 2	Single ice block	1,0	135	135	135	135
Case 3	Two ice blocks (phase shift 360/(2.Z) deg.)	0,5	45	45	36	30
Case 4	Single ice block	0,5	45	45	36	30

The total ice torque is obtained by summing the torque of single blades, taking into account the phase shift 360 deg/Z. In addition, at the beginning and at the end of the milling sequence a linear ramp function for 270 degrees of rotation angle shall be used.

The number of propeller revolutions during a milling sequence shall be obtained with the formula:

$$N_Q = 2 \cdot H_{ice} \tag{19}$$

The number of impacts is $Z \cdot N_Q$ for first blade order excitation.

The dynamic simulation shall be performed for all excitation cases starting at MCR nominal, MCR bollard condition and just above all resonance speeds (1^{st} engine and 1^{st} blade harmonic), so that the resonant vibration responses can be obtained. For a fixed pitch propeller plant the dynamic simulation shall also cover bollard pull condition with a corresponding speed assuming maximum possible output of the engine.

If a speed drop occurs down to stand still of the main engine, it 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 shall be applied. On these cases, the excitation shall follow the shaft speed.

.2 Frequency domain excitation

For frequency domain calculations the following torque excitation may be used. The excitation has been derived so that the time domain half sine impact sequences have been assumed to be continuous and the Fourier series components for blade order and twice the blade order components have been derived. The frequency domain analysis is generally considered as conservative compared to the time domain simulation provided there is a first blade order resonance in the considered speed range.

$$Q_F(\varphi) = Q_{max} \cdot \left(C_{q0} + C_{q1} \cdot \sin(Z \cdot E_0 \cdot \varphi + \alpha_1) + C_{q2} \cdot \sin(2 \cdot Z \cdot E_0 \cdot \varphi + \alpha_2)\right) \text{ [kNm]} \qquad (20)$$

where:

C_{q0} = mean torque component

C_{q1} = first blade order excitation amplitude

C_{q1} = second blade order excitation amplitude

φ = angle of rotation

$\alpha_{1,2}$ = phase angle of excitation component

Z = number of blades

Table 13.19: Coefficients for simplified excitation torque estimation

Torque excitation	Z = 3					
	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Case 1	0,375	0,375	-90	0	0	1
Case 2	0,7	0,33	-90	0,05	-45	1
Case 3	0,25	0,25	-90	0	0	2
Case 4	0,2	0,25	0	0,05	-90	1
Torque excitation	Z = 4					
	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Case 1	0,45	0,36	-90	0,06	-90	1
Case 2	0,9375	0	-90	0,0625	-90	1
Case 3	0,25	0,251	-90	0	0	2
Case 4	0,2	0,25	0	0,05	-90	1
Torque excitation	Z = 5					
	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Case 1	0,45	0,36	-90	0,06	-90	1
Case 2	1,19	0,17	-90	0,02	-90	1
Case 3	0,3	0,25	-90	0,048	-90	2
Case 4	0,2	0,25	0	0,05	-90	1
Torque excitation	Z = 6					
	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Case 1	0,45	0,375	-90	0,05	-90	1
Case 2	1,435	0,1	-90	0	0	1
Case 3	0,3	0,25	-90	0,048	-90	2
Case 4	0,2	0,25	0	0,05	-90	1

Torsional vibration responses shall be calculated for all excitation cases.

The results of the relevant excitation cases at the most critical rotational speeds are to be used in the following way:

The highest response torque (between the various lumped masses in the system) is in the following referred to as peak torque Q_{peak}.

The highest torque amplitude during a sequence of impacts is to be determined as half of the range from max to min torque and is referred to as Q_{Amax}.

An illustration of Q_{Amax} is given in Figure 4. It can be determined by

$$Q_{Amax} = \left(\frac{\max\left(Q_r(\text{time})\right) - \min\left(Q_r(\text{time})\right)}{2} \right) \ [\text{kNm}] \tag{21}$$

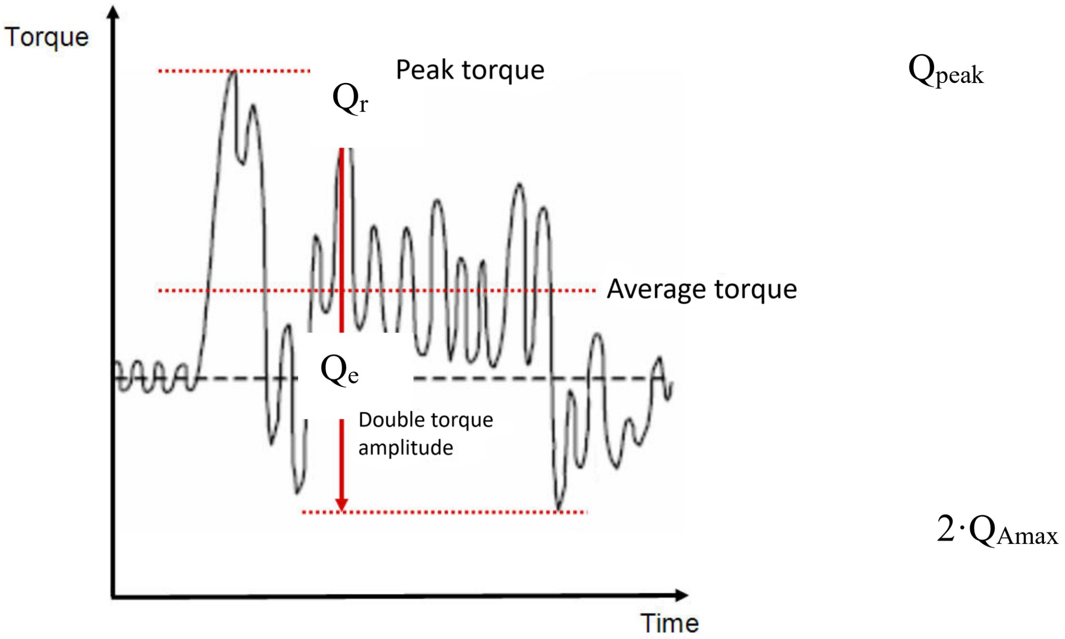


Figure 13.3: Interpretation of different torques in a measured curve, as example

5.3.5 Peak Torque Q_{peak}

The peak torque has to be taken as the maximum of $Q(\varphi)$ (according 5.3.4) and Qr (according 5.3.1).

5.4 Blade failure load for both Open and Ducted Propellers

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 with the formula below. The ultimate load is acting on the blade at the 0,8R radius in the weakest direction of the blade.

For calculation of the extreme spindle torque, the spindle arm is to be taken as 2/3 of the distance between the axis of blade rotation and the leading/trailing edge (whichever is the greater) at the 0,8R radius.

$$F_{ex} = \frac{300 \cdot c \cdot t^2 \cdot \sigma_{ref}}{0,8 \cdot D - 2 \cdot r} \tag{20}$$

Where:

c = length of the cylindrical root,

t = thickness of the cylindrical root,

r = radius of the cylindrical root,

section of the blade at the weakest section outside the root filet.

5.4.2 Spindle torque Q_{s-ex}

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 equation 20 below.

$$Q_{s-ex} = \max(c_{LE0.8}; 0,8 \cdot c_{TE0.8}) \cdot C_{spex} \cdot F_{ex} \quad [\text{kNm}] \tag{21}$$

where:

$$C_{spex} = C_{sp} \cdot C_{fex} = 0,7 \cdot \left(1 - \left(4 \cdot \frac{EAR}{Z}\right)^3\right) \quad [-] \tag{22}$$

C_{sp} is non-dimensional parameter taking into account the spindle arm

C_{fex} is non-dimensional parameter taking into account the reduction of blade failure force at the location of maximum spindle torque.
If $_{spex}$ 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

The figure below illustrates the spindle torque values due to blade failure loads across the whole chord length

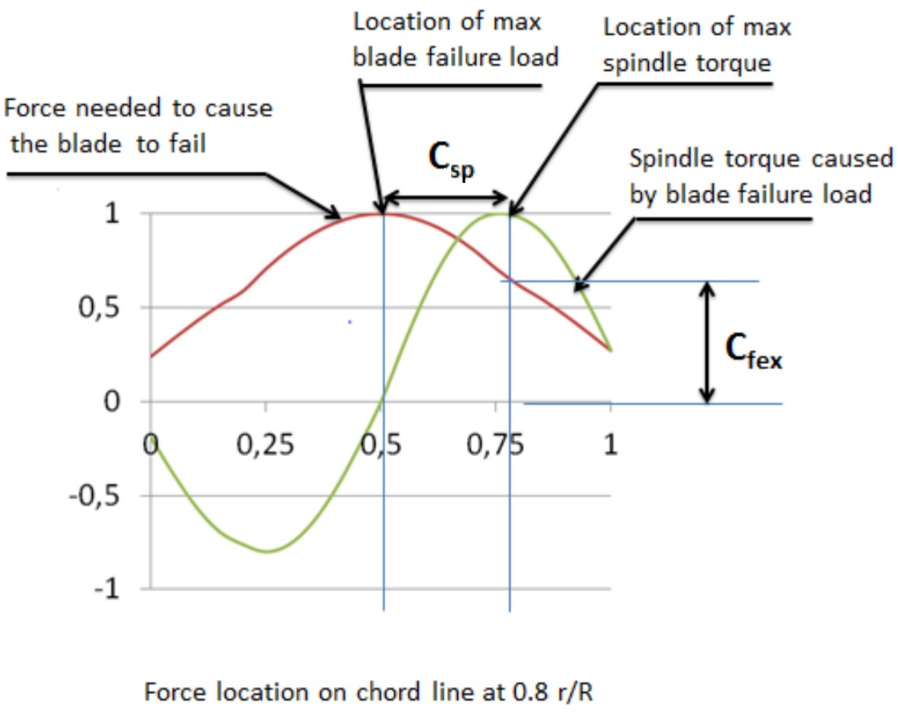


Figure 13.4: Schematic figure showing blade failure load and related spindle torque when the force acts at different location on the chord line at radius 0,8R.

5.5 Guideline for torsional vibration calculation

The aim of torsional vibration calculations is to estimate the torsional loads for individual shaft line components over the life time in order to determine scantlings for safe operation. The model can be taken from the normal lumped mass elastic torsional vibration model (frequency domain) including the damping. Standard harmonics may be used to consider the gas forces. The engine torque - speed curve of the actual plant shall be applied.

For time domain analysis the model should include the ice excitation at propeller, the mean torques provided by the prime mover and the hydrodynamic mean torque produced by the propeller as well as any other relevant excitations. The calculations should cover the variation of phase between the ice excitation and prime mover excitation. This is extremely relevant for propulsion lines with direct driven combustion engines.

For frequency domain calculations the load should be estimated as a Fourier component analysis of the continuous sequence of half sine load peaks. The first and second order blade components should be used for excitation. The calculation should cover the whole relevant shaft speed range. The analysis of the responses at the relevant torsional vibration resonances may be performed for open water (without ice excitation) and ice excitation separately. The resulting maximum torque can be obtained for directly coupled plants by the following superposition:

$$Q_{peak} = Q_{emax} + Q_{opw} + Q_{ice} \; [\text{kNm}] \qquad \text{(xx)}$$

where:

Q_{emax} = the maximum engine torque at considered rotational speed

Q_{opw} = the maximum open water response of engine excitation at considered shaft speed and determined by frequency domain analysis

Q_{ice} = the calculated torque using frequency domain analysis for the relevant shaft speeds, ice excitation cases 1-4, resulting in the maximum response torque due to ice excitation

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.

The propulsion line components shall withstand maximum and fatigue operational loads with the relevant safety margin. The loads do not need to be considered for shaft alignment or other calculations of normal operational conditions.

6.2 Propeller blade

6.2.1 Calculation of blade stresses

The blade stresses shall be calculated for the design loads given in 5.1. Finite element analysis shall be used for stress analysis for final approval for all propellers. The following simplified formulae can be used in estimating the blade stresses for all propellers at the root area (r/R < 0,5).

$$\sigma_{st} = C_1 \frac{M_{BL}}{100 \cdot ct^2} \quad [MPa] \tag{21}$$

where,

constant C_1 is the $\frac{\text{stress according FEM}}{\text{stress obtained with beam equation}}$

If the actual value is not available, C_1 should be taken as 1,6.

$M_{BL} = (0{,}75 - r / R) \cdot R \cdot F$, for relative radius r/R < 0,5

F is the maximum of F_b and F_f .

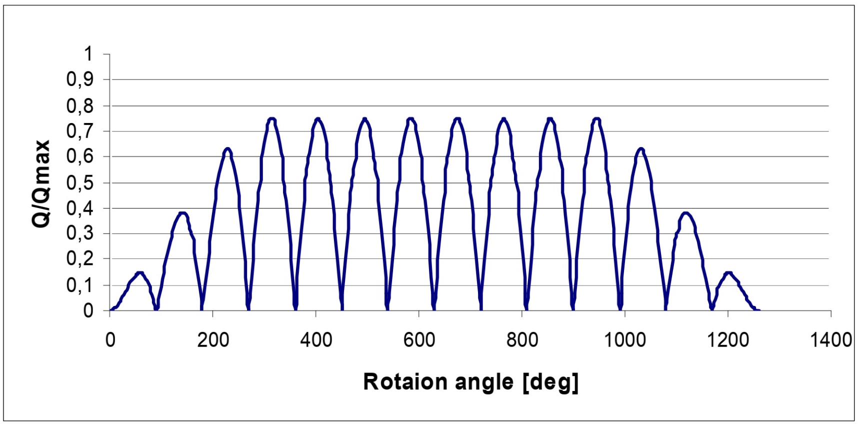
6.2.2 Acceptability criterion

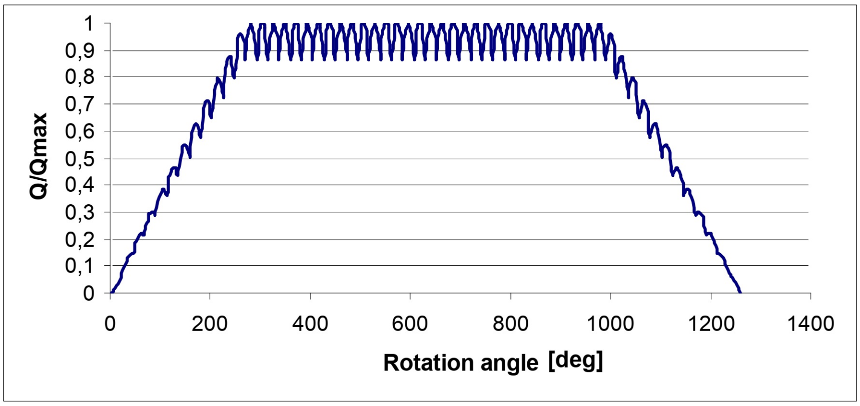
The following criterion for calculated blade stresses has to be fulfilled.

$$\frac{\sigma_{refz}}{\sigma_{st}} \geq 1{,}5 \tag{22}$$

where,

σ_{st} is the calculated stress for the design loads. If FEM analysis is used in estimating the stresses, von Mises Stresses shall be used.





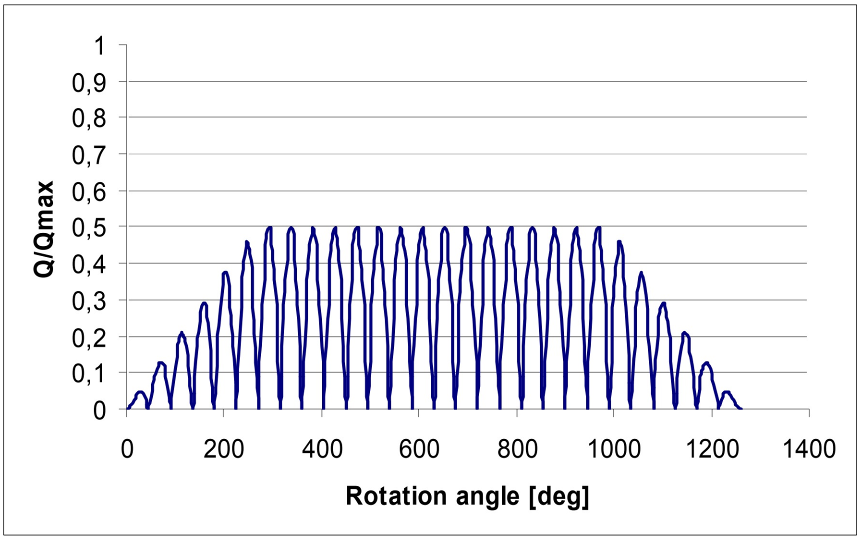


Figure 13.5: The shape of the propeller ice torque excitation for 90, and 135 degree single blade impact sequences and 45 degree double blade impact sequence. (Figures apply for propellers with 4 blades.)

6.2.3 Blade tip and edge thickness $t_{1.0\ E}$, t_E

The blade edges and tip have to be designed such that during normal operation, ice contact and ice milling no essential damage can be expected.

The blade tip thickness has to be greater than $t_{1.0\ E}$ given by the following formula:

$$t_{1.0\ E} = (t_{1.0\ B} + 2 \cdot D)\sqrt{\frac{500}{\sigma_{ref}}} \quad [mm] \tag{23}$$

The tip thickness $t_{1.0\ E}$ has to be measured at a distance X_{th} perpendicular to the contour edge, above 0,975 R. It needs to be demonstrated that the thickness is smoothly interpolated between lower bound leading edge thickness at 0,975R, tip and lower bound trailing edge at 0,975R. The basic tip thickness $t_{1.0\ B}$ has to be chosen according to Table 13.19

Table 13.20: Basic tip thickness for propeller blades.

ICE CLASS	ES1	ES2	ES3	ES4
$t_{1.0\ B}$ [mm]	8	8,75	9,75	11

$$X_{th} = \text{MIN}(0,025\ c_{0,975}; 45) \quad [\text{mm}] \tag{24}$$

X_{th} = distance from the blade edge [mm]

$c_{0,975}$ = chord length at 0,975 · R [mm]

The blade edge thickness t_E measured at a distance of X_{th} along the cylindrical section at any radius up to 0,975 R has to be not less than 50 % of the required tip thickness. This requirement is not applicable to the trailing edge of non-reversible propellers.

6.2.4 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 shall be calculated and the acceptability criterion for fatigue should be fulfilled as given in this Section. The equivalent stress is normalized for 100 million cycles. If the following criterion is fulfilled fatigue calculations according to this chapter are not required.

$$\sigma_{exp} \geq B_1 \cdot \sigma_{ref2}{}^{B_2} \cdot \log(N_{ice})^{B_3} \tag{25}$$

where B_1, B_2 and B_3 coefficients for open and ducted propellers are given in the table below.

Table 13.21:

	Open Propeller	Ducted propeller
B_1	0,00270	0,00184
B_2	1,007	1,007
B_3	2,101	2,470

σ_{exp} according to Table 13.23, if not known.

For calculation of equivalent stress two types of S-N curves are available.

Two slope S-N curve (slopes 4.5 and 10), see Fig.13.4.

One slope S-N curve (the slope can be chosen), see Fig. 13.5.

The type of the S-N curve shall be selected to correspond to the material properties of the blade. If S-N curve is not known the two slope S-N curve shall be used.

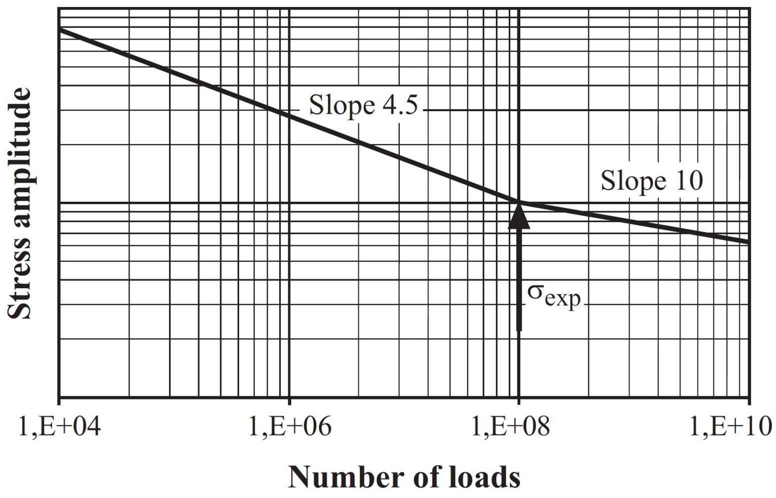


Figure 13.6: Two-slope S-N curve

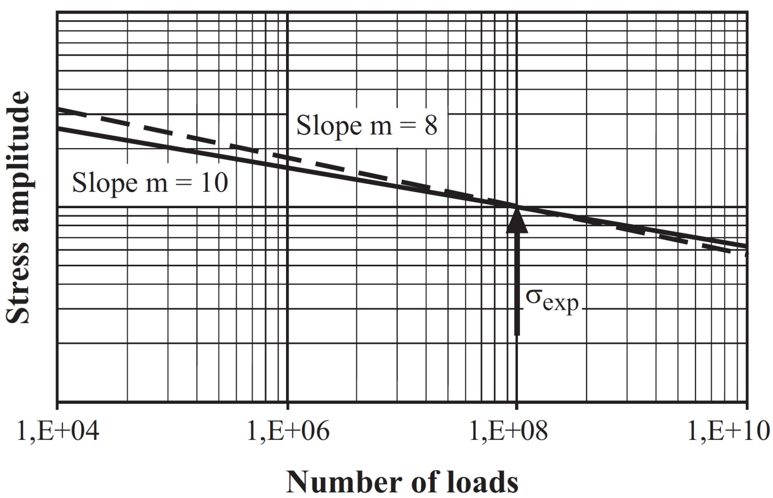


Figure 13.7: Constant-slope S-N curve

Equivalent fatigue stress

The equivalent fatigue stress for 100 million stress cycles which produces the same fatigue damage as the load distribution is:

$$\sigma_{fat} = \rho \cdot (\sigma_{ice})_{max} \quad [MPa] \tag{26}$$

where:

$$(\sigma_{ice})_{max} = 0,5 \cdot ((\sigma_{ice})_{fmax} - (\sigma_{ice})_{bmax}) \quad [MPa] \tag{27}$$

$(\sigma_{ice})_{max}$ is the mean value of the principal stress amplitudes resulting from design forward and backward blade forces (F_f and F_b) at the location being studied.

$(\sigma_{ice})_{fmax}$ is the principal stress resulting from forward load (F_f)

$(\sigma_{ice})_{bmax}$ is the principal stress resulting from backward load (F_b)

In calculation of $(\sigma_{ice})_{max}$, case 1 and case 3 (or case 2 and case 4) are considered as a pair for $(\sigma_{ice})_{fmax}$, and $(\sigma_{ice})_{bmax}$, calculations. Case 5 is excluded from the fatigue analysis.

Calculation of ρ parameter 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.

$$\rho = C_1 \cdot (\sigma_{ice})_{max}{}^{C_2} \cdot \sigma_{fl}{}^{C_3} \cdot \log(N_{ice})^{C_4} \tag{28}$$

where:

$$\sigma_{fl} = \gamma_\varepsilon \cdot \gamma_v \cdot \gamma_m \cdot \sigma_{exp} \quad [MPa] \tag{29}$$

where γ_ε is the reduction factor for scatter and test specimen size effect

γ_v is the reduction factor for variable amplitude loading

γ_m is the reduction factor for mean stress

σ_{exp} is the mean fatigue strength of the blade material at 10^8 cycles to failure in seawater (see Table 13.21).

The following values should be used for the reduction factors if actual values are not available:

γ_ε = 0,67,

γ_v = 0,75, and γ_m = 0,75.

The coefficients C_1, C_2, C_3, and C_4 are given in Table 13.21.

Table 13.22:

	Open Propeller	Ducted propeller
C_1	0,000711	0,000509
C_2	0,0645	0,0533
C_3	-0,0565	-0,0459
C_4	2,22	2,584

Calculation of ρparameter for constant-slope S-N curve

For materials with a constant-slope S-N curve – see Fig. 13.5 - the ρ factor shall be calculated with the following formula:

$$\rho = \left(G \frac{N_{ice}}{N_R}\right)^{\frac{1}{m}} (\ln(N_{ice}))^{-\frac{1}{k}} \tag{30}$$

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 (=100 million)

Values for the G parameter are given in Table 13.22. Linear interpolation may be used to calculate the G value for other m/k ratios than given in the Table 13.22.

Table 13.23: Value for the G parameter for different m/k ratios

m/k	G	m/k	G	m/k	G
3	6	5,5	287,9	8	40320
3,5	11,6	6	720	8,5	119292
4	24	6,5	1871	9	362880
4,5	52,3	6	5040	9,5	1,133E6
5	120	7,5	14034	10	3,623E6

6.2.5 Acceptability criterion for fatigue

The equivalent fatigue stress at all locations on the blade has to fulfil the following acceptability criterion:

$$\frac{\sigma_{fl}}{\sigma_{fat}} \geq 1,5 \qquad (31)$$

where:

$$\sigma_{fl} = \gamma_\varepsilon \cdot \gamma_v \cdot \gamma_m \cdot \sigma_{exp} \quad [MPa] \qquad (32)$$

Symbols according 6.2.4

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 shall be designed to withstand the maximum and fatigue design loads, as defined in 5. The safety factor against yielding S_Q shall be greater than 1,3 and that against fatigue S_F greater than 1,5. In addition, the safety factor for loads resulting from loss of the propeller blade (F_{ex}) through plastic bending as defined in 5.4 S_{Fex} shall be greater than 1,0 against yielding.

Table 13.24: Stress σ_{exp} for different materials

σ_{exp} for different materials types			
Bronze and brass (a = 0,10)		**Stainless steel (a = 0,05)**	
Mn-Bronze, CU1 (high tensile brass)	72 MPa	Martensitic (12Cr 1Ni)	95 MPa
Mn-Ni-Bronze, CU2 (high tensile brass)	72 MPa	Martensitic (13Cr 1Ni/13Cr 6 Ni)	120 MPa
Ni-Al-Bronze, CU3	110 MPa	Martensitic (16Cr 5Ni)	131 MPa
Mn-Al-Bronze, CU4	80 MPa	Austenitic (19Cr 10Ni)	105 MPa

6.3.1 Propeller blade mounting

The propeller blade has normally to be mounted using shear pin(s) and blade retaining bolts.

The thread core diameter of blade retaining bolts shall not be less than

$$d_{bb} = 41 \cdot \sqrt{\frac{F_{ex} \cdot S_{Fex} \cdot (0,8D - d) \cdot \alpha_A}{\sigma_{yield} \cdot Z_{bb} \cdot PCD}} \quad [mm] \qquad (33)$$

where:

F_{ex} = according to 5.4 [kN]
PCD = pitch circle diameter of bolt holes [m]
Z_{bb} = number of bolts
α_A = bolt tightening factor (c.f. Section 6)
α_{yield} = yield strength of bolt material [MPa]

6.3.2 CP mechanism

A maximum spindle torque resulting from the blade bending force (F_{ex}) applied as defined in 5.4 must not result in yielding of transmitting components. A reduction of the spindle torque by friction between blade, blade carrier and hub may be taken into account applying a friction coefficient of μ = 0,1.

.1 Blade shear pins

The required minimum diameter of shear pins between blade and blade carrier can be determined according to the following formula:

$$d_{sp} = 51 \cdot \sqrt{\frac{Q}{\sigma_{yield} \cdot Z_{sp} \cdot PCD}} \quad [mm] \tag{34}$$

where:

Q	=	Max (Q_{Smax}; S_Q; Q_{SFex} ; S_{Fex}) maximum spindle torque enlarged by safety factor
Q_{SFex}	=	Fex ·l_m [kNm]
l_m	=	maximum of 2/3 distance between blade spindle axis and leading and trailing edge respectively, measured at 0,8R [m]
Z_{sp}	=	number of shear pins
PCD	=	pitch circle diameter of shear pin holes [m]
α_{yield}	=	yield strength of pin material [MPa]

A reduction of the spindle torque Q due to friction between blade flange and blade carrier caused by blade bolt clamping force may be taken into account.

.2 Actuating pin

The minimum diameter and maximum height of the actuating pin respectively, has to be such that the following condition is complied with:

$$\sigma_r = 1800 \cdot \frac{F_p}{{d_p}^2} \sqrt{\left(\frac{hp}{dp}\right)^2 + 1,5} \quad [MPa] \tag{35}$$

where:

d_p	=	diameter of actuating pin [mm]	
h_p	=	height of actuating pin [mm]	
F_p	=	maximum force at 1/3 the pin height amplified by the respective safety factor	
	=	$Max(Q_{Smx}; S_Q; Q_{Sfex}; S_{Fex})/l_p \quad [kN]$	(36)
l_p	=	distance of actuating pin and spindle axis [m]	

Stress raisers have to be considered in the fatigue calculation. A Weibull load distribution has to be applied for the fatigue analysis based on the spindle torque amplitude resulting from applying formula (5) for F_f and F_b. The number of load cycles shall be taken as given in 5.1.7. For steel castings and forgings normally the highest amplitude with lowest cycle number will be dimensioning.

6.4 Propulsion shaft line

The shafts and shafting components, such as the thrust and stern tube bearings, couplings, flanges and sealings, shall be designed to withstand the propeller/ice interaction loads as given in 5. The safety factor is to be at least S_Q = 1,3.

6.4.1 Shafts and shafting components

The ultimate load resulting from total blade failure as defined in 5.4 should not cause yielding in shafts and shaft components. The loading shall consist of the combined axial, bending, and torsion loads, wherever this is significant. The minimum safety factor against yielding is to be S_{Fex} = 1,0 for bending and torsional stresses. If detailed torsional loads according to 5.3.2 cannot be determined, the alternative torque calculation according 5.3.3 may be applied.

6.5 Detailed requirements in addition to FSICR

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/mm^2] in the area of the mean taper diameter $d_{\Theta mean}$ is to be determined by formula (37).

Where:

$$P_E = \frac{\sqrt{\Theta^2 \cdot T_r^2 + f \cdot (K_r^2 + T_r^2)} - \Theta \cdot T}{0,001 \cdot A \cdot f} \quad [Nmm^2] \tag{37}$$

where:

K_r = tangential force in the contact area

$$K_r = \frac{Q_{peak}}{\left(\frac{d_{\Theta mean}}{2}\right)} \quad [kN] \tag{38}$$

A, Θ = see Section 6
$d_{\Theta mean}$ = mean cone diameter [m]

The calculation has to be performed for Tr according to formula (12) and (13). Tr 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 realised as a minimum.

$$f = \left(\frac{\mu_o}{S}\right)^2 - \Theta^2 \tag{39}$$

The safety factor has to be at minimum S = 2,0, however $S \cdot Q_{peak} \geq 2{,}8 \cdot Q_{e\ max}$ has to be ensured.

Other symbols in accordance with Section 4 and Section 6.

Keyed connections may be applied, provided that the peak torque Q_{peak} is transmitted via friction. Keyed connections are not permitted for ice class **ES4**.

6.5.2 Propulsion shafts

The plain shaft diameter at the aft end should comply at minimum with the calculated diameter according to

$$d_{sp} = 140 \cdot \sqrt[6]{\left((F_{ex}) \cdot S_{Fex} \cdot \frac{D}{\sigma_{yield}}\right)^2 + 5,6 \cdot \left(\frac{Q_r \cdot S_Q}{\sigma_{yield}}\right)^2} \cdot \sqrt[3]{\frac{1}{1 - \frac{{d_i}^4}{d_{ps}^4}}} \quad [mm] \tag{40}$$

where:

d_i = inner shaft diameter [mm]

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 equation (40), while F_{ex} = 0 and Q_r is replaced by Q_{peak}.

6.5.4 Shaft fatigue calculation

A load distribution as defined in 5.1.6, 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 (see Section 16) 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_f. A load distribution according to 5.1.6 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 against slipping 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

.1 Shrink fit

A shrink fit calculation may be performed according to formula (37) 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 paragraph 5.3.1 may be applied.

.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 class **ES4**, an emergency repair can be performed without dry-docking.

.3 Flange connections

Section 4, D.4. has to be applied accordingly.

1) Any additional stress raisers such as recesses for bolt heads shall not interfere with the flange fillet.

2) The flange fillet radius is to be at least 10 % of the shaft diameter.

3) The diameter of ream fitted (light press fit) bolts shall be chosen so that the peak torque Q_{peak} (see 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.

4) The bolts are to be designed so that blade failure load F_{ex} (see 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 d_{sp} of the fitted pin is to be determined by applying formula (41).

$$d_{sp} = 67 \sqrt{\frac{(Q_{peak}) \cdot S_Q}{PCD \cdot Z_{sp} \cdot \sigma_{yield}}} \quad [mm] \tag{41}$$

where:

d_{sp} = root diameter of shear pin [mm]
PCD = pitch circle diameter of bolts [m]
Z_{sp} = number of shear pins
σ_{yield} = yield strength of shear pin material [MPa]

The thread core diameter dk of propeller flange bolts shall not be less than

$$d_k = 41 \sqrt{\frac{F_{ex} \cdot \left(0,8\frac{D}{PCD}+1\right) \cdot \alpha_A}{\frac{\sigma_{yield}}{S_{Fex}} \cdot Z_b}} \quad [mm] \qquad (42)$$

where:

PCD	=	pitch circle diameter of bolts [m]
Z_b	=	number of bolts
α_A	=	application factor see Section 6
σ_{yield}	=	yield strength of bolt material [MPa]

6.6 Azimuth main propulsors

In addition to the above requirements, special consideration shall be given to those loading cases which are extraordinary for propulsion units when compared with conventional propellers. The estimation of loading cases has to reflect the way of operation of the ship and the thrusters. In this respect, for example, the loads caused by the impacts of ice blocks on the propeller hub of a pulling propeller have to be considered. Furthermore, loads resulting from the thrusters operating at an oblique angle to the flow have to be considered. The steering mechanism, the fitting of the unit to the ship hull, and the body of the thruster shall be designed to withstand the loss of a blade without damage. The loss of a blade shall be considered for the propeller blade orientation which causes the maximum load on the component being studied. Typically, top-down blade orientation places the maximum bending loads on the thruster body.

Azimuth thrusters shall also be designed for estimated loads caused by thruster body/ice interaction. The thruster has to withstand the loads obtained when the maximum ice blocks, which are given in 3, strike the thruster body when the ship is at a typical ice operating speed. In addition, the design situation in which an ice sheet glides along the ship's hull and presses against the thruster body should be considered. The thickness of the sheet should be taken as the thickness of the maximum ice block entering the propeller, as defined in 3.

6.7 Vibrations

The propulsion system shall be designed in such a way that the complete dynamic system is free from harmful torsional, axial, and bending resonances at a 1_{st}-order blade frequency within the designed running speed range, extended by 20 per cent above and below the maximum and minimum operating rotational speeds. If this condition cannot be fulfilled, a detailed vibration analysis has to be carried out in order to determine that the acceptable strength of the components can be achieved.

7. Alternative design procedure

7.1 Scope

As an alternative to 5 and 6, a comprehensive design study may be carried out to the satisfaction of BKI. The study has to be based on ice conditions given for different ice classes in 3. It has to include both fatigue and maximum load design calculations and fulfil the pyramid strength principle, as given in 6.1.

7.2 Loading

Loads on the propeller blade and propulsion system shall 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.

7.4 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 6.2, respective counter measures have to be taken. Ice strengthening according to 6.2 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 7.4.*

8. Gears

8.1 General

Gears in the main propulsion plant of ships with ice classes **ES1**, **ES2**, **ES3** and **ES4** are to be of strengthened design. Besides the strengthening prescribed here for the design of tooting, 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}

$$Q_{rg} = Q_{emax} + 0,75 \cdot Q_{max} \cdot \frac{I_H \cdot u^2}{I_L + I_H \cdot u^2} \geq K_A \cdot Q_n \quad [kNm] \tag{43}$$

Q_r	=	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 5.3.2, 5.3.3
I_H	=	mass moment of inertia of all components rotating at input rpm [kgm^2]
I_L	=	mass moment of inertia of all components rotating at output rpm (including
	=	mass moment of inertia of all components propeller with entrained water) [kgm^2]
K_A	=	application factor in accordance with Section 5, Table 5.3
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
- $K_A \cdot Q_n$ 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 6335 – Pt. 6)
For dimensioning of the tooth system, the following ice class strengthening factor has to be used.

$$K_E = \frac{Q_{eq,g}}{Q_{emax}} \tag{44}$$

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 acc. 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.

$$K_E = \frac{Q_{rg}}{Q_n} \geq K_A \tag{45}$$

8.2.1 Tooth systems The calculated safety factors for tooth root and flank stress are to satisfy the requirements stated in Section 5, Table 5.1 when the application factor K_A is substituted by the calculated ice class strengthening facto K_E in equation (5.1) and (5.3).

8.2.2 Gear shafts

$$d_E = q_E \cdot d \tag{46}$$

d_E = increased gear shaft diameter [mm]
d = gear shaft diameter in accordance with Section 5, D.1. [mm]

$$q_E = 0,84 \sqrt[3]{K_E} \geq 1,0 \tag{47}$$

K_E = ice class strengthening factor in accordance with formula (44)

8.2.3 Shrink fits

Shrink fits within the gear may be calculated according to formula (37) 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 5, 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_{Nenn}, they are able to withstand safely brief torque shocks T_E [Nm] of magnitude:

$$T_E = K_E \cdot T_{Nenn} \tag{48}$$

where:

$$T_E \leq T_{Kmax1}$$

K_E = ice class strengthening factor in accordance with formula (44)
T_{Nenn} = 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 11, I.2. have 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 the Rules for Hull Structures (Pt.1, Vol.II), Sec. 14 and 15.

12. Electric propeller drive

For ships with electrical propeller drive, see Rules for Electrical Installations (Pt.1, Vol.IV), Sec. 13.

13. Lateral thrusters

Ice strengthening of the machinery part of lateral thrusters is not required as long as the thruster is protected against ice contact by suitable means, such as grids at the tunnel inlets.

If such protection does not exist, the above mentioned. 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.

D. Necessary Reinforcements for Ice Class ES

1. Propeller shafts, intermediate shafts, thrust shafts

1.1 General

The necessary propeller shaft reinforcements in accordance with formula (1), in conjunction with the formulae and factors specified in Section 4.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.

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 formula (2).

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.

1.2 Reinforcements

$$d_E = C_{EW} \cdot d \tag{1}$$

d_E = increased diameter of propeller, intermediate or thrust shaft [mm]
d = shaft diameter according to Section 4.C.2. [mm]
C_{EW} = ice class strengthening factor

$$c \cdot \sqrt[3]{1 + \frac{85 \cdot m_{ice}}{{P_W}^{0,6} \cdot {n_2}^{0,2}}} \geq 1.0 \tag{2}$$

P_W = main engine power [kW]
n_2 = propeller shaft speed [Rpm]
m_{ice} = ice class factor according to Table 13.24
c = 0,7 for shrink fits in gears
c = 0,71 for the propeller shafts of fixed-pitch propellers
c = 0,78 for the propeller shafts of controllable pitch propellers

In the case of ducted propellers, the values of c can be reduced by 10 %.

Table 13.25: Values of ice class factor m_{ice}

Ice class	ES	ES1	ES2	ES3	ES4
m_{ice}	8	12	13	16	21

2. Shrunk joints

When designing shrink fits in the shafting system and in gearboxes, the necessary pressure per unit area P_E. [N/mm^2] is to be calculated in accordance with for Formula (3).

$$P_E = \frac{\sqrt{\Theta^2 + T^2 \cdot f \cdot (C_A^2 \cdot c_e^6 \cdot Q^2 + T^2)} - \Theta \cdot T}{A \cdot f} \tag{3}$$

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.

$$f = \left(\frac{\mu_o}{S}\right) - \Theta^2 \tag{4}$$

For direct coupled propulsion plants with a barred speed range is has to be confirmed by separate calculation that the vibratory torque in the main resonance is transmitted safety. 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.

c_A = see Section 4
c_e = $0,89 \times C_{EW} \geq 1,0$ (5)
c_{EW} to be calculated according to 1.2, the higher value of the connected shaft ends has to be taken for the coupling

Other symbols in accordance with Section 4.D.4.

3. Propellers

3.1 General

The propellers of ships with ice classes **ES** must be made of the cast copper alloys or cast steel alloys specified in Section 6.

3.2 Strengthening

3.2.1 Blade sections

$$t_E = C_{EP} \cdot t \quad [mm] \tag{6}$$

= increased thickness of blade section

t = blade section thickness in accordance with Section 6, C.2.

If $C_{EP} \geq C_{dyn}$ then

$t_E = t$

If $C_{EP} > C_{dyn}$ then

$t_E = (C_{EP})/C_{dyn} \cdot t$

C_{EP} = ice class strengthening factor

$$f \cdot \sqrt{1 + \frac{21 \cdot z \cdot m_{ice}}{p_w^{0,6} \cdot n_2^{0,2}}} \geq 1.0 \tag{7}$$

f = 0,62 for solid propellers

= 0,072 for controllable pitch propellers

In the case of ducted propellers, the values of f may be reduced by 15 %.

z = number of blades

m_{ice}, P_w, n_2 = see 1.2

C_{dyn} = dynamic factor in accordance with Section 6, formula (3)

3.2.2 Blade tips

$$t_{1,0E} = \sqrt{\frac{500}{C_w}} \cdot (0,002 \cdot D + t') \tag{8}$$

$t_{1,0E}$ = strengthened blade tip [mm]

t = increase in thickness [mm]

= 10 for ice class **ES**

D [mm] propeller diameter

Cw [N/mm^2] material factor in accordance with Section 6, C.1, Table 6.1

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 solid propellers and the thickness of the leading edge of controllable pitch propellers must, be equal for ice class **ES** to at least 35% of the blade tip $t_{1,0E}$ when measured at a distance of 1,25 · $t_{1,0E}$ 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 (8).

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 addition should be added to the blade thickness determined should be increased in order to achieve an adequate service time with respect to 3.2.4.

3.2.5 Propeller mounting

Where the propeller is mounted on the propeller shaft by the oil injection method, the necessary pressure per unit area P_E [N/mm^2] in the area of the mean taper diameter is to be determined by formula (9).

$$P_E = \frac{\sqrt{\Theta^2 + T^2 \cdot f \cdot (C_A^2 \cdot c_e^6 \cdot Q^2 + T^2)} - \Theta \cdot T}{A \cdot f} \tag{9}$$

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.

$$f = \left(\frac{\mu_o}{s}\right) - \Theta^2 \tag{10}$$

For direct coupled propulsion plants with a barred speed range is has to be confirmed by separate calculation that the vibratory torque in the main resonance is transmitted safely.

c_e = ice class reinforcement factor in accordance with formula (5).

Other symbols in accordance with Section 6.

In the case of flanged propellers, the required diameter dsE of the alignment pin is to be determined by applying formula (11).

$$d_{sE} = C_{EW}{}^{1,5} \cdot d_s \tag{11}$$

d_{sE} = reinforced root diameter of alignment pin [mm]
d_s = diameter of alignment pin for attaching the propeller in accordance with Section 4, D.4.2. [mm]
C_{EW} = ice class reinforcement factor in accordance with formula (2).

Other symbols in accordance with Section 6.

4. Gears

4.1 General

Gears in the main propulsion plant of ships with ice classes are not to be strengthened

5. Sea chests and discharge valves

Sea chests and discharge valves are to be designed in accordance with Section 11, I.2.

6. Steering gear

The dimensional design of steering gear components is to take account of the rudderstock diameter specified in Rules for Hull Structures (Pt.1, Vol.II), Sec. 14 and 15.

7. Electric propeller drive

For ships with electrical propeller drive, see Rules for Electrical Installations (Pt.1, Vol. IV), Sec.13.

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Section 14 Steering Gears, Rudder Propeller Units, Lateral Thrust Units, Winches, Hydraulic Control Systems, Fire Door Control Systems, Stabilizers, Water Jets

A. General

1. General

1.1 Scope

The requirements contained in this subsection. apply to electrohydraulic and hand hydraulic steering gear operating a rudder for the purpose of steering the vessel, 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 the Rules for Hull (Part.1, Vol.II) Sec. 14.

Steering gear other than electrohydraulic type, will be accepted provided that safety and reliability can be documented to be equivalent to or better than the requirements of this section.

The requirements set out in, SOLAS II-1/29 and SOLAS II-1/30 as well as related Guidelines (see Annex 2 of IMCO document MSC XLV/4 are integral part of this rules and are to be applied in their full extent.

For integrated propulsion and steering units such as azimuth drives, waterjets, etc. the interpretation of SOLAS II-1/29 as given in Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Sect. 11, SC242, is to be applied. See also B.

1.2 Documents for approval

Assembly and general drawings of all steering gears, diagrams of the hydraulic and electrical equipment together with detail drawings of all important load-transmitting components are to be submitted to BKI in electronic format. The plans and related documents submitted for approval and review may be itemized as follows:

- Arrangement of steering gear machinery,
- Hydraulic piping system diagram,
- Power supply system diagrams,
- Motor control systems diagrams,

— Steering control system diagrams,

— Instrumentation and alarm system diagrams,

— Drawings and details for rudder actuators,

— Drawings and detailes for torque transmitting parts and parts subjected to internal hydraulic pressure,

— Details and specifications of welding procedure,

— Rated torque

The drawings and other documents are to contain all the information relating but not limited to materials, working pressures, pump delivery rates, drive motor ratings etc. necessary to enable the documentation to be checked.

Regarding seating see the Guidance for Seating of Diesel Engine Installation (Pt.1, Vol.U).

2. Definitions

For the purpose of this Section the definitions in Table 14.1 are applied.

Table 14.1: Definitions

Item	Description
Steering gear control system	The equipment by which orders are transsmitted 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. Steering gear control system is also understood to cover ”the equipment required to control the steering gear power actuating system”
Main steering gear	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.
Steering gear power unit	in the case of electric steering gear, and electric motor and its associated electrical equipment, in the case of electrohydraulic 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.
Auxiliary steering gear	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.
Power actuating system	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.
Maximum ahead service speed	The greatest speed which the ship is designed to maintain in service at sea at her deepest sea going draught at maximum propeller RPM and corresponding engine MCR.
Hydraulic locking	means all situations where two hydraulic systems (usually identical) oppose each other in such a way that it may lead to loss of steering. It can either be caused by pressure in the two hydraulic systems working against each other or by hydraulic ”bypass” meaning that the systems puncture each other and cause pressure drop on both sides or make it impossible to build up pressure.
Rudder actuator	The component which converts directly hydraulic pressure into mechanical action to move the rudder
Maximum working pressure	The maximum expected pressure in the system when the steering gear is operated to comply with SOLAS II-1/29.3.2.

3. Materials

3.1 Approved materials

3.1.1 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 complying the Rules for Materials (Pt.1, Vol.V). In general, such material should not have an elongation of less than 12 % nor a tensile strength in excess of 650 N/mm^2.

With the consent of BKI, cast iron may be used for certain components.

Pressure vessels in general are to be made of steel, cast steel or nodular cast iron (with a predominantly ferritic matrix).

For welded structures, the Rules for Welding (Pt.1, Vol.VI), are to be observed.

3.1.2 Casings with integrated journal and guide bearings on ships with a nozzle rudder and ice class are not to be made of grey cast iron.

3.1.3 The pipes of hydraulic steering gears are to be made of seamless or longitudinally welded steel tubes. The use of cold-drawn, annealed tubes is not permitted.

At points where they are exposed to damage, copper pipes for control lines are to be provided with protective shielding and are to be safeguarded against hardening due to vibration by the use of suitable fastenings.

3.1.4 High-pressure hose assemblies may be used for short pipe connections subject to compliance with Section 11.T., if this is necessary due to vibrations or flexibly mounted units.

3.1.5 The materials used for pressurized components including the seals are to be suitable for the hydraulic oil in use.

3.2 Testing of materials

3.2.1 The materials of important force-transmitting components of the steering gear as well as of the pressurized casings of hydraulic steering gears are to be tested under the supervision of BKI in accordance with the Rules for Materials (Pt.1, Vol.V).

For pressurized oil pipes the requirements according to Section 11, Table 11.3 are to be observed.

For welded pressurized casings, the Rules for Welding (Pt.1, Vol.VI), are to be considered.

3.2.2 In the case of small hand-operated main steering gears and small manually operated auxiliary steering gear BKI may dispense with testing the materials of individual components such as axiometer gear shafts, etc.

4. Design and equipment

4.1 Number of steering gears

Every ship is to 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 rudder stock. BKI may agree to components being used jointly by the main and auxiliary steering gear.

For a ship fitted with multiple steering systems, such as but not limited to azimuthing propulsors or water jet propulsion systems, the requirement in 4.1 is considered satisfied if each of the steering systems is equipped with its own dedicated steering gear.

4.2 Main steering gear

4.2.1 Main steering gears are, with the rudder fully immersed in calm water, to be capable of putting the rudder from 35 degree port to 35 degree starboard and vice versa at the ship's speed for which the rudder has been designed in accordance with the Rules for Hull (Pt.1, Vol.II) Sec.14. The time required to put the rudder from 35 degree port to 30 degree starboard or vice versa is not to exceed 28 seconds.

The main steering gear is to be as a rule power operated. In every tanker, chemical tanker or gas carrier of 10000 GT and upwards and in every other ship of 70000 GT and upwards, the main steering gear is to comprise two or more identical power units.

4.2.2 Manual operation is acceptable for rudder stock diameters up to 120 mm calculated for torsional loads in accordance with the Rules for Hull (Pt.1, Vol.II) Sec.14.C.1. Not more than 25 turns of the hand wheel are to 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 hand wheel is generally not to exceed 200 N.

4.3 Auxiliary steering gear

4.3.1 Auxiliary steering gears are, with the rudder fully immersed in calm water, to be capable of putting the rudder from 15 degree port to 15 degree starboard or vice versa within 60 seconds at 50% of the ship's maximum speed, subject to a minimum of seven knots. Hydraulically operated auxiliary steering gears are to be fitted with their own piping system independent of that of the main steering gear. The pipe or hose connections of steering gears are to be capable of being shut off directly at the pressurized casings.

4.3.2 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 ReH = 235 N/mm^2.

4.4 Power Unit

4.4.1 Where power operated hydraulic main steering gears are equipped with two or more identical power units, no auxiliary steering gear need be installed provided that the following conditions are fulfilled.

4.4.2 On passenger ships, requirements 4.2.1 and 5.1 are to be complied with while any one of the power units is out of operation.

4.4.3 On cargo ships, the power units are to be designed in a way that requirements 4.2.1 and 5.1 are complied with while operating with all power units.

The main steering gear of tankers, chemical tankers or gas carriers of 10.000 GT and upwards is to comprise either:

- two independent and separate power actuating systems (power units(s), hydraulic pipes, power actuator), each capable of meeting the requirements as set out in 4.2.1 and 5.1, or

- at least two identical power actuating systems which, acting simultaneously in normal operation, are to be capable of meeting the requirements as set out in 4.2.1 and 5.1.

.1 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 are to be provided for quickly regaining control of one steering system.

For tankers, chemical tankers or gas carriers of 10000 GT and upwards, steering capability is to be regained within 45 second after a single failure.

.2 In the event of a loss of hydraulic oil, it is to be possible to isolate the damaged system in such a way that the second control system remains fully operable.

4.5 Rudder angle limitation

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 degree on both sides. Deviations from this requirement are permitted only with the consent of BKI.

4.6 End position limitation

For the limitation by means of stoppers of the end positions of tillers and quadrants, see the Rules for Hull (Pt.1, Vol.II) Sec.14.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 is to be fitted within the rudder actuator.

4.7 Locking equipment

Steering gear systems are to be equipped with a locking system effective in all rudder positions, see also Rules for Hull (Pt.1, Vol II) Sec.14.G.

Where hydraulic plant is fitted with shut-offs directly at the cylinders or rotary vane casings, special locking equipment may be dispensed with.

For steering gears with cylinder units which may be independently operated these shut-off devices do not have to be fitted directly on the cylinders.

4.8 Overload protection

4.8.1 Power-operated steering gear systems are to be equipped with overload protection (slip coupling, relief valves) to ensure that the driving torque is limited to the maximum permissible value.

The overload protection device is to be secured to prevent re-adjustment by unauthorized persons. Means are to 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 4.7 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 rudder stock cannot cause rupture, deformation or other damage of the pressurized casing.

4.8.2 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.

The relief valves are to be set to a pressure value equal or higher than 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 5.1).

The minimum discharge capacity of the relief valve(s) are not to be less than 1,1 times the total capacity of the pumps, which can deliver through it (them).

With this setting any higher peak pressure in the system than 1,1 times the setting pressure of the valves is to be prohibited.

4.9 Controls

4.9.1 Control of the main and auxiliary steering gears is to be exercised from a steering station on the bridge. Controls are to be mutually independent and so designed that the rudder cannot move unintentionally.

4.9.2 Means are also to be provided for exercising control from the steering gear compartment. The transmission system is to be independent of that serving the main steering station.

4.9.3 Suitable equipment is to be installed to provide means of communication between the bridge, all steering stations and the steering gear compartment.

4.9.4 Failures of single control components (e.g. control system for variable displacement pump or flow control valve) which may lead to loss of steering are to cause an audible and visible alarm on the navigating bridge, if loss of steering cannot be prevented by other measures.

4.10 Rudder angle indication

4.10.1 The rudder position is to be clearly indicated on the bridge and at all steering stations. Where the steering gear is operated electrically or hydraulically, the rudder angle is to be indicated by a device (rudder position indicator) which is actuated either by the rudder stock 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 is to 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 Rules for Electrical Installations (Pt.1, Vol.IV) Sec.9.C.

4.10.2 The actual rudder position is also to be indicated at the steering gear itself.

An additional rudder angle indicator fitted at the main engine control station is recommended.

4.11 Piping

4.11.1 The pipes of hydraulic steering gear systems are to be installed in such a way as to ensure maximum protection while remaining readily accessible.

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.

4.11.2 For the design and dimensions of pipes, valves, fittings, pressure vessels etc., see Section 8 and Section 11.A, B, C, D and T.

4.12 Oil level indicators, filters

4.12.1 Tanks within the hydraulic system are to be equipped with oil level indicators.

4.12.2 The lowest permissible oil level is to be monitored. Audible and visual alarms are to be provided for the navigating bridge and in the machinery space or machinery control room. The alarm on the navigating bridge is to be an individual alarm.

4.12.3 Arrangements are to be provided to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system.

4.13 Storage tank

In hydraulic operated 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.

This 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.

4.14 Arrangement

Steering gears are to be so installed in away to be accessible at any time and can be easily maintainable.

4.15 Electrical equipment

For the electrical equipment, Rules for Electrical Installations (Pt.1, Vol.IV) Sec.7.A. have to be observed.

4.16 Seating

Seating of the steering gear has to be applied according to Guidance for Seating of Diesel Engine Installation (Pt.1, Vol.U). 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.

5. Power and dimensioning

5.1 Power of steering gears

The power of the steering gear has to comply with the requirements set out in 4.2 and 4.3, see also SOLAS Part C II-1/29.

The maximum effective torque for which the steering gear is to be equipped is not to be less than:

$$M_{max} = \frac{\left(\frac{D_t}{4,2}\right)}{K_r} \quad (1)$$

D_t = theoretical rudder stock diameter [mm], derived from the required hydrodynamic rudder torque for the ahead running conditions in accordance with the Rules for Hull (Pt.1, Vol.II) Sec.14.C.1 and Sec.15.B.9 and D.3.7.

The working torque of the steering gear is to be larger than the hydrodynamic torque QR of the rudder according to Rules for Hull (Pt.1, Vol.II) Sec.14.B.1.2, B.2.2, B.2.3 and cover the friction moments of the related bearing arrangement.

The corresponding maximum working pressure is the maximum expected pressure in the system, when the steering gear is operated to comply with the power requirements as mentioned above.

Frictional losses in the steering gear including piping have to be considered within the determination of the maximum working pressure.

The design pressure pc for calculation 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 the relief valves as described under 4.8.2.

In the case of multi-surface rudders controlled by a common steering gear the relevant diameter is to be determined by applying the formula:

$$D_{ti} = \sqrt[3]{D_{t1}^3 + D_{t2}^3 + ...}$$

k_r = material characteristic

$$k_r = \left(\frac{235}{R_{eH}}\right)^e \quad (2)$$

e = 0,75 where R_{eH} > 235 N/mm^2
= 1,0 where R_{eH} ≤ 235 N/mm^2

R_{eH} = yield strength of rudder stock material. The applied value for R_{eH} is not to be greater than 450 N/mm^2 or 0,7 · R_m, whichever is less [N/mm^2]

R_m = tensile strength [N/mm^2]

5.2 Design of transmission components

5.2.1 The design calculations for those parts of the steering gear which are not protected against overload are to be based on the elastic-limit torque of the rudder stock.

The elastic-limit torque to be used is

$$M_F = 2 \cdot \frac{\left[\frac{D}{4,2}\right]^3}{k_r} \tag{3}$$

D = minimum actual rudder stock diameter [mm]. The value used for the actual diameter need not be larger than 1,145 · D_t

The stresses in the components of the steering gear determined in this way are not to exceed the yield strength of the materials used. The design of parts of the steering gear with overload protection is to be based on the loads corresponding to the response threshold of the overload protection.

5.2.2 Tiller and rotary vane hubs made of material with a tensile strength of up to 500 N/mm^2 have to satisfy the following conditions in the area where the force is applied, see Fig 14.1:

Height of hub	$H \geq 1{,}0 \cdot D$ [mm]
Outside diameter	$D_a \geq 1{,}8 \cdot D$ [mm]

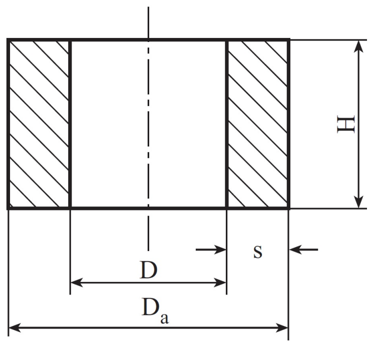


Figure 14.1: Hub dimension

In special cases the outside diameter may be reduced to:

D_a = 1,7 · D [mm]

but the height of the hub must then be at least:

H = 1,14 · D [mm]

5.2.3 Where materials with a tensile strength greater than 500 N/mm^2 are used, the section of the hub may be reduced by 10%.

5.2.4 Where the force is transmitted by clamped or tapered connections, the elastic-limit torque may be transmitted by a combination of frictional and positive locking mechanism using adequately pre-tensioned bolts and a key.

For the elastic limit torque according to formula (3), the thread root diameter of the bolts can be determined by applying the following formula:

$$d_k > 9,76 \cdot D\sqrt{\frac{1}{z \cdot k_r \cdot R_{eH}}} \quad \text{[mm]} \tag{4}$$

D = actual rudder stock diameter [mm]. The value used for the actual diameter need not be larger than 1,145 D_t

Z = total number of bolts

R_{eH} = yield strength of the bolt material [N/mm^2]

5.2.5 Split hubs of clamped joints are to be joined together with at least four bolts.

The key is not to be located at the joint in the clamp.

5.2.6 Where the oil injection method is used to join the rudder tiller or rotary vanes to the rudder stock, methods of calculation appropriate to elasticity theory are to be applied. Calculations are to be based on the elastic-limit torque allowing for a coefficient of friction μ_o = 0,15 for steel and μ_o = 0,12 for nodular cast iron. The von Misses equivalent stress calculated from the specific pressure p and the corresponding tangential load based on the dimensions of the shrunk joint is not to exceed 80% of the yield strength of the materials used.

5.2.7 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 working torque of streering gear (but not more than the elastic limit torque) allowing for a coefficient of friction of μ_o = 0,12. The von Misses equivalent stress calculated from the contact pressure p and the corresponding tangential load based on the dimensions of the shrunk-on connection is not to exceed 80% of the yield strength of the materials used.

When more than one circumferential tension components are used, the torque capacity of the connection is to be determined by adding the torques of the sole tension components and applying a reduction factor of 0,9.

6. Tests in the manufacturer's works

6.1 Testing of power units

The power units are required to undergo test on a test stand in the manufacturer's works.

6.1.1 For diesel engines, see Section 2.

6.1.2 For electric motors, see Rules for Electrical Installations (Pt.1, Vol.IV) Sec.21.

6.1.3 For hydraulic pumps and motors, the Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W) Sec.3.L is to be applied analogously. Where the drive power is 50 kW or more, this testing is to be carried out in the presence of the BKI Surveyor.

6.1.4 A power unit pump is to be subjected to a type test. The type test shall be for a 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. 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 no abnormal heating, excessive vibration or other irregularities are 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.

6.2 Pressure and tightness tests

Pressure components are to undergo the pressure test.

The test pressure is p_p

$$p_p = 1,5 \cdot p_c \tag{5}$$

p_c = design pressure for which a component or piping system is designed with its mechanical characteristics [bar].

For pressures above 200 bar the test pressure need not exceed p_c + 100.

For pressure testing of pipes, their valves and fittings, see Section 11.B.4 and T.5.

Tightness tests are to be performed on components to which this is appropriate.

6.3 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, hydrostatic and an operational test. Among other things the overload protection is to be adjusted at this time.

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 the ship. In these cases, at least functional testing under no-load conditions is to be performed in the manufacturer's works.

7. Shipboard trials

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:

7.1 The operational efficiency of the steering gear is to be proved during the sea trials. For this purpose, the Z manoeuvre corresponding to 4.2.1 and 4.3.1 is to be executed as a minimum requirement.

7.2 the steering gear, including demonstration of the performances required by Regulation 29.3.2 and 29.4.2. For controllable pitch propellers, the propeller pitch is to be at the maximum design pitch approved for the maximum continuous ahead R.P.M. at the main steering gear trial.

If the vessel cannot be tested at the deepest draught, steering gear trials shall be conducted at a displacement as close as reasonably possible to full-load displacement as required by Section 6.1.2 of ISO 19019:2005 on the conditions that either the rudder is fully submerged (zero speed waterline) and the vessel is in an acceptable trim condition, or the rudder load and torque at the specified trial loading condition have been predicted and extrapolated to the full load condition.

In any case for the main steering gear trial, the speed of ship corresponding to the number of maximum continuous revolution of main engine and maximum design pitch applies.

7.3 The steering gear power units, including transfer between steering gear power units.

7.4 The isolation of one power actuating system, checking the time for regaining steering capability.

7.5 the hydraulic fluid recharging system.

7.6 the emergency power supply required by the Rules for Electrical Installations (Pt.1, Vol.IV) Sec.7 A.2.3.

7.7 the steering gear controls, including transfer of control and local control.

7.8 the means of communication between the wheelhouse, engine room, and the steering gear compartment.

7.9 the alarms and indicators

7.10 where steering gear is designed to avoid hydraulic locking this feature shall be demonstrated

8. Operating instruction

Where applicable, following standard signboard should be fitted at a suitable place on steering control post on the bridge or incorporated into operating instruction on 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.

B. Rudder Propeller Units

1. General

1.1 Scope

The requirements of B are valid for the rudder propeller as main drive, the ship's manoeuvring station and all transmission elements from the manoeuvring station to the rudder propeller.

1.2 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 to BKI for approval. For propellers, this only applies to an input power exceeding 500 kW.

2. Materials

2.1 Approved materials

The selection of materials is subject, as and where applicable, to the provisions of A.2.1 and to those of Sections 4, 5 and 6.

2.2 Testing of materials

All important components of the rudder propeller involved in the transmission of torques and bending moments are to be tested under the supervision of BKI in accordance with Rules for Materials (Pt.1, Vol.V).

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.

3.2 Locking devices

Each rudder propeller is to be provided with a locking device to prevent unintentional movements of the steering mechanism. The locking device is to be designed to securely lock the steering mechanism of any non-operated unit while operating the ship with the maximum power of the remaining rudder propeller units, however at a ship speed of at least 7 knot.

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 are to be of sound reliable construction to the satisfaction of BKI. 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 shall be:

— of adequate strength and capable of steering the ship at maximum ahead service speed,

— capable of slewing the rudder propeller from one side to the other at declared steering angle limits at an average rotational speed of not less than 2,3 degree per sec. with the ship running ahead at maximum ahead service speed,

— operated by power,

— so designed that they will not be damaged at maximum astern speed.

“Declared steering angle limits” are the operational limits in terms of maximum steering angle, or equivalent, according to manufacturers’s guidelines for safe operation, also taking into account the vessel’s speed or propeller torque/speed or other limitation. The “declared steering angle limits” are to be declared by the rudder propeller manufacturer.

3.3.4 The auxiliary steering arrangement shall meet the interpretation of SOLAS II-1 Regulations 29.4 and 29.6.1 as per IACS Unified Interpretation SC242. 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 maneuvering.

3.3.5 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 slewing mechanism of each rudder propeller are to be controlled from a manoeuvring station on the navigating bridge.

The controls are to be mutually independent and so designed that the rudder propeller cannot be turned unintentionally.

An additional combined control for all rudder propellers is permitted.

Means have to be provided, fulfilling the same purpose as the steering angle limitation in A.3.5. These may be dispensed with in case where no danger for the ship is caused by unintentional 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 is not to lead to the failure of the other units.

3.4.3 An auxiliary steering device is to be provided for each rudder propeller. In case of a failure of the main steering system the auxiliary steering device is at least to be capable of moving the rudder propeller to midship position.

Where the propulsion power exceeds 2500 kW per thruster unit, an alternative power supply, sufficient at least to supply the steering arrangements which complies with the requirements of A.3.3.1 in this section and also its associated control system and the steering system response indicator, shall be provided automatically, within 45 sec., 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.

3.4.4 Where the hydraulic systems of more than one rudder propeller are combined, it is to be possible in case of a 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 is to be clearly discernible on the navigating bridge and at each manoeuvring station.

3.5.2 The actual position is also to 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 systems in which the main lubricating oil pumps can be replaced with the means available on board, the standby pump may be replaced by a complete spare pump. This spare pump is to be carried on board and is to be ready for mounting.

4. Dimensioning

4.1 Gears

For the design of gears see Section 5.

The slewing gears are in general to be designed as spur or bevel gears.

4.2 Shaft line

For the dimensioning of the propeller shaft, between propeller and gear wheel, see Section 4. For the dimensioning of the remaining part of this shaft and all other gear shafts see Section 5.

4.3 Propellers

For the design of propellers, see Section 6.

4.4 Support pipe

The design of the support pipe and its attachment to the ship's hull is to take account of the loads due to the propeller and nozzle thrust including the dynamic components.

4.5 Pipes

For arrangement and design of pipes, valves, fittings and pressure vessels, see Section 8 and Section 11.A, B, C, D and U.

5. Tests in the manufacturer's works

5.1 Testing of power units

A.6.1 applies wherever relevant.

5.2 Pressure and tightness test

A.6.2 applies wherever relevant.

5.3 Final inspection and operational test

5.3.1 After inspection of the individual components and completion of assembly, rudder propellers are to undergo a final inspection and operational test. The final inspection is to be combined with a trial run lasting several hours under part or full-load conditions. A check of the tooth clearance and of the tooth contact pattern is to be carried out.

5.3.2 When no suitable test bed is available for the operational and load testing of large rudder propellers, the tests mentioned in 5.3.1 can be carried out on the occasion of the dock test.

5.3.3 Limitations on the scope of the test require BKI consent.

6. Testing on board

6.1 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 5, Table 5.6.

6.2 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 5.3.1 and 5.3.2 have been satisfactory.

6.3 Regarding steering gear trials A.6 has to be observed analogously. Ship's manoeuvrability tests such as res. MSC.137(76) are to be carried out with steering angles not exceeding the "declared steering angle limits", see B.3.3.3.

C. Lateral Thrust Units

1. General

1.1 Scope

The requirements contained in C apply to the lateral thrust unit, the control station and all the transmission elements from the control station to the lateral thrust unit.

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 BKI in form of electronic format for approval. For propellers, this only applies to an input power exceeding 500 kW.

2. Materials

Materials are subject, as appropriate to the provisions of Sections 4 and 5.

Section 6 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 the Rules for Materials (Pt.1, Vol.V). Proof may take place by manufacturer's inspection certificates.

3. Dimensioning and design

3.1 General requirements

The design of the relevant components of lateral thrust units is to be in accordance with Sections 4 and 5, that of the propellers with Section 6.

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 are to be capable of being operated independently of other connected systems.

Wind milling 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 wind milling, e.g. a shaft brake.

In the propeller area, the thrusters tunnel is to be protected against damages caused by cavitation erosion by effective measures, such as stainless-steel plating.

For monitoring the lubricating oil level, equipmentn shall be fitted to enable the oil level to be determined.

For the electrical part of lateral thrust units, see Rules for Electrical Installations (Pt.1, Vol.IV) Sec.7.B.

3.2 Additional requirements for lateral thrust units for dynamic positioning (DP)

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 5, Table 5.1. The lubrication system for the gearbox must comply with Section 5.E.

For units with controllable pitch propellers, the hydraulic system must comply with Section 6.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 Rules for Automations (Pt.1, Vol.VII).

4. Tests in the manufacturer's works

A.6 is applicable as appropriate. For hydraulic pumps and motors with a drive power of 100 kW or more,

the test are to be conducted in the presence of a BKI 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.

D. Windlasses

1. General

1.1 Scope

The requirements contained in D. apply to bower anchor windlasses, stern anchor windlasses, combined anchor and mooring winches and chain stoppers. For anchors and chains, see Rules for Hull (Pt.1, Vol.II), Sec. 18.

1.2 Documents for approval

1.2.1 For each type of anchor windlass and chain stopper, general and sectional drawings and detail drawings of the main shaft, cable lifter, brake, stopper bar, and chain pulley and axle are to be submitted in form of electronic format 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.

1.2.2 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 corresponding to all the relevant types of anchor and chain cable.

1.2.3 One copy of the strength calculation for bolts, chocks and stoppers securing the windlass to the deck is likewise to be submitted. This calculation is to consider forces acting on the windlass caused by a load specified in 4.2 and 4.3.

1.2.4 Regarding seating see Guidance for Seating of Diesel Engine Installations (Pt.1, Vol.U).

1.2.5 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.

1.2.6 Hydraulic system, to include:

— piping diagram along with system design pressure,

— safety valves arrangement and settings,

— material specifications for pipes and equipment,

— typical pipe joints, as applicable, and

— technical data and details for hydraulic motors.

1.2.7 Electric one-line diagram along with cable specification and size; motor controller; protective device rating or setting; as applicable.

1.2.8 Control, monitoring and instrumentation arrangements.

1.2.9 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.

1.2.10 Plans and data for windlass electric motors including associated gears rated 100 kW and over.

1.2.11 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.

1.2.12 Operation and maintenance procedures for the anchor windlass are to be incorporated in the vessel operations manual.

2. Materials and Fabrication

2.1 Approved materials

2.1.1 The provisions contained in A.2.1 are to be applied as appropriate to the choice of materials.

2.1.2 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 Kl 1

up to 42 mm diameter for grade Kl 2

up to 35 mm diameter for grade Kl 3.

In special cases, nodular cast iron may also be used for larger chain diameters by arrangement with BKI.

Grey cast iron is permitted for stud link chain cables of

up to 30 mm diameter for grade Kl 1

up to 25 mm diameter for grade Kl 2

up to 21 mm diameter for grade Kl 3

2.2 Testing of materials

2.2.1 The materials for forged, rolled and cast parts which are stressed by the pull of the chain when the cable lifter is disengaged (e.g. main shaft, cable lifter, housing, frame, brake bands, brake spindles, brake bolts, tension straps, stopper bar, chain pulley and axle) are to be tested under the supervision of BKI in accordance with Rules for Materials (Pt.1, Vol.V).

In case of housing and frame of anchor windlasses a Manufacturer Inspection Certificate issued by the producer may be accepted as proof.

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.

2.2.2 In the case of hydraulic systems, the material used for pipes (see Section 11, Table 11.3) as well as for pressure vessels is also to be tested.

2.3 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, and welding consumables are to be approved in accordance with Rules for Welding (Pt.1, Vol.VI). Welding consumables are to be approved by BKI in the case their type and grade fall within the scope of Rules for Welding (Pt.1, Vol.VI) Sec. 5; when their type and grade fall outside the scope, the welding consumables are to comply with the applicable BKI Rules, if any, 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. Design and equipment

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.

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 are, however, to be capable of being operated independently of 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 the case of hydraulic drives with a piping system connected to other hydraulic systems a second pump unit is recommended.

3.1.4 In the case of windlasses with two cable lifters both cable lifters are to be engage able simultaneously.

3.2 Reversing mechanism

Power-driven windlasses are to be reversible. On windlasses for ships with a Range of Service rating up to ”L” 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 (see 4.1.2). 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 disengage able couplings between the cable lifter and the drive shaft. In an emergency, hydraulic or electrically operated couplings are to be capable of being disengaged by hand.

3.5 Braking equipment

Windlasses are to 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 8 and Section 11, A, B, C, D and T.

3.7 Cable lifters

Cable lifters are to have at least five snugs.

3.8 Windlass as warping winch

Combined windlasses and warping or mooring winches are not to be subjected to excessive loads even when the maximum pull is exerted on the warping rope.

3.9 Electrical equipment

For the electrical equipment the Rules for Electrical Installations (Pt.1, Vol.IV) Sec.7.E.2. have to be observed.

3.10 Hydraulic equipment

For oil level indicators see A.3.12.1. For filters see F.3.2.2.

4. Power and dimensioning

4.1 Driving power

4.1.1 Depending on the grade of the chain cable and anchor depth windlasses must be capable of exerting 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_1 as specified in Table 14.1 at a mean speed of at least 0,15 m/s.

Table 14.2: Lifting Power

Grade of chain	KI 1	KI 2	KI 3
Z_1 [N]	37,5 d^2	42,5 d^2	47,5 d^2
d = diameter of anchor chain [mm]			

The values in Table 14.1 are applicable when using ordinary stockless anchors for anchorage depth down to 82,5 m.

The pull of stern windlasses with an anchor rope can be determined by reference to the anchor weight and the diameter of corresponding chain cable.

For anchorage depth deeper than 82,5 m, a continuous duty pull Z_2 is:

$$Z_2 = Z_1 + (D-82,5)\,0,27\,d^2 \quad [N] \tag{6}$$

Where:
D = is the anchor depth [m]

The anchor masses are assumed to be the masses as given in Table 18.2 of the Rules for Hull (Pt.1, Vol.II) Sec.18. Also, the value of Z_1 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.

4.1.2 The power units are to be able to provide the necessary temporary overload capacity for breaking out the anchor. This temporary overload capacity or “short term pull” is equal to a maximum pull Z_{max} of

$$Z_{max} = 1,5 \cdot Z_1 \quad [N]$$

at a reduced speed for at least two minutes.

4.1.3 At the maximum torque specified in 4.1.2, a short-time overload of up to 20% is allowed in the case of internal combustion engines.

4.1.4 An additional reduction gear stage may be fitted in order to achieve the maximum torque.

4.1.5 With manually operated windlasses, steps are to be taken to ensure that the anchor can be hoisted at a mean speed of 0,033 m/s with the pull specified in 4.1.1. This is to be achieved without exceeding a manual force of 150 N applied to a crank radius of about 350 mm with the hand crank turned at about 30 rpm.

4.2 Dimensioning of load-transmitting components and chain stoppers

4.2.1 The basic for the design of the load-transmitting components of windlasses and chain stoppers are the anchors and chain cables specified in Rules for Hull (Pt.1, Vol.II) Sec.18.

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. 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.

4.2.3 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 (Pt.1, Vol.V), for the chain in question. The design of the main shaft is to take account of the braking forces, and the cable lifter brake is not to 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 BKI is fitted.

4.2.5 The design of all other windlass components is to be based upon force acting on the cable lifter pitch circle and equal to the maximum pull specified in 4.1.2.

4.2.6 At the theoretical pull specified in 4.2.3 and 4.2.4, the force exerted on the brake hand wheel is not to 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 each load bearing components are to be below the minimum yield point (or 0,2% proof stress) of the materials used.

4.2.9 The foundations and pedestals of windlasses and chain stoppers are governed by the Rules for Hull (Pt.1, Vol.II) Sec.10.B.5.

4.2.10 The design of the drive train, including prime mover, reduction gears, bearings, clutches, shafts, cable lifter 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.

4.3 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 0,1 **L** or 22 m above the summer load waterline, whichever is lesser, the attachment of the windlass located within the forward quarter length of the ship has to resist the green sea forces.

The following pressures and associated areas are to be applied (Fig. 14.2):

- 200 kN/m^2 normal to the shaft axis and away from the forward perpendicular, over the projected area in this direction
- 150 kN/m^2 parallel to the shaft axis and acting both inboard and outboard separately, over the multiple off 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.

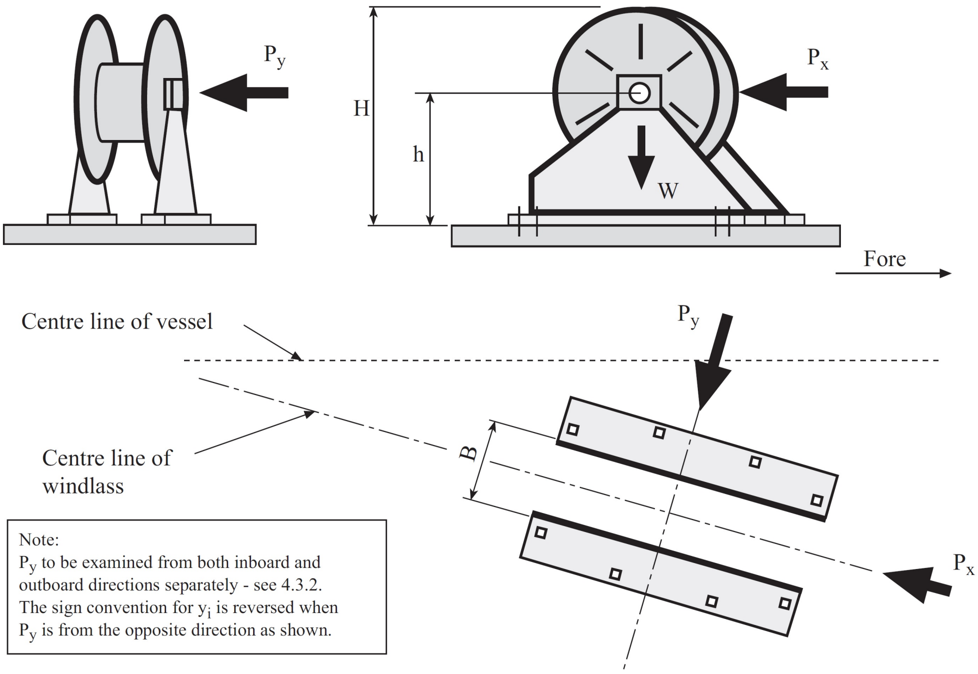


Figure 14.2: Direction of forces and weight

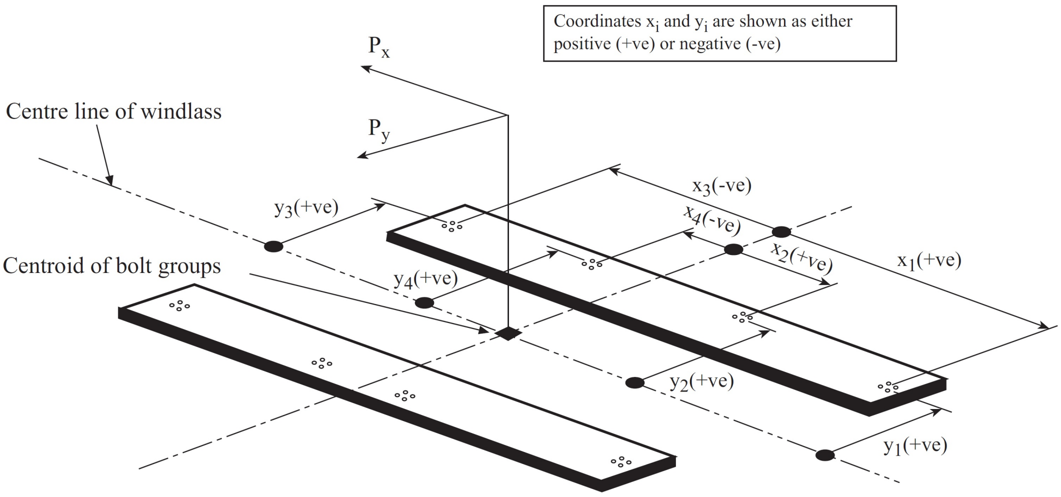


Figure 14.3: Sign Convention

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 (Fig. 14.3).

The axial forces Ri in bolt group (or bolt) i, positive in tension, is to be obtained from:

$$R_{xi} = \frac{P_x \cdot h \cdot x_i \cdot A_i}{I_x} [kN] \quad (7)$$

$$R_{yi} = \frac{P_x \cdot h \cdot y_i \cdot A_i}{I_y} [kN]$$

$$Ri = Rxi + Ryi - Rsi [kN]$$

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 all bolts in group i [cm^2]

I_x = $\Sigma A_i x_i^2$ for N bolt groups [cm^4]

I_y = $\Sigma A_i y_i^2$ for N bolt groups [cm^4]

R_{si} = static reaction at bolt group i, due to weight of windlass [kN]

4.3.3 Shear forces Fxi and Fyi applied to the bolt group i, and the resultant combined force are to be obtained from:

$$F_{xi} = \frac{P_x - \alpha\, m_w}{N} \quad [kN] \qquad (8)$$

$$F_{yi} = \frac{P_y - \alpha\, m_w}{N} \quad [kN]$$

$$F_i = \sqrt{(F_{xi}^2 + F_{yi}^2)} \quad [kN]$$

α = coefficient of friction, to be taken equal to 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 holding down arrangement, due account is to be taken in the calculations.

The safety factor against bolt proof strength is not to be less than 2,0.

5. Tests in the manufacturer’s works

5.1 Testing of driving engines

A.6.1 is applicable as appropriate.

5.2 Pressure and tightness tests

A.6.2 is applicable as appropriate.

5.3 Final inspection and operational testing

5.3.1 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 witness ed by the Surveyor and include the following tests, as a minimum.

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.

2) Load test. The windlass is to be tested to verify that the continuous duty pulls, overload capacity and hoisting speed as specified in 4.1 can be attained.

3) Brake capacity test. The holding power of the brake is to be verified either through testing or by calculation.

5.3.2 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.

5.3.3 Following manufacture, chain stoppers are required to undergo final inspection and operational testing in the presence of the BKI Surveyor.

6. Shipboard trials

The anchor equipment is to be tested during sea trials.

As a minimum requirement, this test is required to demonstrate that the conditions specified in 4.1.1 and 4.2.2 can be fulfilled.

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 cable lifter, proper transit of the chain through the hawse pipe and the chain pipe, and effecting proper stowage of the chain and the anchor. It is to be confirmed that anchors properly seat in the stored position and that chain stoppers function as designed if fitted. The mean hoisting speed, as specified in 4.1.1, is to be measured and verified. The braking capacity is to be tested by intermittently paying out and holding the chain cable by means of the application of the brake. Where the available water depth is insufficient, the proposed test method will be specially considered.

7. Marking

Windlass shall be permanently marked with the following information:

1) Nominal size of chain (e.g. 100/3/45 is the size designation of a windlass for 100 mm diameter chain cable of KI-K3, with a holding load of 45 % of the breaking load of the chain cable)

2) Maximum anchorage depth, in metres.

E. Winches

1. Towing winches

The design and testing of towing winches are to comply with Rules for Hull (Pt.1, Vol.II) Sec.27.C.5.

2. Winches for cargo handling gear and other lifting equipment

The design and testing of these winches are to comply with Regulations for the Construction and Survey of Lifting Appliances (Pt.6, Vol.IV).

3. Lifeboat winches

The design and testing of life boat winches are to comply with Regulations for Life Saving Launching Appliances (Pt.6, Vol.III).

4. Winches for special equipment

Regulations for the Construction and Survey of Lifting Appliances (Pt.6, Vol.IV) are to be applied, as appropriate, to winches for special equipment such as ramps, hoisting gear and hatch covers.

F. Hydraulic Systems

1. General

1.1 Scope

The requirements contained in F. apply 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 of Section 11.

1.2 Documents for approval

The diagram of the hydraulic system 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 for approval.

1.3 Dimensional design

For the design of pressure vessels, see Section 8; for the dimensions of pipes and hose assemblies, see Section 11.

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 the Rules for Materials (Pt.1, Vol.V). The use of other materials is subject to special agreement with BKI.

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.

2.1.3 The pressure-loaded walls of valves, fittings, pumps, motors etc. are subject to the requirements of Section 11.B.

2.2 Testing of materials

The following components are to be tested under supervision of BKI in accordance with the Rules for Materials (Pt.1, Vol.V):

Pressure pipes with $D_N > 50$ (see Section 11, Table 11.3)

Cylinders, where the product of the pressure times the diameter:

$$P_{eperm} \cdot D_i > 20.000 \tag{9}$$

$p_{e,perm}$ = maximum allowable working pressure [bar]
D_i = inside diameter of tube [mm]

For testing the materials of hydraulic accumulators, see Section 8, B.

3. Hydraulic operating equipment for hatch covers

3.1 Design and construction

3.1.1 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.

3.1.2 Movement of hatch covers is not to 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.

3.1.3 Suitable equipment is to 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 allowable working pressure.

3.2.2 The piping system is to be fitted with filters for cleaning the hydraulic fluid.

Equipment is to be provided to enable the hydraulic system to be vented.

3.2.3 The accumulator space of the hydraulic accumulator is to 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 BKI.

3.2.5 For oil level indicators, see A.3.12.1.

3.2.6 The hydraulic fluids must be suitable for the intended ambient and service temperature.

3.3 Hose assemblies

The construction of hose assemblies is to conform to Section 11.T. The requirement that hose assemblies should be of flame-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 not normally operated while at sea. For the design and arrangement of the closures, see the Rules for Hull (Pt.1, Vol.II) Sec.6.H.

4.2 Design

4.2.1 The movement of shell doors etc. may not be initiated merely by the starting of the pumps at the power station.

4.2.2 Local control, inaccessible to unauthorized persons, is to be provided for every closing appliance in the ship's shell. As soon as the controls (pushbuttons, levers or similar) are released, movement of the appliance is to stop immediately.

4.2.3 Closing appliances in the ship's shell normally are to 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.

4.2.4 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 are to be provided for locking closing appliances in the open position.

4.2.5 Every power unit driving horizontally hinged or vertically operated closing appliances is to be fitted with throttle valves or similar devices to prevent sudden dropping of the closing appliance.

4.2.6 It is recommended that the driving power be shared between at least two mutually independent pump sets.

4.3 Pipes, hose assemblies

3.2 and 3.3 are to 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

.1 The following requirements apply to the power equipment of hydraulically-operated watertight bulkhead doors on passenger and cargo vessel.

.2 For details of the number, design and arrangement of bulkhead doors, see Rules for Hull (Pt.1, Vol.II) Sec.11, 29 and 36.

The SOLAS, Chapter II-1, Regulation 15, 16 and 25.9 are not affected by these provisions.

5.1.2 Design

Bulkhead doors are to be power-driven sliding doors moving horizontally. Other designs require the approval of BKI and the provision of additional safety measures where necessary.

5.1.3 Piping

.1 Wherever applicable, the requirements for pipes in hydraulic bulkhead closing systems are governed by the Rules in 3.2, with the restriction that the use of flexible hoses is not permitted.

.2 The hydraulic fluids must be suitable for the intended ambient and service temperatures.

5.1.4 Drive unit

.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 is to 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 are to 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.

.2 Closed or open bulkhead doors are not to be set in motion automatically in the event of a power failure.

.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.

.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 are to return to their original position automatically when released.

.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.

.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 is not to be impaired.

.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.

.8 The control and monitoring equipment for the drive units is to be housed in the central control station on the bridge.

5.1.5 Manual control

Each door is to 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 Rules for Electrical Installations (Pt.1, Vol.IV) Sec.9 and 14.D.

5.2 Passenger vessels

In addition to 5.1, the following requirements are to be taken into consideration in the case of passenger vessels:

5.2.1 Design and location

.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 x B from the perpendiculars which interset the hull contour line when the ship is at load draught (B = beam).

.2 The bulkhead doors are to 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 degree.

.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.

.4 All power-driven doors are to be capable of being closed simultaneously from the bridge with the ship upright in not more than 60 seconds.

.5 The closing speed of each individual door must have a uniform rate. Their closing time with power operation and with the ship upright may be no more than 40 seconds and no less than 20 seconds from the start of the motion with the door completely open until it is closed.

.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.

.7 The bulkhead closing system is not to be connected to other systems.

5.2.2 Central hydraulic system - power drives

.1 Two mutually independent power pump units are to be installed if possible above the bulkhead or freeboard deck and outside the machinery spaces.

.2 Each pump unit is to be capable of closing all connected bulkhead doors simultaneously.

.3 The hydraulic system is to incorporate accumulators with sufficient capacity to operate all connected doors three times, i.e. close, open and reclose, at the minimum permitted accumulator pressure.

5.2.3 Individual hydraulic drive

.1 An independent power pump unit is to be fitted to each door for opening and closing the door.

.2 An accumulator is also to be provided with sufficient capacity to operate the door three times, i.e. close, open and reclose, at the minimum permitted accumulator pressure.

5.2.4 Individual electric drive

.1 An independent electric drive unit is to be fitted to each door for opening and closing the door.

.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

.1 Manual control is to be capable of being operated at the door from both sides of the bulkhead as well as from an easily accessible control station located above the bulkhead or freeboard decks and outside the machinery space.

.2 The controls at the door is to allow the door to be opened and closed.

.3 The control above the deck is to allow the door to be closed.

.4 The fully open door is to be capable of being closed using manual control within 90 seconds with the ship upright.

.5 A means of communication is to be provided between the control stations for remote manual drive above the bulkhead of freeboard decks and the central control station on the 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 freeboard deck for each door.

5.2.7 Alarms

.1 While all the doors are being closed from the bridge, an audible alarm is to sound at each door. This alarm is to start at least 5 seconds - but not more than 10 seconds - before the door start moving and is to continue right throughout the door movement.

.2 When the door is being closed by remote control using the manual control above the bulkhead or freeboard deck, it is sufficient for the alarm to sound only while the door is actually moving.

.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.

.4 With a central hydraulic system, the minimum permitted oil level in the service tank is to be signalled by means of an independent audible and visual alarm at the central control station on the bridge.

.5 The alarm described in 5.2.7.4 is also to be provided to signal the minimum permitted accumulator pressure of the central hydraulic system.

.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 at 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

.1 The manual control is to be capable of being operated at the door from both sides of the bulkhead.

.2 The controls are to 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 is to be sounded all the time they are in motion.

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 appliances.

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 is not to 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 normally is to 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 are to 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 3.1.3 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

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

The power units are required to undergo testing on a test bed. Manufacturer Test Report for this testing are to be presented at the final inspection of the hydraulic system.

7.2 Pressure and tightness tests

A.6.2 is applicable in analogous manner.

8. Shipboard trials

After installation, the equipment is to undergo an operational test.

The operational test of watertight doors has to include the emergency operating system and determination of the closing times.

G. Fire Door Control Systems

1. General

1.1 Scope

The requirements of G apply to power operated fire door control systems on passenger vessel. These Rules meet the requirements for the control systems of fire doors laid down in SOLAS 74, Chapter II-2, Regulation 9.4 as amended. The following requirements may be applied as appropriate to other fire door control systems

1.2 Documents for approval

The electric and pneumatic diagram 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 form of electronic format for approval.

1.3 Dimensional design

For the design of pressure vessels, see Section 8; for the dimensions of pipes, see Section 11.

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 requires the special agreement of BKI.

The use of hose assemblies is not permitted.

Insulation material has to be of an approved type.

The quality properties of all critical components for operation and safety is to conform to recognized rules and standards.

2.2 Material testing

Suitable proof of the quality properties of the materials used is to be furnished. For parts under pressure Certificates according to Table 11.3, for all other parts Manufacturer Test Reports are required.

BKI Surveyor reserves the right to order supplementary tests of his own to be carried out where he considers that the circumstances justify this.

See Section 8.B. for details on the materials testing of compressed air accumulators.

3. Design

3.1 Each door is to be capable of being opened and closed by a single person from both sides of the bulkhead.

3.2 Fire doors are to be capable of closing automatically even against a permanent heeling angle of the ship of 3,5 degree.

3.3 The closing time of hinged doors, with the ship upright, 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 are to be taken to ensure that any persons in the door areas are protected from any excessive danger.

3.4 All doors are to be capable of being closed from the central control station either jointly or in groups. It also is to be 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, Regulation 3.46 of SOLAS 74 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 as described in 3.12.

3.7 Operating agents for the 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 are to return to their original position when released, thereby causing the door to close again.

In an emergency it is to be possible to use 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 designed in such a way that an open door can be closed locally. In addition, each door is to be capable of being locked locally in such a way that it can no longer be opened by 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 is to close automatically should 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 their supply of air being sufficient to allow the door to be completely opened and closed at least ten more times, with the ship upright, using the local controls.

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 is to 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 m.

3.14 Local door controls, including all components, are to be accessible for maintenance and adjustment.

3.15 The control system is to be of approved design. Their capability to operate in the event of fire is to be proven in accordance with the FTP-Code[1)] and under supervision of BKI.

The control system is to conform to the following minimum requirements.

3.15.1 The door still is to 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 At ambient temperatures in excess of 300 °C the central energy supply is to be shut off automatically and the local control system is to be de-energized. The residual energy is still to be sufficient to close an open door completely during this process.

The shut-off device is to be capable of shutting off the energy supply for one hour with a temperature variation corresponding to the standardized time-temperature curve given in SOLAS 74, Chapter II-2, Regulation 3.

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 details of the electrical equipment, see Rules for Electrical Installations (Pt.1, Vol.IV) Sec.14. D.

4. Tests 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 have to be proven for the complete drive.

5. hipboard trials

After installation, the systems are to be subjected to an operating test which also includes emergency operation and the verification of closing times.

H. Stabilizers

1. General

1.1 Scope

The requirements contained in this sub section apply to stabilizer drive units necessary for the operation and safety of the ship.

1.2 Documents for approval

Assembly and general drawings together with diagrams of the hydraulic and electrical equipment containing all the data necessary for checking are to be submitted in form of electronic format for approval.

2. Design

A.2.1.3 and A.2.1.4 are applicable in analogous manner to the pipe connections of hydraulic drive units.

3. Pressure and tightness test

A.6.2 is applicable in analogous manner.

4. Shipboard trials

The operational efficiency of the stabilizer equipment is to be demonstrated during the sea trials.

I. Water Jets

1. General

1.1 Application

1.1.1 This subsection sets out the requirements applicable for axial water jets intended for main propulsion and steering for all types of ships.

1.1.2 Water jet units with main steering function are also considered as steering gear for the ship.

1.1.3 When the water jet units are not intended for main propulsion, they are only subject to classification after special consideration.

1.2 Definitions

1.2.1 The following definition is used in this subsection.

Ducting

Water streaming along the vessel bottom flows into a duct, leading the water to the water jet. The duct forms an integral part of the vessel hull. It is normally manufactured at the yard.

Impeller

The rotating hub with blades. The impeller is connected to the shaft. The impeller is usually cast in one piece. Alternatively, the blades are welded onto the hub.

1.3 Documents to be submitted

1.3.1 The following documents in Table 14.2 are to be submitted.

Table 14.2: Documents to be submitted

Documents	A/I
Water jet arrangement	I
Cross section drawing of unit	I
Structural drawings (housing, mounting flanges etc.) and connections to the water inlet	A
Impeller	A
Shafting parts to be documented according to Rules for High Speed Craft (Pt.3, Vol.III) Section 9 Part A 9.5	A
Stator housing (with guide vanes)	A
Steering arrangement	A
Reversing arrangement	A
Hydraulic actuators for steering and reversing, see 2.2.7 and 2.2.8	A
Bearing arrangement with particulars	A
Seal box [1)]	A
Stern flange with bolting	A
Water inlet ducting with respect to hydrodynamic design	I
All bolt connections carrying thrust or torque, specification of bolt material and tightening procedure (bolt pre-stress)	A
Control system set points	A
Water jet pump characteristic, with operation limits including cavitation limits	I
Normal operating parameters that define the permissible operating conditions, such as thrust , impeller r.p.m., vessel speed, impeller r.p.m. versus vessel speed	I
Operation manual and maintenance manual (for type approval only, otherwise UR (I))	I
Calculated lifetime of roller bearings	A
Impeller blade strength calculations	A[2)]
For ducting design that can not be substantiated by experi ence from earlier applications (i.e. equivalent flow conditions); Analysis or small scale measurements of the circumferential flow variations plus cavitation in the water duct. The documentation shall cover all permissible operating modes, and shall evaluate the effect on thrust eccentricity, see 2.2	I[2)]
Strength calculation of the steering and reversing mechanism	A[2)]
Housing strength calculation, see 2.2	A[2)]

[1)] Type approval is required for oil lubricated standard design.
[2)] Upon request
A = For approval
I = For information

Stator housing

By leading the water flow through a row of stationary vanes downstream of the impeller, the swirl added to the water by the impeller is reduced, and the longitudinal speed of the water flow is increased. The vanes are usually formed as an integral part of the water jet housing.

Impeller housing

The water jet casing surrounding the impeller.

Steering nozzle

The water flow is lead through a passageway that can be tilted horizontally in relation to the vessel's longitudinal axis, there by changing the direction of the water jet flow. This creates a turning moment used for steering the vessel.

Reversing bucket

For reversing purposes, the water jet incorporates components that can force its entry into the water flow thereby turning the water jet discharge to be thrown somewhat forwards. This creates a reversing force that acts on the vessel. The flow is either thrown forwards in an angle directed below the vessel, or to both of the sides of the water jet. The components used for this purpose is denoted a bucket.

Hydraulic actuators

Used for either steering or reversing as the driving force that impose the reversing bucket or acts on the steering nozzle to create a change in the water flow direction.

2. Design

2.1 General

2.1.1 For general design principles for machinery, see the Rules for High Speed Craft (Pt.3, Vol.III) Section 9 Part A.

2.1.2 The water jet unit is to be capable of withstanding the loads imposed by all permissible operating modes, including the condition when the inlet of the suction is blocked.

2.1.3 The stresses in water jet components are to be considered based on loads due to the worst permissible operating conditions, taking into account:

- Hydrodynamic loads, including varying hydrodynamic loads due to water flow disturbances introduced e.g. by the ducting or hull.
- Vessel accelerations versus water jet r.p.m.
- Air suction as assumed in 4.1.3, transient cavitation, waves, shaft motions etc.

Note:

At full design speed on a straight course and with the vessel designated trim, giving the designed water head above the water in take, harmful impeller cavitation will normally not occur. Harmful cavitation in this context is that cavitation which will reduce shafting system and waterjet component lifetime by introducing vibration or impeller erosion.

However, the waterjet may be exposed to operating conditions outside the intended design. Such situations may occur for instance due to increased vessel weight, increased hull resistance, vessel operating at deeper waters etc. In situations where operation exceeds the design premises, harmful impeller cavitation may occur as a consequence of abnormal waterjet flow conditions. This phenomenon has showed to be of increasing importance with increasing waterjet size.

To combat this, the waterjet should be designed with reasonable margin for cavitation, and care should be taken to avoid vessel overweight due to e.g. reasons mentioned in the above. The bigger the waterjets are the more important this advice become.

2.1.4 The water jet units are to be provided with inspection facilities for inspection of the shaft and impeller.

2.2 Design of components

2.2.1 The dimensions of the shafts and the shafting components, including bearings, are to comply with the requirements in 2.2.2, 2.2.3 and the Rules for High Speed Craft (Pt.3, Vol.III) Section 9 Part A.9.5.

2.2.2 Shafts, flange bolt connections, bearings and other relevant shafting components are to be designed to withstand the occasional forces resulting from peak bending moments in the shaft. The design criterion shall be the moment set up in the shaft when 50% of the normal (continuous rating) impeller thrust is applied to 180° of the impeller circumference. This is not to cause yielding in any component or connection (e.g. bolts).

2.2.3 Impeller shafts are to be designed for the force caused by water flow passing the rotating shaft, unless properly shielded.

2.2.4 The impeller housing and stator housing shall be designed against fatigue considering impeller pulses and other flow pulses.

2.2.5 Steering and reversing mechanisms are to be designed in consideration of the worst permissible operation conditions.

2.2.6 The materials used in the hydraulic actuators are to be suitable for the expected environmental conditions.

2.2.7 Hydraulic actuators for steering are to comply with the requirements given in the Rules for High Speed Craft (Pt.3, Vol.III) Section 5, as applicable.

2.2.8 Hydraulic actuators for reversing are to comply with requirements given in Ch.6 Sec.5 H. However, if the hydraulic system for the reversing actuators is the same as for the steering system, the design and test pressure for the reversing actuators are to be the same as for the steering actuators. Higher nominal stresses may be accepted for the reversing actuator.

3. Arrangement

3.1 General

3.1.1 The installation and arrangement of the water jet unit with auxiliaries are to comply with the manufacturers specification.

3.1.2 Ship external parts of the water jet are to be protected by guard rails or other suitable means.

4. Vibration

4.1 General

4.1.1 For requirements concerning whirling calculations and shaft alignment specification, see Rules for High Speed Craft (Pt.3, Vol.III) Section 9 Part A.9.5.

4.1.2 For requirements concerning torsional vibration calculations for diesel driven water jets, see the Rules for High Speed Craft (Pt.3, Vol.III) Section 9 Part A.9.2. For turbine driven water jets, torsional vibration calculations are not required.

4.1.3 Torsional shock vibration calculations may be required upon request. Such calculations shall evaluate the torque variations deriving from water jet load shedding from full load down to 20% and back to full load again due to of aeration of water jet .

5. Control, Alarm, Safety Functions and Indications

5.1 General

5.1.1 The systems are to comply with the requirements in the Rules for High Speed Craft (Pt.3, Vol.III) Section 11.

5.2 Monitoring and bridge control

5.2.1 The monitoring of water jets as propulsion shall be in accordance with Table 14.3 with regard to indications, alarms and requests for slowdown.

5.2.2 Monitoring and bridge control is also to be in compliance with the Rules for High Speed Craft (Pt.3, Vol.III) Section 11.

Table 14.3: Monitoring of water jets

Failure		Documentation by certificates		
		Indication on bridge	Alarm with individual indication	Request for slowdown
Lubrication oil tank level (if provided)	Low		x	
Lubrication oil pressure (if forced lubrication)	Low			x
Hydraulic oil supply tank level	Low			x
Hydraulic oil pressure	Low		x	
Loss of steering and/or reversing signal			x	x
Maximum permissible acceleration exceeded (1)	High	x		
Impeller r.p.m. versus vessel speed ratio (1)	High		x	x
(1) This requirement is only valid for waterjets above 1500 mm inlet diameter				

6. Inspection and Testing

6.1 General

6.1.1 The water jet unit is to be delivered with a BKI certificate.

6.1.2 The certification principles and the principles of manufacturing survey arrangements are described in Guidance for Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W) Section 4 and 5.

6.1.3 Welding procedures are to be qualified according to a recognised standard or the Rules for Welding (Pt.1, Vol.VI).

6.2 Certification of parts

6.2.1 Water jet parts, semi-products or materials are to be tested and certified according to Table 14.4.

6.3 Testing and inspection of parts

6.3.1 The inspection and testing described in the following are complementary to 6.2.

6.3.2 If not otherwise stated, all non-destructive testing (NDT) of components shall be carried out according to an approved specification. The specifications shall include procedures to follow, details on the extent of testing together with acceptance criteria.

6.3.3 The surface crack detection of impellers, by e.g. dye penetrant, shall include the transition area of blade and hub in addition to the inner bore (bore for mounting to shaft, that be flange mounting, tapered shrink-fit connections etc.) including all stress concentration areas such as diameter decrease etc.

6.3.4 The visual inspections by the BKI shall include random dimensional check of vital areas such as flange transition radius, bolt holes etc., in addition to the main overall dimensions.

6.3.5 Particulars concerning ducting inspections are stated in 7.1.5.

6.3.6 The impeller is to be statically balanced.

Note:

ISO 1940/1 Balance Guide G6.3 may be used as reference.

Table 14.4: Requirements for certification of parts

	Product certificate	Documentation by certificates						
		Material certificate	Ultra-sonic or X ray testing	Surface crack detection [3]	Pressure testing	Dimensional inspection	Visual inspection	Other
Impeller	BC	W		BC		W	BC	W[1]
Stator housing		W	W[4]	W		W	BC	
Impeller housing		W	W[4]	W		W	BC	
Shafting	See Table 14.5							
Hydraulic actuators for reversing and steering [6]	BC	BC or W[2]	U-S or surface crack detection (W)[4]		BC or W [2]			
Other steering and reversing components		W		(W)[4]			W	
Bolts		TR						
Ducting when integral with the water jet		5)	5)			W	BC	

1) See 6.3.6.

2) BC for steering hydraulic actuators, W for reversing hydraulic actuators.

3) Crack detection in final condition.

4) NDT of welds upon request.

5) See Rules for High Speed Craft (Pt.3, Vol.III) Section 3 C.3.9 for details on ducting and hull interface.

6) Hydraulic actuator include cylinder, rod, cylinder end eye and rod end eye.

Table 14.5: Requirements for certification of parts

Part	Product certificate	Chemical composition (ladle analysis)	Mechanical properties	Mechanical properties	Crack detection [1]	Hydraulic testing	Visual and dimensional check [2]
Shafts [3),7)] for propulsion when torque >100 kNm	BC	W	BC	BC*	BC	-	BC
Other shafts [3),7)] for propulsion	BC	W	W	W	W	-	BC
Shafts [3)] in thrusters 8) and gear transmissions	-	W	W	W	W	-	W
Rigid couplings for propulsion when torque >100 kNm	BC	W	BC	W	W	-	BC
Other rigid couplings and rigid couplings in thrusters and gear transmission	-	W	W	W	W	-	W
Keys, bolts and shear pins	-	TR	TR	-	-	-	W[4)]
Propeller shaft liners		W	-	-	W[5)]	W[6)]	-

1) By means of magnetic particle inspection or dye penetrant. To be carried out in way of all stress raisers (fillets, keyways, radial holes, shrinkage surfaces on propulsion shafts etc.). If especially required due to nominal stress levels, also the plain parts shall be crack detected. No cracks are acceptable.

2) The visual inspection by the surveyor shall include checking of all stress raisers (see above) with regard to radii and surface roughness, and for plain portions, the surface roughness. It is also to include the shaft's protection against corrosion, Dimensional inspection to be done in way of shrinkage surfaces if this is provided prior to installation onboard. (actual shrinkage amount or individual dimensions shall be documented).

3) Any welds to be NDT checked (ultrasonic testing and surface crack detection) in the presence of the surveyor and documented with NV certificate.

4) Can be omitted for keys, bolts and shear pins in reduction gears and thruster. Can also be omitted for friction bolts of standard type.

5) In way of fusion between pieces.

6) Test pressure 2 bar.

7) However, not applicable for rotor shafts in generators providing electric power for propulsion.

8) Valid for propulsion, dynamic positioning and auxiliary thrusters.

* Can be relaxed to "W" if the Guidance for Marine Industry (Pt.1, Vol.AC) Section 3, R-68 is used as basis for the UT.

7. Installation Survey

7.1 Surveys

7.1.1 The fastening of the water jet to the hull and the structural strengthening around the water jet unit with ducting shall be carried out in agreement with the approved drawings.

7.1.2 Impeller clearances shall be checked after installation and shaft alignment and is to be in accordance with the manufacturers specification.

7.1.3 Normal procedures for shafting apply, see the Rules for High Speed Craft (Pt.3, Vol.III) Section 9 Part A.9.5.

7.1.4 Thrust bearing axial clearances after installation shall be verified to be in accordance with the manufacturer specification, unless verified during assembly of the water jet.

7.1.5 The ducting shall be manufactured in accordance with approved drawings and specifications from the water jet designer. The surfaces shall be smooth and free from sharp edges or buckling that could give raise to turbulence in the water flow and thereby adversely affect water jet operating conditions.

Note:

Great care should be taken in assuring that the ducting dimensions agree with the water jet designer's drawings. The ducting designer should be consulted for use of possible dimensional checking equipment, such as templates especially made for that purpose.

7.1.6 All piping systems shall be properly flushed, in accordance with the manufacturers specification. This shall be documented by a work certificate.

8. Shipboard Testing

8.1 General

8.1.1 For general requirements related to the testing of control and monitoring, see the Rules for High Speed Craft (Pt.3, Vol.III) Section 11.

8.1.2 Final acceptance of the control system is depending on satisfactory results of the harbour testing and the final sea trial, as specified in 8.1.3, 8.1.4 and 8.1.5.

8.1.3 The control system with all functions shall perform correctly, with the result and course of events as described in the water jet "Operating manual" and or "Users manual".

8.1.4 Attention shall be paid to combinations of operational functions especially requested by the buyer (i.e. outside standard functions). Testing of all combinations of functions shall be carried out.

8.1.5 Frequent corrections in the steering control system when the vessel is on straight course shall be avoided to the practicable extent.

> ***Note:***
>
> *The actual corrections should be read preferably by monitoring the control signal. Alternatively, direct measurements on mechanical feedback device from the water jet can be used.*

8.1.6 Indication and alarm (if applicable) of operation outside the specified operation limits shall be checked. This applies to acceleration as well as impeller r.p.m. versus vessel speed.

8.1.7 The water jet r.p.m. versus vessel speed shall be noted and plotted against the manufacturers operational curves. The surveyor shall verify the correct reading of values, and the results shall be submitted to the approval centre after completion of test.

Section 15 Special Requirement for Tankers

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 requirements, 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 requirements for tankers in B:

— tankers for the carriage of oil cargoes are subject to the provisions of C.
— tankers for carriage of hazardous chemicals in bulk are subject to the provisions of Rules for Ships Carrying Dangerous Chemicals in Bulk (Pt.1, Vol. X).
— tankers for the carriage of liquefied gases in bulk are subject to the provisions of Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol. IX).
— for inert gas plants see D.
— Location of fuel tanks in cargo area on oil and chemical tankers see section 10.B.2.1.6

2. Definitions

For the purposes of this Section, the **cargo area** includes cargo tanks, 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 BKI in electronic format.

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 valve including flame arrestors and cargo tank vapor return and collecting pipes
- cargo tank gauging/sounding devices, level/ overfill alarms and temperature indicating equipment
- bilge and ballast water lines 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 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 vent system based on the maximum loading/unloading rates
- gas freeing arrangements for cargo and ballast tanks and cofferdams
- emergency release system 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.
- details and arrangement of the inert gas generating plant including all control and monitoring devices;
- arrangement of the piping system for distribution of the inert gas.

4. References to further Rules

The Rules for the Classification and Construction of Seagoing Ships:

- For the ship's hull: Rules for Hull (Pt.1, Vol.II) Section 24.
- For pipelines, pumps, valves and fittings: Section 11.
- For fire extinguishing and fire protection: Section 12.
- For electrical equipment: Rules for Electrical Installation (Pt.1, Vol.IV) Section 15.
- 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 & 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 shall be accessible only from the cargo area and shall 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 shall 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 Bbar prior to fitting.

1.2 Equipment and operation

1.2.1 Cargo pumps are to be protected against over pressure by means of relief valves discharging 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 piping, 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 shall 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 shall 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 Rules for Electrical Installations (Pt.1, Vol.IV) Sec.15.

2. Cargo Line system

2.1 Line installation

2.1.1 Cargo line systems shall 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 and Rules for Ships Dangerous Chemical in Bulk (Pt.1, Vol.X) Sec.3.3.7.

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 shall be separated from cargo lines e.g. by two stop valves, one of which is to be locked in the closed position.

2.1.5 Seawater inlet and outlet (sea chest) 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 11.C. Minimum wall thickness shall be in accordance with Table 11.5, 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 pipe may be approved by BKI on condition that 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 shut-off 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 shut-off 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 shall be made for the safe draining, gas-freeing and cleaning of the cargo line system.

3. Tank heating and steaming out lines

3.1 Tank heating

This is subject to the appropriate requirements concerning the heating of fuels, Section 10.B.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 feedwater 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 shall be fitted with flame arrester complying with 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 Sections 7.II and 11.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 7.II, 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 shut-off 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 Rules for Ships Carrying Dangerous Chemicals in Bulk (Pt.1, Vol.X) Sec.7.

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 11.M.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 11.M.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:

$$d_H = 1,68 \cdot \sqrt{(B + H)\ell_2 - (b + h)\ell_{T2}} + 25 \quad [mm]$$

$$d_H = 2,15 \cdot \sqrt{(B + H)\ell - (b + h)\ell_T} + 25 \quad [mm]$$

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
ℓ_T	=	length of tanks in the watertight compartment [m]

The capacity of each bilge pump is to be calculated according to Section 11.M.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 independent tanks 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 m^3/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 shall 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 to cargo tanks shall 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 ballast systems under following conditions:

1) the fore peak tank is considered as gas dangerous space
2) the hazardous zones as defined in IEC 60092-502 are to be considered around the air vent pipes.
3) means are to be provided on the open deck for the measurement of flammable gas concentrations inside the peak tank.
4) The sounding arrangement to the fore peak tank is direct from open deck;
5) The access to the fore peak tank is direct from open deck. Alternatively, indirect access from the open deck to the fore peak tank through an enclosed space may be accepted provided that:
   A) In case the enclosed space is separated from the cargo tanks by cofferdams, the access is through a gas tight bolted manhole located in the enclosed space and a warning sign is to be provided at the manhole stating that the fore peak tank may only be opened after:
      — it has been proven to be gas free; or
      — any electrical equipment which is not certified safe in the enclosed space is isolated.
   B) In case the enclosed space has a common boundary with the cargo tanks and is therefore a hazardous area, the enclosed space can be well ventilated.

4.3.3 On oil tankers 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 back flow of cargo into ballast tanks. The spool piece together with a warning notice shall be mounted in a conspicuous location in pump room.

4.3.4 Ballast piping passing through cargo tanks and cargo oil pipes passing through segregated ballast tanks, as permitted by Regulation 19.3.6 of MARPOL Annex I, are to comply with the following requirements:

- The pipes are to be of heavy gauge steel of minimum wall thickness according to the table hereunder with welded or heavy flanged joints [1] the number of which is to be kept to a minimum.

  Expansion bends [2] only are permitted in these lines within cargo tanks for serving the ballast tanksdiplacement caused by thermal expansion or hull deformati which could be fabricated from straight lengths of pipe. and within the ballast tanks for serving the cargo tanks. Minimum wall thicknesses:

up to	DN 50	6,3 mm
	DN 100	8,6 mm
	DN 125	9,5 mm
	DN 150	11,0 mm
	DN 200 and larger	12,5 mm

- The thicknesses shown in the above refer to carbon steel. Only completely welded pipes or equivalent are permitted
- Where cargoes other than oil products are carried, relaxation from these requirements may be approved by BKI.
- Connection between cargo piping and ballast piping referred to above is not permitted except for emergency discharge as specified in the Unified Interpretation to Regulation 1.18 of MARPOL Annex I as amended by IMO resolutions up to MEPC.314(74)

  Nevertheless, provision may be made for emergency discharge of the segregated ballast by means of a connection to a cargo pump through a portable spool piece. In this case non-return valves should be fitted on the segregated ballast connections to prevent the passage of oil to the ballast tanks. The portable spool piece should be mounted in a conspicuous position in the pump room and a permanent notice restricting its use should be prominently displayed adjacent to it.

  Shut-off valves shall be provided to shut off the cargo and ballast lines before the spool piece is removed.
- The ballast pump is to be located in the cargo pump room, or a similar space within the cargo area not containing any source of ignition.

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. Fresh air is to be inducted into the pump room from above. These ventilation systems shall not be connected to those of other spaces.

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 2,0 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.

[1] Heavy flanges joints means welded flange joints rated at least PN10 or one pressure rating higher than required design pressure, whichever is greater.

[2] Expansion bends means expansion loops such as an omega bend (Ω) in piping system to counteract excessive stresses or

Further requirements see C.3 or Rules for Ships Carrying Dangerous Chemicals in Bulk (Pt.1, Vol.X) Sec.12 respectively.

5.2 Gas-freeing of cargo tanks, double hull spaces, ballast tanks, pipe tunnels and cofferdams

5.2.1 Provision shall be made for the gas freeing of cargo 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 vapors can penetrate into the fans when not in use.

5.2.2 The inlet openings in cargo tanks used for gas-freeing or purging with inert gas shall be located either immediately below deck or at a height of 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 shall 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 will 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 On ships without inerting systems, the vent openings used for gas-freeing are to be fitted with flame arresters in accordance with 6.

The fitting of flame arresters may be dispensed with if a velocity of at least 30 m/s in the vent openings is proven.

5.2.8 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 inlet and outlet 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:

1) impellers and/or housings of non-metallic material, due regard being paid to the elimination of static electricity,

2) impellers and housings of non-ferrous materials,

3) Impellers of aluminium alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness on non-ferrous materials is fitted in way of the impeller,

4) any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm tip design clearance.

5.3.4 The following impellers and housings are considered as sparking and are not permitted:

1) impellers of an aluminium alloy or magnesium alloy and a ferrous housing, regardless of tip clearance,
2) housing made of an aluminium alloy or a magnesium alloy and a ferrous impeller, regardless of tip clearance,
3) any combination of ferrous impeller and housing with less than 13 mm design tip clearance.

Type tests on the finished product are to be carried out in accordance with the requirements of BKI or an equivalent national or international standard.

5.3.5 Fan drives are subject to the requirements in 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 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 shut-off device is to be provided at each tank. Where stop valves are used, they shall be provided with locking arrangements.

5.4.5 When shut-off devices according to 5.4.4 are provided, cargo tanks are to be protected against excessive positive and negative pressures caused by thermal variations. Pressure/vacuum relief devices as specified in 5.4.2 b) are to be fitted.

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:

— 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.
— The vapor mixtures are to be discharged vertically upwards.
— 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 shall clearly show whether the by-pass valve is in the open or closed position.

5.4.12 Using the pressure/vacuum relief devices it shall be possible to depressurize the cargo tanks completely. Indicators shall 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 C and Rules for Ships Carrying Dangerous Chemicals in Bulk (Pt.1, Vol.X).

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 Rules for Ships Carrying Dangerous Chemicals in Bulk (Pt.1, Vol.X).

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 vapor return lines. Vapor return line connections are to be fitted with shut-off valves and blind flanges.

5.4.17 Vents 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 BKI on case to case basis.

5.5 Ventilation of other ship's spaces

When 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, flame screens, detonation arresters and high velocity vents are subject to Approval by BKI.

6.2 Flame arresters shall be made of material which is resistant both to the cargo and to sea water.

The arrester elements are to be so designed that fastenings are protected against loosening under service conditions. The arrester elements shall 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 BKI.

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 BKI.

6.6 High-velocity vents may be used for controlled venting instead of pressure-relief valves.

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 type approved by BKI.

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 shall 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 spaces.

7.3 Sounding pipes

7.3.1 Sounding pipes shall 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 4.3.4 analogously.

7.4 Tank Overfill Protection

Provision shall be made to guard against liquid rising in the venting system to a height which will exceed the design head of cargo tanks. This shall be accomplished by high level alarms or overflow control systems or other equivalent means, together with gauging devices and cargo tank filling procedures.

High level alarms shall be independent of the closed level measuring system.

Combined level measuring system and high level alarm systems may be accepted as equivalent to independent systems provided extensive self-monitoring is incorporated in the system covering all credible faults.

For ship with vapour emission control system, high level alarm and over flow alarm are required in accordance with MSC/Circ.585.

7.5 Sampling equipment

Equipment for taking samples of the cargo from pressurized tanks is subject to approval by BKI.

8. Tank cleaning equipment

8.1 Fixed tank cleaning equipment is subject to approval by BKI. 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 BKI.

8.4 Tank washing equipment is to be bonded to the ship's hull.

8.5 Tankers equipped for crude oil washing are to be fitted with an inert gas system in accordance with D.

9. Precautions against electrostatic charges, generation of sparks and hot surfaces

9.1 Precautions against electrostatic charges

9.1.1 The entire cargo systems 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.

Aluminum and glass reinforced plastic (GRP) are not allowed.

9.3 Precautions against sparks from engine and boiler exhausts

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 5,0 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 Rules for Hull (Pt.1, Vol.II) Sec.24.A.12 (prohibition of aluminum paints) hot-dipped aluminum 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 chemical tankers this temperature shall not exceed the temperature class of the cargo.

10. Gas detecting equipment

Every oil tanker is to be provided with at least two portable gas detectors capable of measuring:

- flammable vapours 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).

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 allowable working pressure pe,perm, provided that the test pressure shall be at least 5 bar.

12. Tankers engaged exclusively in the carriage of oil cargoes with a flash point above 60 °C

In general, 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 (except 5.4.9), 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

1. General

These requirements apply in addition to the general requirements in B.

1.1 Inerting of cargo tanks

For tankers of 20,000 DWT and upwards constructed on or after 1 July 2002 but before 1 January 2016, and tankers of 8,000 DWT and upwards constructed on or after 1 January 2016 when carrying the following:

— 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,

are to be protected with a fixed inert gas system in accordance with Subsection D. Other equivalent systems or arrangement may be accepted by Administration, as desrcibed in 1.16.

For tankers not covered 1.1, see D,9.

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:

The space categorizes as double hull spaces are those rooms specify in Guidance for Code and Convention Interpretations (Pt.1, Vol.Y), Section 11, SC 272

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 vapour entering the double hull spaces.

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 vapors.

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 2,0 m above the gangway, where the distance between the outlets and this gangway is less than 3,0 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.

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 (redundant device as per 4.1) of venting, the settings are to be fixed and not arranged for blocking or adjustment in operation.

The requirement in the Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Sec.11 SC 140 is also to be applied.

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 and equipment liable to constitute a source of ignition.

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 4,0 m of this gangway are to be maintained:

- outlet openings of high-velocity vents 2,0 m
- outlet openings of other vents 6,0 m

4.4 Openings for the relief of small quantities of vapours (breather valves) are to be located at a horizontal distance of at least 5,0 m from air intakes or openings to enclosed spaces containing sources of ignition and from deck machinery liable to constitute a source of ignition.

They shall be located at least 2 m above the weather deck.

4.5 The opening 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 Rules for Hull (Pt.1, Vol.II) Sec.4.D.1.1.

4.6 Slop tanks are to be equipped with the same venting arrangements 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 shall only be located on the open deck.

5.3 Pipelines forward and aft of the cargo area shall have welded connections. Flanged connections to valves, fittings and compensators may be permitted where necessary. The pipelines shall be clearly marked and shall be fitted with shut-off valves in the cargo area. When they are not in service, it shall 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 shut-off 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. 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 12.K. 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 3,0 m beyond the cargo shore connection shall meet the requirements stated in Rules for Electrical Installations (Pt.1, Vol.IV) Sec.15.

5.10 Bow and stern cargo equipment shall 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 shall meet the following requirements in addition to 5.1 to 5.10:

— A fixed water spraying system is to be provided covering the areas of chain stoppers and hose couplings.

— Air pipes to the fore peak tanks are to be sited as far as possible from the gas dangerous areas.

— An emergency quick release system is to be provided for the cargo hose and ship's mooring system. The points of separation of which are to be located outside the ship's hull, see also Rules for Hull (Pt.1, Vol.II) Sec.24.

— An operating manual shall 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 shut-off 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 shall 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 shall 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 shut-off 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 D.3.9.

6.6 Cofferdams adjacent to slop tanks shall have no pipe connections with cargo or ballast systems. Facilities shall be provided to enable the cofferdams to be filled with water and to be drained, see also Rules for Hull (Pt.1, Vol.II) Sec.24.G.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 shall be sited in the cargo area. It shall not be connected with machinery spaces.

6.10 Cargo spaces and adjoining spaces shall 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 sensing devices shall be fitted on cargo, ballast and stripping pump casings, bearings and on their gastight bulkhead shaft glands.

Visible and audible alarms shall be effected in the cargo control room or the pump control station.

7.2 Pump room lighting, except emergency lighting, shall be interlocked with the ventilation such that lighting can only be switched on when the ventilation is in operation. Failure of the ventilation shall not cause the lighting to go out.

7.3 A system for continuous monitoring of 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 reasonably 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, 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:

.1 Gas sampling pipes shall be equipped with flame arresters. Sample gas outlets are to be arranged in the open at a safe location.

.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.

.3 The gas detection equipment include sample piping, sample pumps, solenoids, analyzer, 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.

.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 of bulkhead valves and the analyzing unit. The pipes are to be routed on the shortest way through this space.

7.3.3 When the flammable vapour concentration exceeds 10% of the lower flammable limit, visible and audible alarms shall be effected in the pump room, engine control room, cargo control room and navigation bridge.

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.

D. Inert Gas Systems for Tankers

1. General

1.1 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. However, inert gas systems fitted on tankers constructed on or after 1 July 2002 but before 1 January 2016 shall comply with the Fire Safety Systems Code, as adopted by resolution MSC.98(73).

1.2 Tankers required to be fitted with inert gas systems shall comply with provisions of item C.2.

1.3 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.

1.4 Tankers fitted with a fixed inert gas system shall be provided with a closed ullage system.

1.5 The inert gas system shall be capable of supplying a low-oxygen gas or gas mixture in order to achieve an inerted atmosphere in cargo tanks and slop tanks.

1.6 Inert gas may be produced by main or auxiliary boilers (flue gas plant), inert gas generators with independent burner units, Nitrogen generators or other equipment.

Additional or deviating requirements for the relevant type of system are prescribed in 5., 6. and 7.

1.7 In normal operation, the inert gas system shall prevent air from flowing into the tanks and shall maintain the oxygen content of the tank atmosphere at less than 8% by volume. Provision shall, however, be made for ventilating the tanks when access is required.

1.8 It shall be possible to purge empty tanks with inert gas in order to reduce the hydrocarbon content to less than 2% by volume as to ensure subsequent safe ventilation.

1.9 Under normal operating conditions, i.e. when tanks are either full or being filled with inert gas, it shall be possible to maintain positive pressure in the tanks.

1.10 Gas discharge openings for tank purging shall be arranged in suitable locations on deck and shall comply with B.5.2.5.

1.11 The system shall be capable of delivering inert gas at a rate of at least 125% of the total discharge capacity of the cargo pumps.

1.12 The oxygen content of the inert gas or nitrogen produced shall not exceed 5% by volume. Lower values may be required for special applications (i.e. on chemical or gas tankers).

1.13 Means shall be provided to stabilize the required oxygen content during start up and to discharge inert gas/nitrogen with too high oxygen content to the atmosphere during abnormal operating conditions.

1.14 The system shall ensure that the gas volume specified in 1.11 is available during discharge. At other times, a sufficient quantity of gas in accordance with 1.9 shall be permanently available.

1.15 Parts of the inert gas system which come into contact with the corrosive vapours and/or liquids from the inert gases shall be resistant to these or are to be protected by suitable coatings.

1.16 Operating instructions are to be compiled for the inert gas system containing instructions for the operation and maintenance of the system together with notices to health hazards and safety regulations for the prevention of accidents.

1.17 Requirements for equivalent systems

1.17.1 The Administration may, after having given consideration to the ship's arrangement and equipment, accept other fixed installations, in accordance with 1.17.3.

1.17.2 For tankers of 8,000 DWT and upwards but less than 20,000 DWT constructed on or after 1 January 2016, in lieu of fixed installations as required by paragraph 1.17.1, the Administration may accept other equivalent arrangements or means of protection in accordance with 1.17.3.

1.17.3 Equivalent systems or arrangements shall:

.1 be capable of preventing dangerous accumulations of explosive mixtures in intact cargo tanks during normal service throughout the ballast voyage and necessary in-tank operations; and

.2 be so designed as to minimize the risk of ignition from the generation of static electricity by the system itself.

2. Installation

2.1 The inert gas system may be installed in the machinery space or in a separate space.

2.2 Separate inert gas spaces shall contain only components of the inert gas system. Inert gas spaces shall have no entrances to, or air intake openings into accommodation and service spaces or control stations.

2.3 Entrances and air intake openings are to be arranged in the end bulkhead of the space not facing the cargo area. Alternatively, they may be located in a side bulkhead at a distance of **L**/25, subject to a minimum of 5,0 m, from the front bulkhead.

2.4 Mechanical forced ventilation is to be provided for inert gas generator rooms. For fire extinguishing equipment, see Section 12, Table 12.1.

2.5 Inert gas lines shall not be led through accommodation and service spaces or control stations.

3. Piping systems

3.1 Downstream of the non-return devices required by 3.11, the inert gas main may be divided into two or more systems.

3.2 The inert gas lines are to be so arranged as to prevent the accumulation of cargo or water.

3.3 The inert gas main is to be equipped with a shore connection.

3.4 The inert gas main is to be fitted with one or more devices to guard against excessive pressure and vacuum. These are to be designed to protect both the tanks and the water seal from excessive pressure in case of failure of the devices specified in 3.8 and are to be protected against freezing.

3.5 Connections between the inert gas main and the cargo system are to be equipped with suitable isolating means. These may consist of:

— two shut-off valves with intermediate vent, or

— two shut-off valves with an intermediate spool piece.

The valve on the cargo line side shall be a screw-down non-return valve.

3.6 The inert gas lines to the individual tanks are to be fitted with shut-off devices. If valves are used for this purpose, they are to be equipped with locking devices.

The requirements in the Guidance for Code and Convention Interpretations (Pt.1, Vol.Y) Section 11.SC-285 should also be observed.

3.7 All tanks are to be equipped with pressure-vacuum relief devices.

3.8 For the displacement of large volumes of vapour/ inert gas during loading or ballasting, the inert gas main is to be fitted with blow-off masts or high velocity vent valves unless these devices are fitted on the cargo tanks themselves. The design of these devices shall comply with B.5.4.

3.9 In combination carriers spectacle flanges are to be fitted in the inert gas line to enable cargo spaces to be isolated from the inert gas system.

Inerting of slop tanks shall be possible when cargoes other than oil are being carried.

3.10 In the discharge line from the blowers to the cargo area a control valve is to be fitted at the bulkhead of the forward most gas safe space through which this line passes. This shall close automatically under the conditions stated in Table 15.1.

In addition, this valve shall automatically control the flow rate in the system unless other equivalent devices are provided for that purpose.

3.11 Two non-return devices are to be fitted in the inert gas main to prevent the entry of hydrocarbon gases or vapours into machinery space, flue gas lines and gas-safe spaces. These non-return devices shall remain operational in all normal trim positions and motions of the ship and shall be located in the cargo area between the control valve (3.10) and the aftermost connection to any cargo tank or cargo piping.

a) The first non-return device shall be a water seal.
Two separate independent water supplies shall be provided for the water seal.
Inlet and outlet lines connected to the water seal are to be fitted with water loops or equivalent devices. Water loops are to be safeguarded against being emptied by vacuum.
The deck water seal and all loop arrangements shall be capable of preventing return of hydrocarbon vapours at a pressure equal to the test pressure of the cargo tanks.
The water seal shall be protected against freezing. Heating devices shall be designed to prevent overheating of the water seal.

b) The second non-return device shall be a screw-down type check valve or consist of a check valve and shut-off valve fitted downstream of the water seal.

c) Between the control valve and the water seal a valve is to be fitted by means of which the inert gas line between these two valves can be depressurized.

4. Monitoring equipment

4.1 Measuring instruments are to be fitted for continuous indication and permanent recording of the pressure in the inert gas main and the oxygen content of the inert gas being supplied.

These instruments are to be arranged in the cargo control room, where provided, or in a location accessible to the cargo officer.

Pressure sensing lines shall not be led directly into gas safe spaces. Transmitters or equivalent equipment shall be fitted.

4.2 For the control of the tank atmosphere, besides the instruments required in B.10, additional portable instruments for measuring hydrocarbon concentrations in an inert atmosphere shall be provided. Tanks and spaces required to be inerted shall be fitted with suitable connections.

4.3 Suitable equipment is to be provided for calibrating permanently installed and portable gas measuring appliances.

4.4 The low-level alarm in the water seal and the pressure alarm for the inert gas main shall remain operational when the inert gas plant is not in service.

4.5 As a minimum requirement, measuring, alarm and safety devices in accordance with Table 15.1 are to be installed.

5. Boiler flue gas plants

5.1 Boiler plants are to be equipped with automatic combustion control.

5.2 At least two inert gas blowers are to be fitted which, acting together, can deliver at least the quantity of gas specified in 1.7. Each blower shall be capable of delivering at least 1/3 of the required gas flow (42% of the total delivery rate of the cargo pumps). The blowers are to be fitted with shut-off valves on the suction and delivery sides.

If blowers are also used for gas-freeing, the air inlets are to be provided with blanking arrangements (for the ventilation of spaces in the cargo area, see B.5.2).

5.3 A gas scrubber is to be provided outside the cargo area, in which the gas is effectively cooled and solids and sulphurous combustion products are removed. Suitable separators are to be fitted at the scrubber outlet.

5.4 The supply of cooling water to the equipment shall be ensured without interfering with any essential shipboard services.

Provision shall also be made for alternative supply of cooling water

5.5 The boiler flue gas uptakes are to be fitted with shut-off valves with remote position indicators. The soot blowers are to be interlocked with these valves in such a way that they can only be operated when the flue gas uptakes are closed.

Provision is to be made (e.g. by means of an air seal and steam connection) for maintaining the sealing efficiency and mechanical function of these valves.

A second shut-off device is to be fitted at the inlet of the scrubber to ensure that gas cannot enter the scrubber during maintenance.

6. Inert gas generators with independent burner equipment

6.1 Burner equipment with automatic combustion control in accordance with Section 9 is to be installed.

6.2 The plant shall be capable of delivering the volume specified in 1.7 and 5.2.

6.3 Notwithstanding 5.2, only one permanently installed blower need to be provided if sufficient spares are carried for the blower and blower drive to ensure that any damage can be rectified with the means available on board.

6.4 To fuel feed pumps 6.3 applies analogously.

6.5 The inert gas equipment is to be fitted with an automatic starting up system which ensures that only gas of the required composition can be supplied.

6.6 If more than one inert gas generator is installed, each unit is to be fitted with shut-off devices on the delivery side.

Table 15.1: Indicating, alarm and safety devices for inert gas system

Monitored Item	Indication			Alarm			Actuation					Application		
	Machinery space/ECR	Cargo control room or station	Navigation bridge	Limit value	Machinery space/ECR	Cargo control room or station	Stop blowers/fans	Close regulating valve	Shut-down N_2 generator	Permanent recording	Double block and bleed[7)]	Flue gas system	IG generator with burner	Nitrogen generator
High O_2 content after blower, IG/N_2 generator	x	x	–	> 5%	x	x	–	x	–	x	–	x	x	x
Pressure in main deck line	–	x	x	[1),2),3)]	x	x	–	–	–	x	–	x	x	x
Pressure in slop tanks (OBO's only)	–	x	x	–	–	–	–	–	–	–	–	x	x	x
Power failure regulating valve	–	–	–	–	x	x	–	–	–	–	–	x	x	x
Power failure alarm and control system	–	–	–	–	x	x	–	–	–	–	–	x	x	x
Cooling water pressure/flow scrubber	x	–	–	low	x	–	x[5)6)]	x[6)]	–	–	–	x	x	–
Water level scrubber	–	–	–	high	x	–	x[6)]	x[6)]	–	–	–	x	x	–
Gas temperature after blower/IG generator	x	–	–	high	x	–	x[5)6)]	x[6)]	–	–	–	x	x	–
Pressure after blower/IG generator	x	–	–	–	–	–	–	–	–	–	–	x	x	–
Blower/fans failure or N_2 compressors	x	–	–	–	x	x	–	x[6)]	–	–	–	x	x	x
Level in deck water seal	x	–	–	low[4)]	x	x	–	–	–	-	–	x	x	–
Flame failure	x	–	–	–	x	–	–	–	–	–	–	–	x	–
Fuel supply	x	–	–	low	x	–	–	–	–	–	–	–	x	–
Air temperature compressor outlet	x	x	-	high	x	x	–	x	x	–	–	–	–	x
Power failure inert generator/N_2 plant	–	–	–	–	x	x	–	x	–	–	–	–	x	x
Feed-air pressure	x	x	–	low	x	x	–	x	x	–	–	–	–	x
Level in water separator	x	x	–	high	x	x	–	x	x	–	–	–	–	x
Failure electrical heater	x	x	–	–	x	x	x	–	x	–	–	–	–	x
Air temperature inlet N_2 generator	x	x	–	–	–	–	–	–	–	–	–	–	–	x
Pressure N_2 generator inlet	x	x	–	–	–	–	–	–	–	–	–	–	–	x
Loss of power	x	x	–	–	–	–	–	–	–	–	x	x	x	x
Loss of inert gas supply	x	x	–	–	–	–	–	–	–	–	x	x	x	x
Isolation valves between IG main and cargo tanks	x	x	–	–	–	–	–	–	–	–	–	x	x	x
Operational status of the inert gas system [8),9)]	–	x	–	–	–	–	–	–	–	–	–	x	x	x

– = not applicable; x = applicable

1) High pressure alarm-setting below P/V-valve/-breaker relief pressure

2) Low pressure alarm-setting at 10 mbar

3) Second low pressure alarm 10 mbar, or alternatively: Stop cargo pumps. The requirements in the Guidance for Code and Convention Interpretations (Pt.1, Vol.Y) Section 11.SC-287 should also be applied.

4) Level alarm shall remain operable when plant is stopped

5) On IG generators with burner: Stop fuel supply

6) See also the Guidance for Code and Convention Interpretation (Pt.1, Vol.Y) Section 11.SC-284

7) For ships with double block and bleed replacing water seal

8) Indication showing that inert gas is being produced and delivered to cargo area. The indication shall be based on the operational status of the gas regulating valve and on the pressure or flow of the inert gas mains forward of the non-return devices. However, the operational status of the IG system is not considered to require additional indicators and alarms other than those specified in the FSS code.

9) The requirements in the Guidance for Code and Convention Interpretations (Pt.1, Vol.Y) Section 11.SC-286 should also be applied.

7. Nitrogen generator systems

7.1 The following requirements apply to generator systems producing nitrogen by separating air into its component gases by passing compressed air through a bundle of hollow fibres, semi-permeable membranes or absorber materials.

7.2 Unless stated otherwise the requirements in 1, 2, 3, and 4. apply. Indicators, alarms and automatic functions as per Table 14.1 are to be fitted and arranged.

7.3 Where nitrogen generators are arranged in a separate compartment an independent mechanical extraction ventilation system providing 6 changes of air per hour is to be fitted instead of the requirements set out in 2.4. The oxygen content in this compartment shall be monitored and concentrations below 19,5% by volume shall be alarmed.

7.4 Two air compressors shall be provided having together the capacity required in 1.7. The capacity shall preferably be divided equally between the two compressors. Where unequal compressors are fitted the lowest capacity shall not be less than 1/3 of the total capacity required.

One air compressor may be accepted on condition that sufficient spares for the compressors and prime mover are carried on board enabling repair by the crew in reasonable time.

7.5 A continuously operating feed air treatment system shall be provided to remove free water and oil from the compressed air and to maintain the specified temperature.

7.6 Where fitted, a nitrogen receiver/buffer tank may be installed together with the nitrogen plant in the same compartment or in a dedicated compartment or in the cargo area. Access to this compartment is to be arranged from the open deck with a door opening outwards. A permanent ventilation and oxygen monitoring according to 7.3 shall be fitted.

7.7 The oxygen-enriched air from the nitrogen generator and the nitrogen enriched product gas from the nitrogen receiver/buffer tanks safety valves are to be discharged to a safe location on the open deck.

7.8 In order to permit maintenance, sufficient means of isolation shall be provided between the generator, receiver, buffer tank and other components.

7.9 In deviation from 3.11.a) the first of the two non-return devices in the main deck line shall be of the double block and bleed arrangement. The second non-return device shall comply with 3.11.b).

8. Inert gas plants for chemical tankers

8.1 These requirements apply in addition to 1., 5. and 6.

8.2 As an alternative to the water seal mentioned in 3.11.a) double shut-off valves with an intermediate vent valve may be fitted with BKI special consent provided that :

- these valves operate automatically and
- the opening/closing is directly controlled by the inert gas flow or the differential pressure and
- alarms are fitted to signal valve malfunctions (e.g. ”Blower stop” with ”Valves open”).

8.3 Notwithstanding 1.7, a lower delivery rate may be approved for the plant if the discharge rate of cargo pumps is limited to 80% of the available inert gas flow. An appropriate note is to be included in the operating instructions.

8.4 It shall be possible to isolate cargo tanks from the inert gas system by spool pieces or double blanks with an intermediate vent.

8.5 The inert gas plant is to be so designed that the maximum allowable working pressure $p_{e,perm}$ does not exceed the test pressure of the cargo tanks.

9. Inert gas generators for tankers not covered by C 1.1

9.1 Inert gas plants used exclusively for blanketing cargo, inerting spaces surrounding tanks and purging systems and installation components are not required to conform to 1.4, 1.7, 3.4, 3.6, 3.8, 3.9, 3.11, 4.4, 5., 6.2, 6.3, 6.4 and 7.

9.2 In the inert gas main within the cargo area two non-return devices are to be fitted in series. If the equipment is provided with fixed connections to the cargo tanks, the design of the non-return devices is to comply with 3.11.a) to 3.11.c) Otherwise, removable spool pieces are to be fitted at all connections to cargo tanks, spaces surrounding tanks, cargo and process pipelines.

Shut-off devices are to be fitted upstream and downstream of these spool pieces. Pressure reducing valves are to be backed up by safety valves.

9.3 Spaces to be inerted, are to be equipped with means for measuring the pressure and with connections for checking the tank atmosphere as well as with suitable safety devices to prevent excessive pressure or vacuum. Suitable measuring instruments are to be provided for the measurement of oxygen and hydrocarbon gases and vapours.

9.4 Where absorption units are installed those shall be designed for automatic regenerative operation.

9.5 Inert gas storage tanks and absorption and filter units operated under pressure shall comply with Section 8.

10. Inert gas storage systems

10.1 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 shall be sufficient to allow for losses of inert gas during the voyage.

10.2 Design

10.2.1 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 8 analogously. The provisions of Sections 12.G.2.2 and G.3. apply wherever relevant to the installation of pressure vessels and cylinders in closed spaces.

10.2.2 A pressure reducing valve backed up by a safety valve is to be fitted to pressure vessels and batteries of cylinders. The downstream piping system is to be installed in accordance with 9.2.

10.2.3 The spaces which shall be inerted are to be equipped in accordance with 9.3.

E. Additional requirements for Installation of Ballast Water Management Systems

1. General

1.1 Hazardous area classification is to be in accordance with IEC 60092-502:1999 with due consideration of Guidance for Code and Convention Interpretations (Pt.1, Vol.Y) Sec.11 SC274.

1.1.1 BWMS using ozone generators (categories 7a and 7b) and de-oxygenation BWMS using inert gas generator by treated flue gas from main or auxiliary boilers or gas from an oil or gas-fired gas generator (categories 3b and 3c) are to be located outside the cargo area in accordance with FSS Code Ch 15 §2.3.1.1.2.

> ***Note:***
>
> *this requirement does not apply to inert gas generators for which FSS Code Ch 15/2.4.1 and 15.D.7 and 15.D.8 apply.*

1.1.2 In-line full flow electrolysis BWMS (category 4), in-line side-stream electrolysis BWMS (category 5) and in-line injection BWMS using chemical which is stored onboard (category 6) can be located inside the hazardous areas with due consideration of the requirement of Section 11 O, 1.6.4.1.6 but should not be located inside the cargo pump room unless it is demonstrated by the BWMS manufacturer that the additional hazards that could be expected from dangerous liquids and dangerous gases stored or evolved from the BWMS (for example H2 generation):

- do not lead to an upgrade of the hazardous area categorization of the cargo pump room,
- are not reactive with the cargo vapours expected to be present in the cargo pump room,
- are not reactive with the fire-extinguishing medium provided inside the cargo pump room,
- are not impacting the performance of the existing fire-fighting systems provided inside the cargo pump room, and
- are not introducing additional hazards inside the cargo pump room such as toxicity hazards that would not have been prior addressed by suitable counter measures.

Notes:

1) *In-line full flow electrolysis BWMS (category 4) could be accepted in cargo compressor rooms of liquefied gas carriers and inside cargo pump rooms of oil tankers or chemical tankers if that cargo pump room is located above the cargo tank deck.*
2) *For submerged cargo pumps, the room containing the hydraulic power unit or electric motors is not to be considered as the "cargo pump room".*
3) *Ballast pump rooms and other pump rooms not containing the cargo pumps are not to be considered as the "cargo pump room".*

1.2 In general, two independent BWMS should be required i.e. one for ballast tanks located within the cargo area and the other one for ballast tanks located outside cargo area. Specific arrangements where only one single In-line BWMS (categories 1, 2, 3a, 3b, 4, 5, 6, 7a and 7b) could be accepted are given in 2.

Notes:

When the Fore Peak Tank is ballasted with the piping system serving the other ballast tanks within the cargo area in accordance with IACS UR F44, the ballast water of the Fore peak tank is to be processed by the BWMS processing the ballast water of the other ballast tanks within the cargo area.

1.3 Isolation between ballast piping serving the ballast tanks inside and outside of the cargo area is to be in accordance with the following requirements:

1.3.1 Interconnection in between the ballast piping serving the ballast tanks located within the cargo area and the ballast piping serving the ballast tanks located outside the cargo area may be accepted if an appropriate isolation arrangement is provided in accordance with 2 is applied.

Notes:

1) *The means of appropriate isolation described in 1.3.1 is necessary for the interconnection specified in said Paragraph regardless of the diameter of the piping.*
2) *As indicated in 2, the means of appropriate isolation described in 1.3.1 is necessary for the interconnection specified in said Paragraph in the case of the active substance piping such as N_2 gas piping, inert gas piping, neutralizer piping, freshwater piping for filter cleaning, compressed air piping for remaining water purge and sea water piping for adjusting the salinity etc. At the discretion of BKI and for active substance piping and neutralizer piping (both up to 2 inches) only, alternative isolation arrangements, provided preferably on the open deck, offering enhanced safety and gastightness may be considered for penetration of the bulkhead separating the non-hazardous areas machinery space from a hazardous area (such as the cargo pump room) at as high an elevation in the machinery space as possible, preferably, just below the main deck. The arrangements are to provide suitable protection measures in addressing the pollution hazards and safety concerns due to the potential migration of hydrocarbon or flammable or toxic liquids or vapours from the hazardous areas.*

3) *The means of appropriate isolation described in 1.3.1 for the interconnection specified in said Paragraph need not be applied to the sampling lines described in 1.4.*

The Means of appropriate isolation is to be one of the following:

.1 Two non-return valves with positive means of closing in series with a spool piece (Fig.15.1) (also mentioned ”means of dis-connection” in 2, or

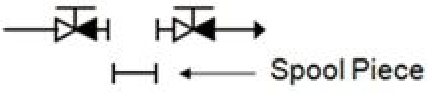


Figure 15.1:

Notes:

As an alternative to positive means of closure, an additional valve having such means of closure may be provided between the non-return valve and the spool piece

.2 Two non-return valves with positive means of closing in series with a liquid seal at least 1,5 m in depth (Fig.15.2), or

Figure 15.2:

Notes:

1) *As an alternative to positive means of closure, an additional valve having such means of closure may be provided between the non-return valve and liquid seal*

2) *For ships operating in cold weather conditions, freeze protection should be provided in the water seal. A portable heating system can be accepted for this purpose.*

.3 Automatic double block and bleed valves and a non-return valve with positive means of closing (Fig.15.3)

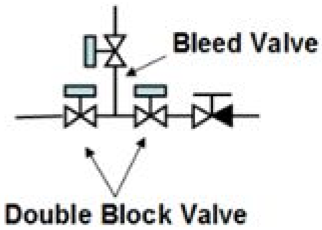


Figure 15.3:

Note:

As an alternative to positive means of closure, an additional valve having such means of closure may be provided after the non-return valve

1.3.2 The above-mentioned means of appropriate isolation is to be provided on the open deck in the cargo area.

Note:

When the Fore Peak Tank is ballasted with the piping system serving the other ballast tanks within the cargo area in accordance with lACS UR F44, the means of appropriate isolation described in 1.3.1 and 1.3.2 is not required in between the Fore Peak Tonk and the common ballast water piping serving the other ballast water tanks within the cargo area

1.4 Sampling lines which are connected to the ballast water piping system serving the tanks in the cargo area and provided for the purpose of the following:

— for any BWMS: ballast water sampling required by the G2 Guideline of the BWM Convention (2004), or

— for BWMS technologies categories 4, 5, 6, 7a and 7b: total residual oxidant (TRO) analysis in closed loop system;

are not to be led into a non-hazardous enclosed space outside the cargo area.

However, the sampling lines may lead into a non-hazardous enclosed space outside the cargo area provided the following requirements are fulfilled:

1) The sampling facility (for BWMS monitoring/control) is to be located within a gas tight enclosure (hereinafter, referred to as a ’cabinet’), and the following i) through iv) are to be complied.

   i) In the cabinet, a stop valve is to be installed on each sampling line.

   ii) Gas detection equipment is to be installed in the cabinet and the valves specified in A) above are to be automatically closed upon activation of the gas detection equipment.

   iii) Audible and visual alarm signals are to be activated both locally and at the BWMS control station when the concentration of explosive gases reaches a pre-set value, which should not be higher than 30% of the lower flammable limit (LFL). Upon an activation of the alarm, all electrical power to the cabinet is to be automatically disconnected.

   Note:

   When the electrical equipment is of a certified safety type, the automatic disconnection of power supply is not required

   iv) The cabinet is to be vented to a safe location in non-hazardous area on open deck and the vent is to be fitted with a flame arrester.

Example of isolation arrangement is shown in Figure 15.4

2) The standard internal diameter of sampling pipes is to be the minimum necessary in order to achieve the functional requirements of the sampling system.

3) The cabinet is to be installed as close as possible to the bulkhead facing the cargo area, and the sampling lines located outside the cargo area are to be routed on their shortest ways.

4) Stop valves are to be located in the non-hazardous enclosed space outside the cargo area, in both the suction and return lines close to the penetrations through the bulkhead facing the cargo area. A warning plate stating ”Keep valve closed when not performing measurements” is to be posted near the valves. Furthermore, in order to prevent backflow, a water seal or equivalent arrangement is to be installed on the hazardous area side of the return pipe.

5) A stop valve is to be installed on the cargo area for each sampling line (i.e. both the suction and return lines).

6) The samples which are extracted from the ballast w water piping system serving the tanks within the cargo area are not to be discharged to a tank located outside the cargo area and not to discharge to a piping line supplying the spaces located outside the cargo area.

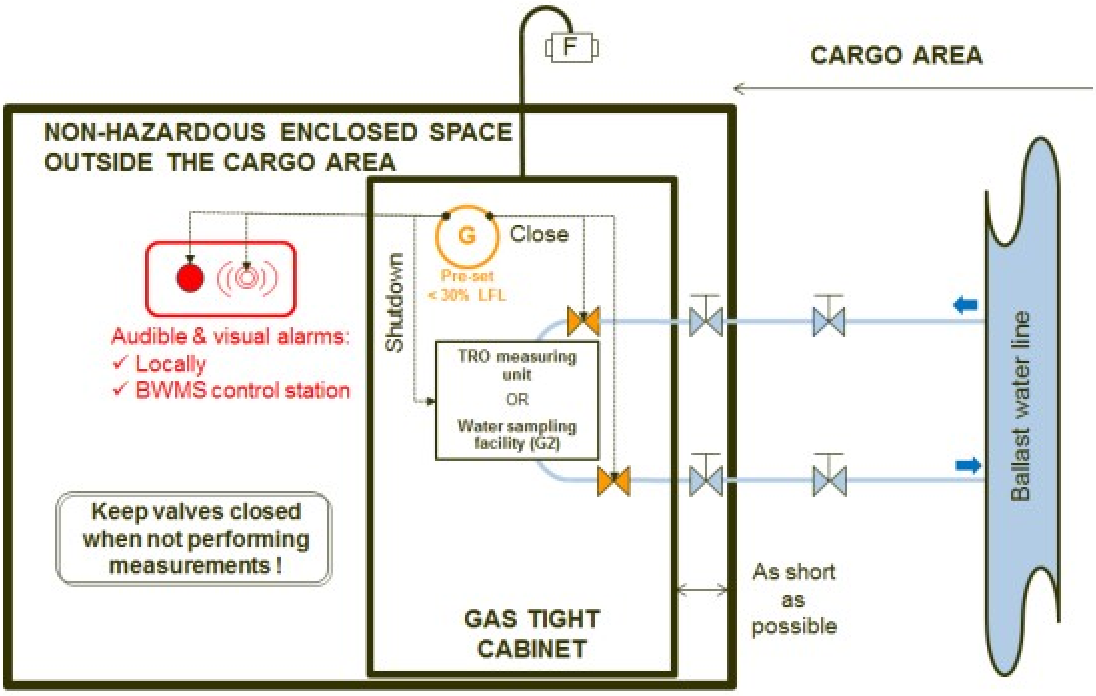


Figure 15.4: Isolation arrangement of BWM sampling system

2. Installation of one single BWMS on tankers

2.1 The BWMS's technology categorization except in-tank technology categories 3c and 8 is described in Table 15.2

Table 15.2: In-line BWMS's technologies categorization

BWMS's technology category		**1**	**2a**	**3a**	**3b**	**4**	**5**	**6**	**7a**	**7b**
Characteristics		In-line UV or UV + Advanced Oxidation Technology (AOT) or UV + TiO2 or UV + Plasma	In-line Flocculation	In-line membrane separation and de - oxygenation (Injection of N_2 from a N_2 Generator)	In-line de-oxygenation (Injection of Inert Gas from Inert Gas Generator)	In-line full flow electrolysis	In-line side stream electrolysis (2)	In-line (stored) chemical injection	In-line side stream ozone injection without gas/liquid separation tank and without discharge treatment tank	In-line side stream ozone injection with gas/liquid separation tank and discharge water treatment tank
Desinfection when ballasting	Making use of active substance		X			X	X	X	X	X
	Full flow of ballast water is passing through the BWMS	X	X	X	X	X				X
	Only a small part of ballast water is passing through the BWMS to generate the active substance						X			
After treatment when de-ballasting	Full flow of ballast water is passing through the BWMS	X								X
	Injection of neutralizer					X	X	X	X	X
	Not required by the Type Approval Certificate issued by the Administration		X	X						
Example of dangerous gas as defined in Section 11.O.1.6.3.2			(1)	O_2 N_2	CO_2, CO	H_2, Cl_2	H_2, Cl_2	(1)	O_2, O_3, N_2	
Arrangement of one single BWMS	BWMS is located in the outside the cargo area	Not accep table	Case 1.2 (2)	Case 1.3a (2)	Case 1.3b	Case 1.4 (2)	Case 1.5	Case 1.6	Case 1.7a	Case 1.7b (2)

Notes:

(1) To be investigated on a case by case basis based on the result of the IMO (GESAMP) MEPC report for Basic and Final approval in accordance with the G9 Guideline.

(2) Only (Means of dis-connection) as described in 1.3.1 are to be applied.

(3) In-line side stream electrolysis may also be applied in-tank in circulation mode (no treatment when ballasting or de-ballasting.

The following Figure 15.5 is to be used as a legend for symbol explanation of each BWMS's technology categories in 2.2.1 to 2.2.7.

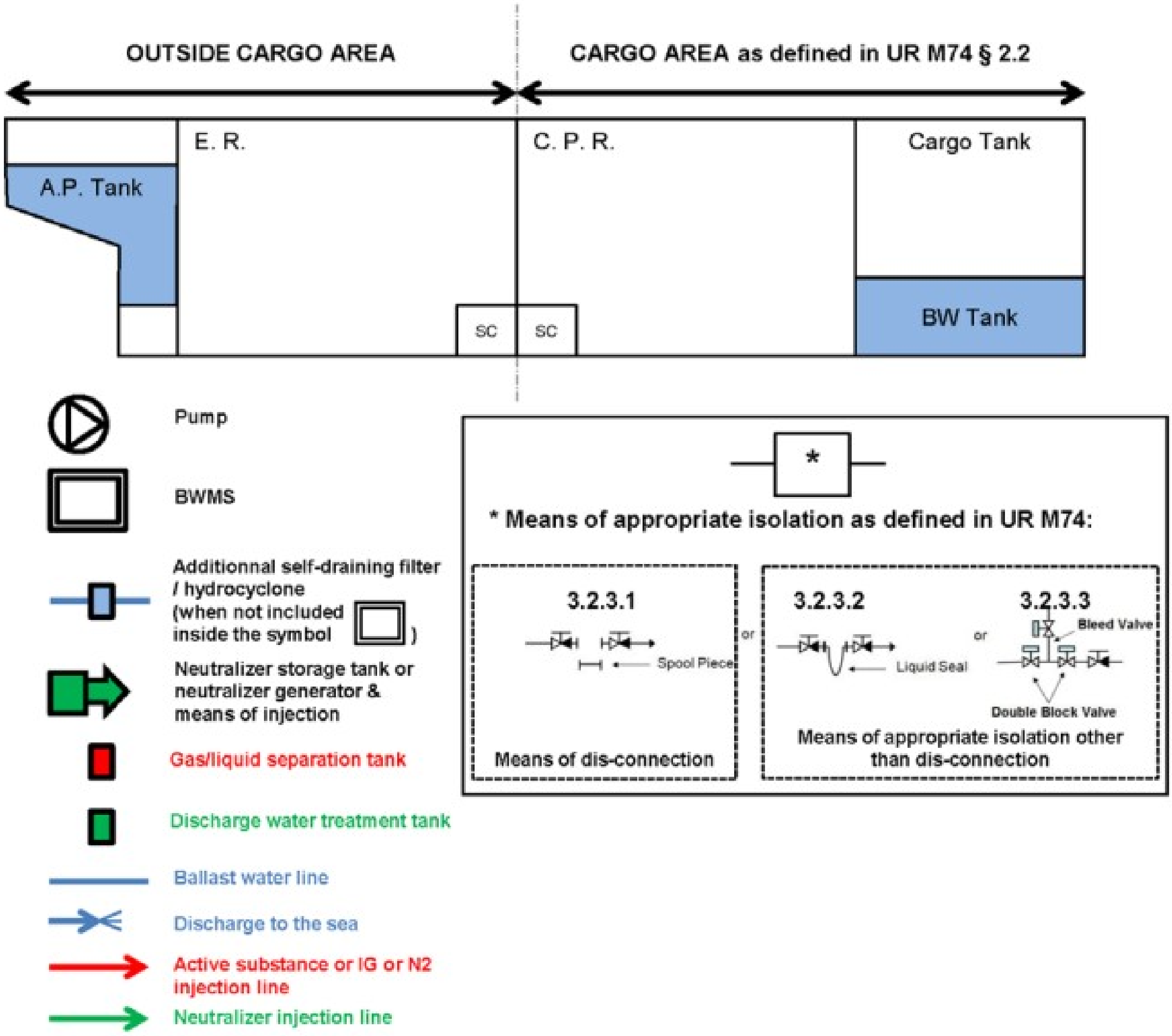
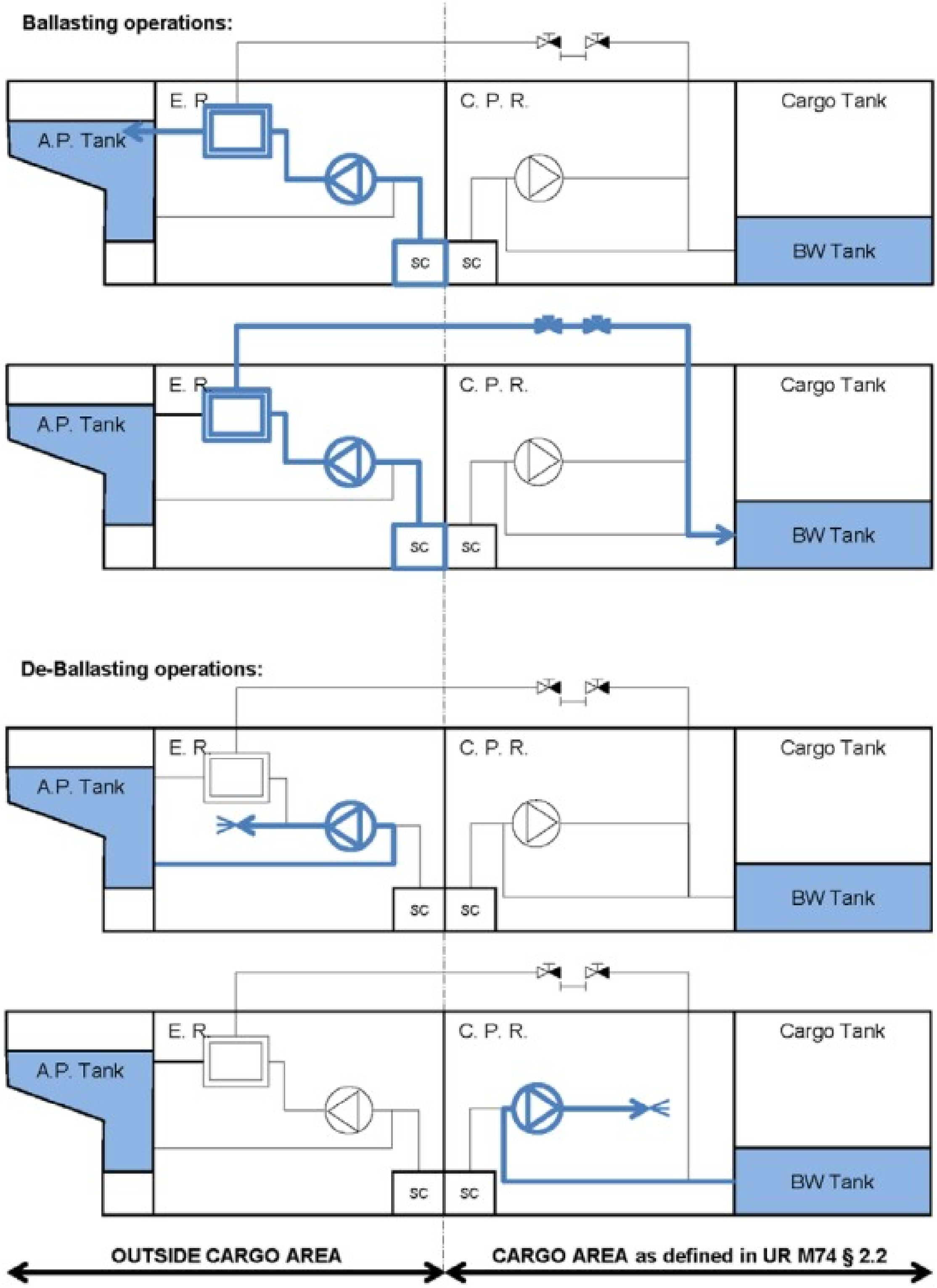


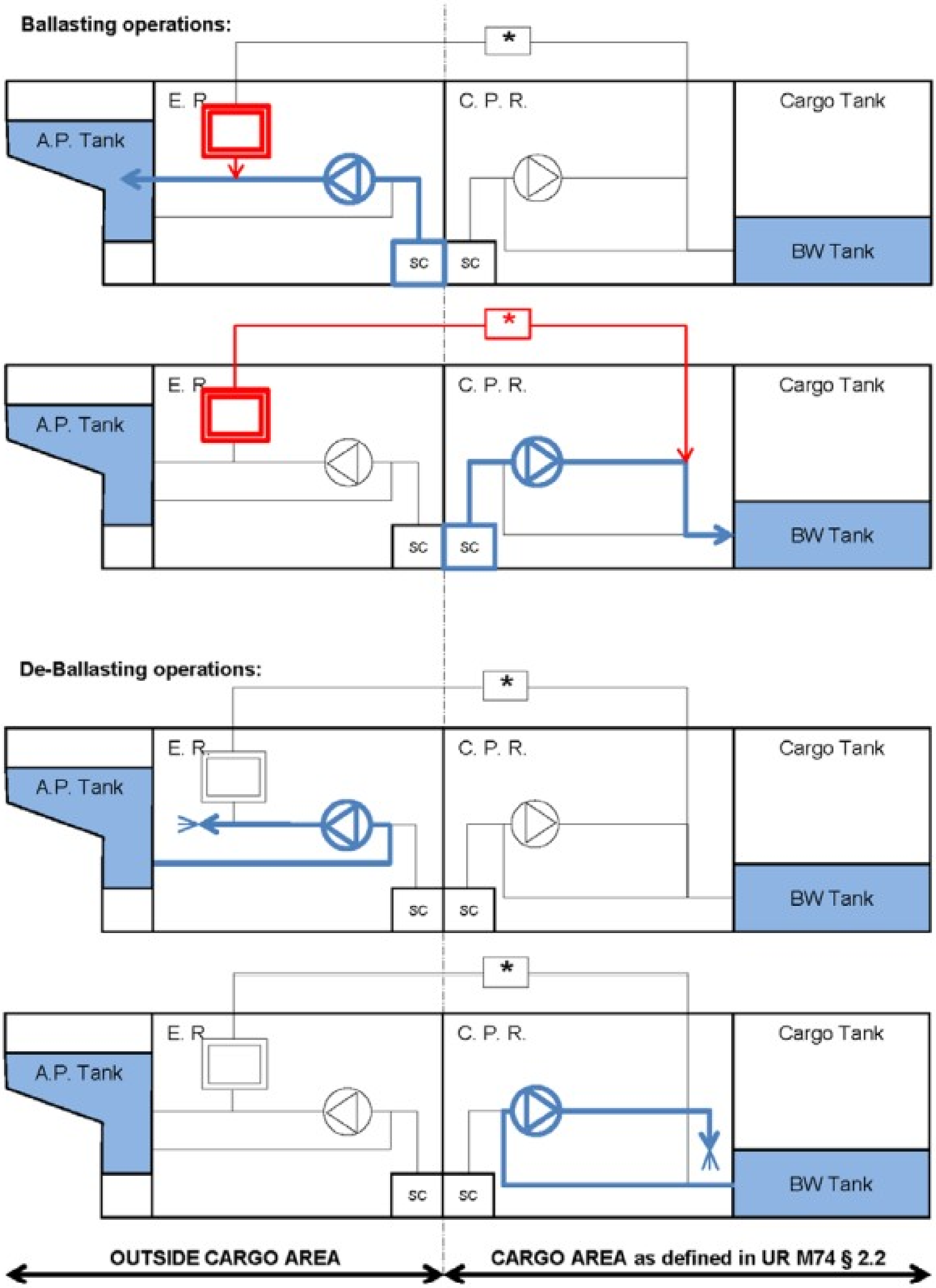
Figure 15.5: Legend

2.2 BWMS Installed outside in the cargo area

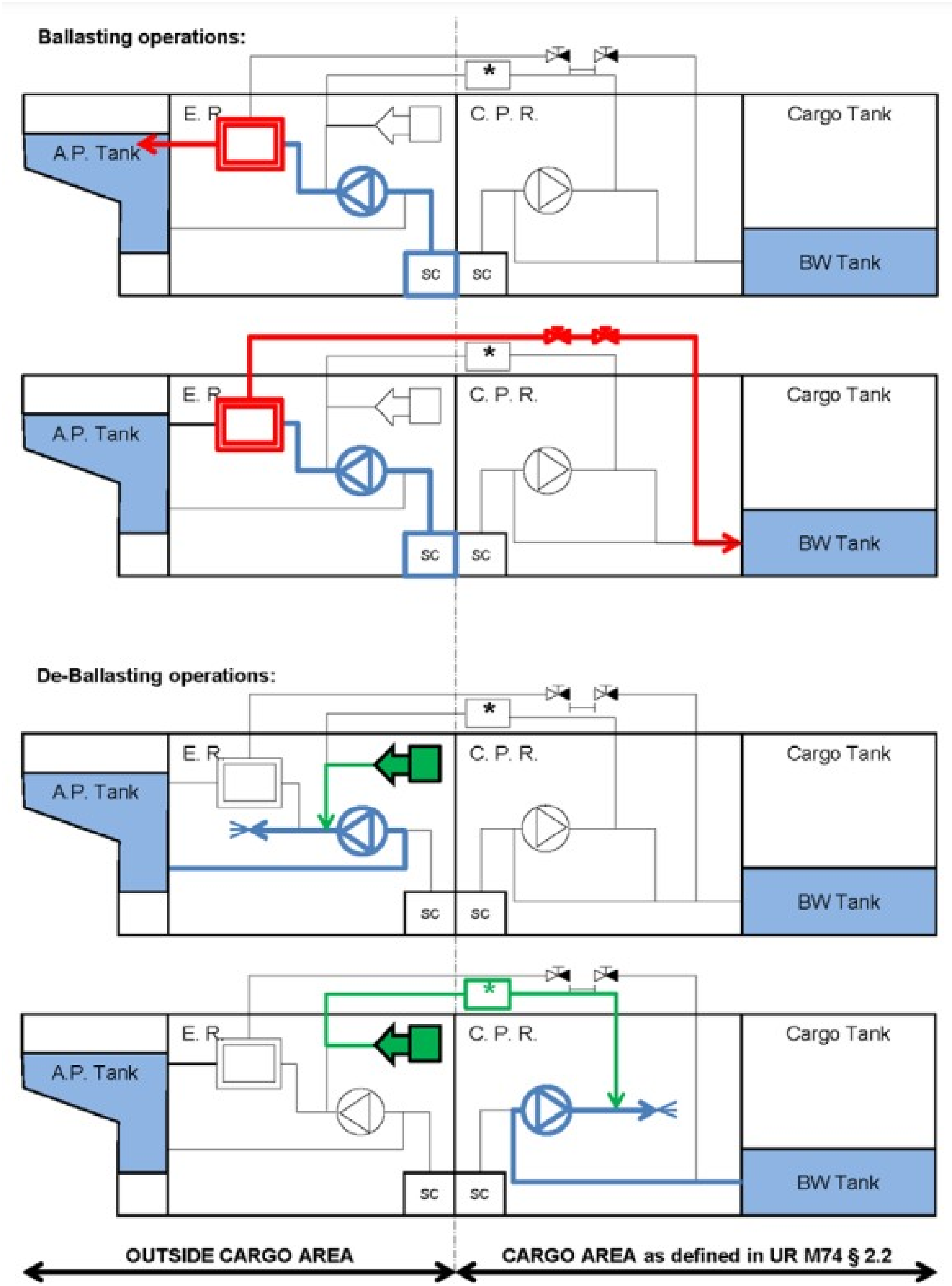
2.2.1 Case 1.2 (Technology category 2, Flocculation); and Case 1.3a (Technology category 3a De-oxygenation with N2 Generator):



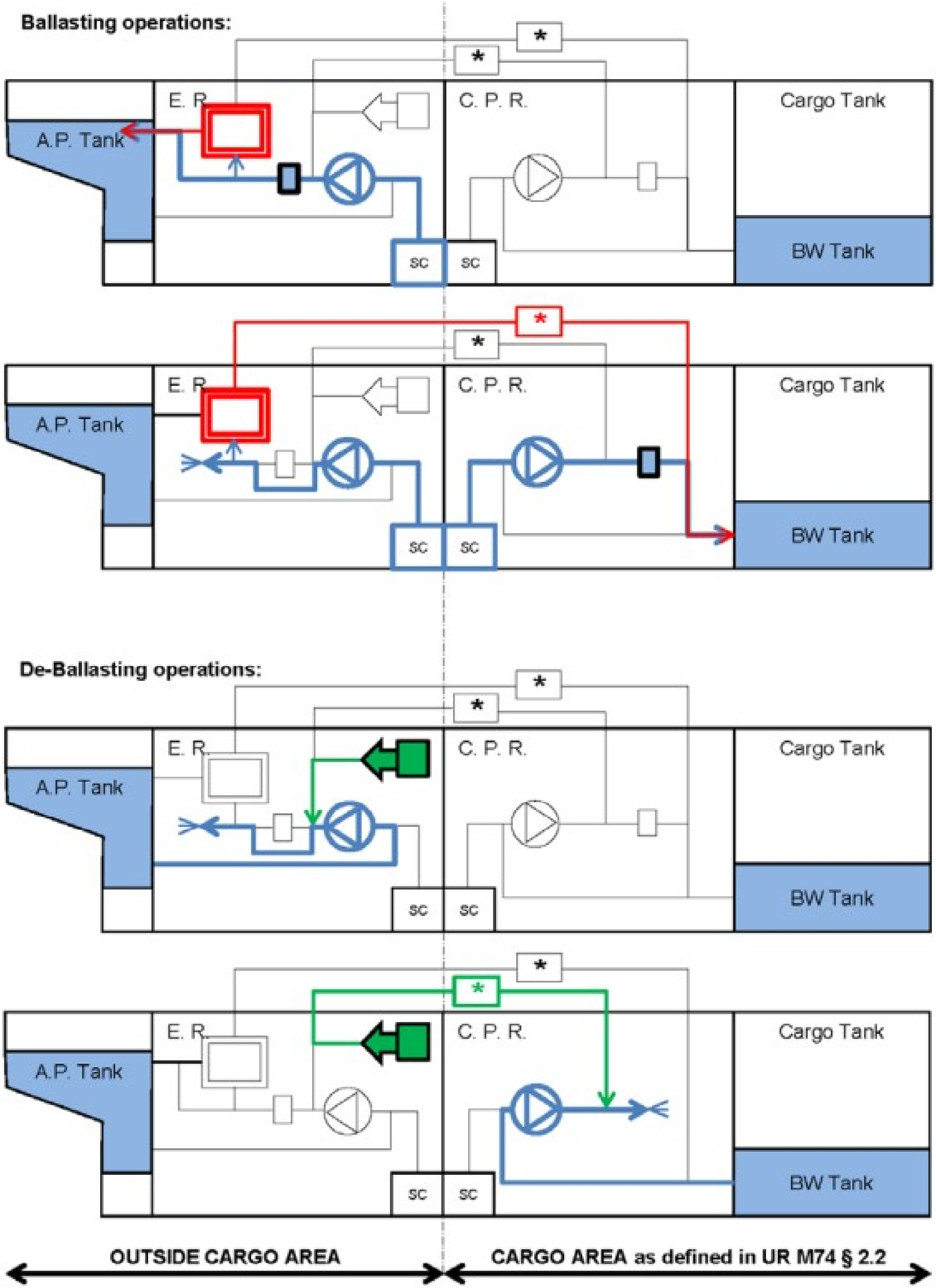
2.2.2 Case 1.3b (Technology category 3b De-oxygenation with Inert Gas Generator):



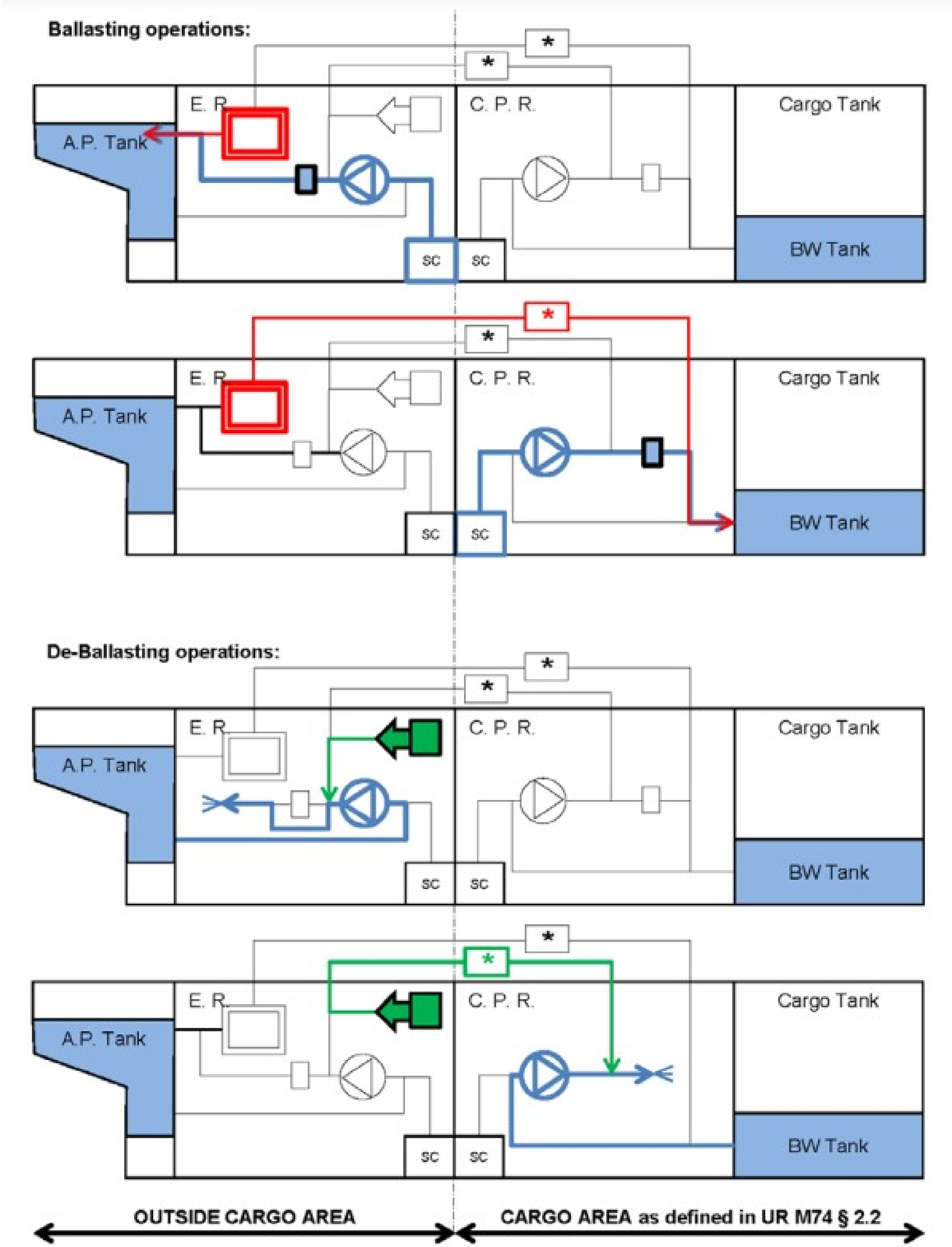
2.2.3 Case 1.4 (Technology category 4, Full-flow electrolysis):



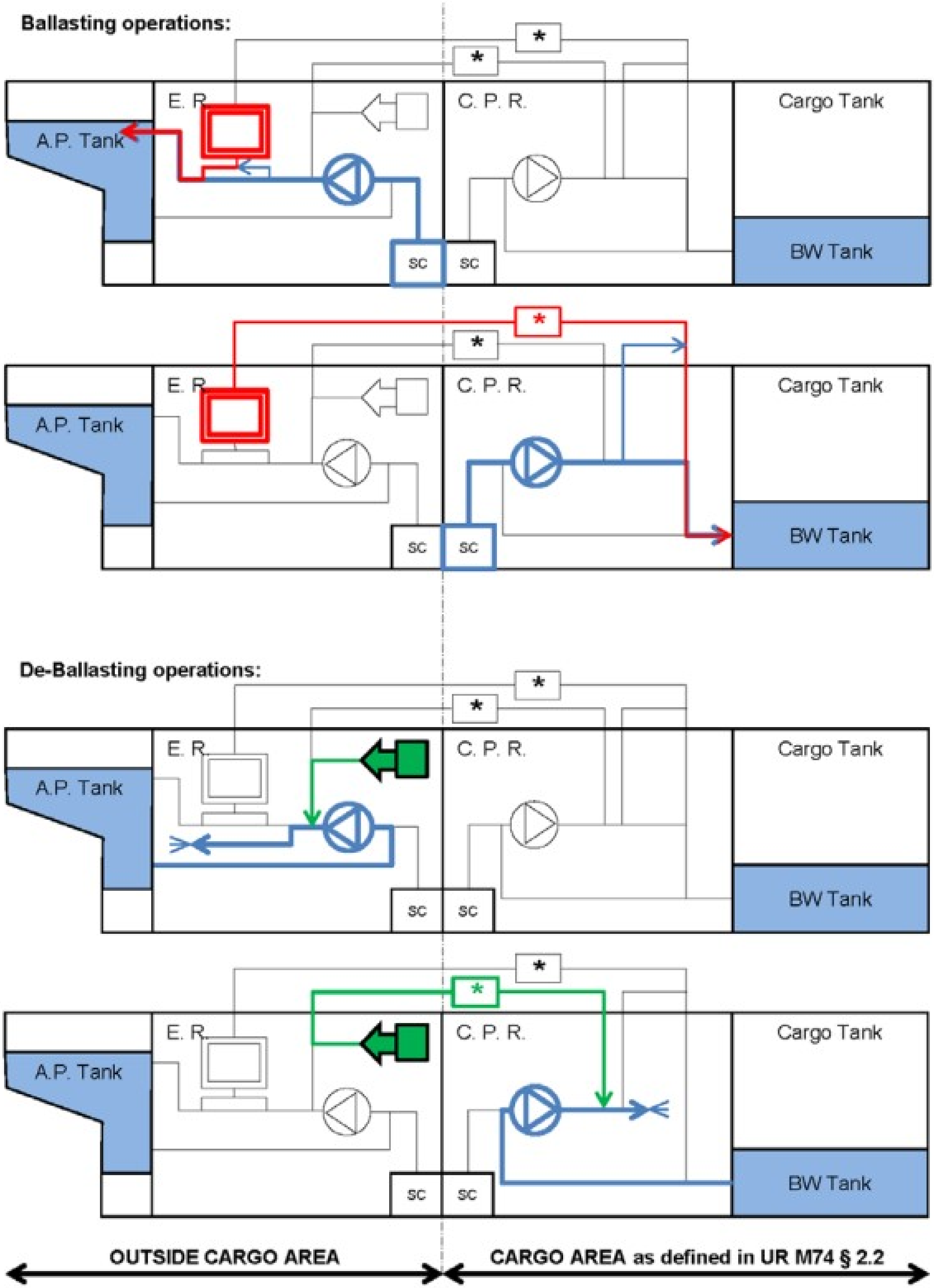
2.2.4 Case 1.5 (Technology category 5, Side-stream electrolysis):



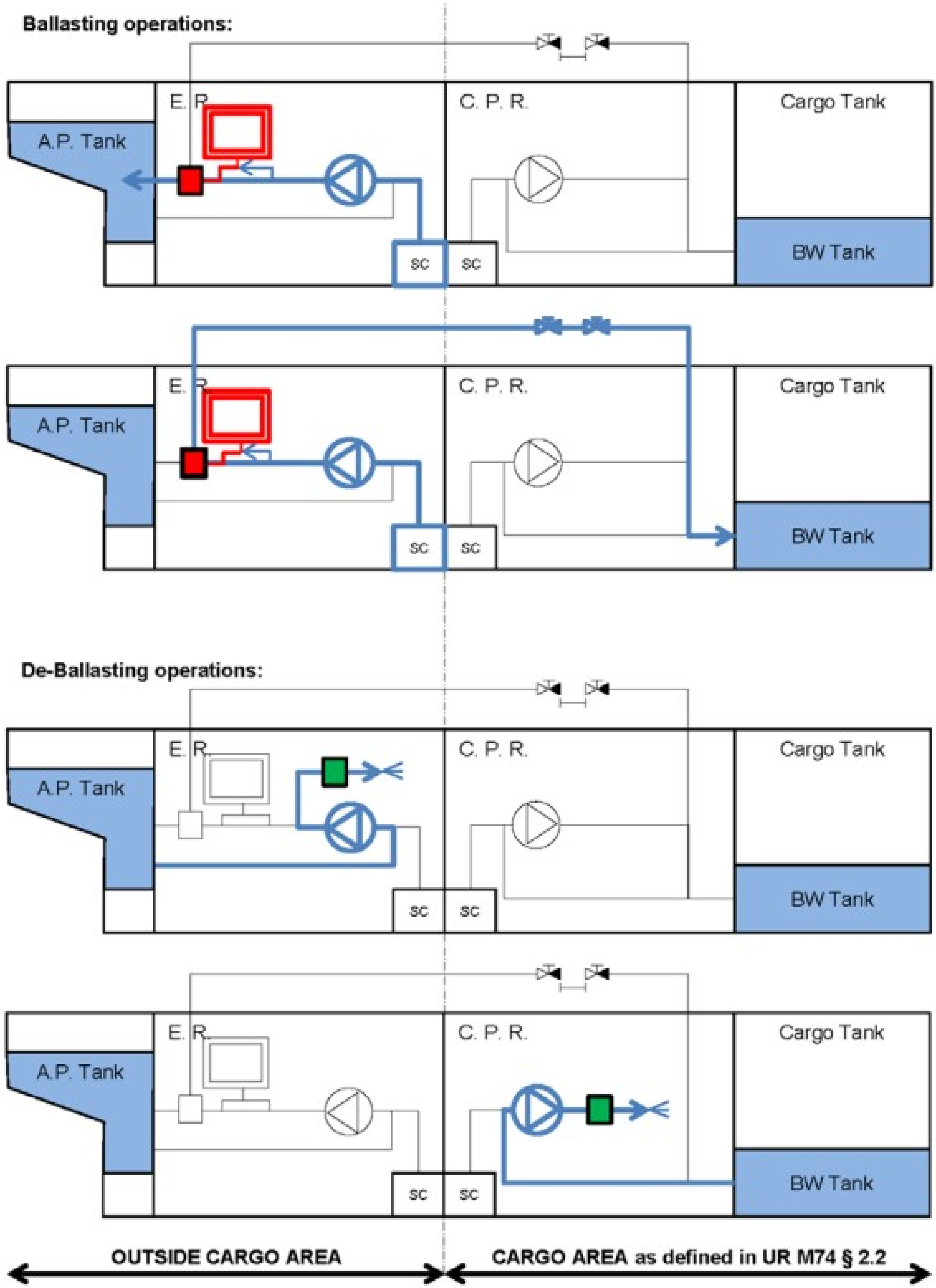
2.2.5 Case 1.6 (Technology category 6, Stored chemical injection):



2.2.6 Case 1.7a (Technology category 7a, Side-stream ozone injection without gas/liquid separation tank and without discharge water treatment tank):



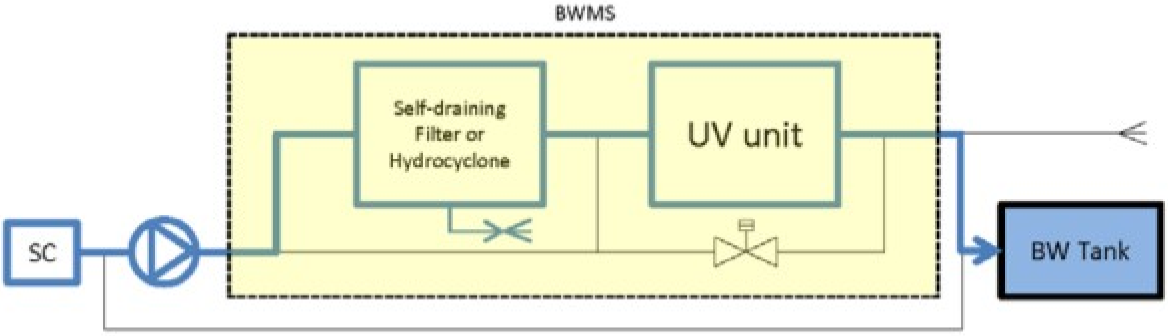
2.2.7 Case 1.7b (Technology category 7b, Side-stream ozone injection with gas/liquid separation tank and discharge water treatment tank):



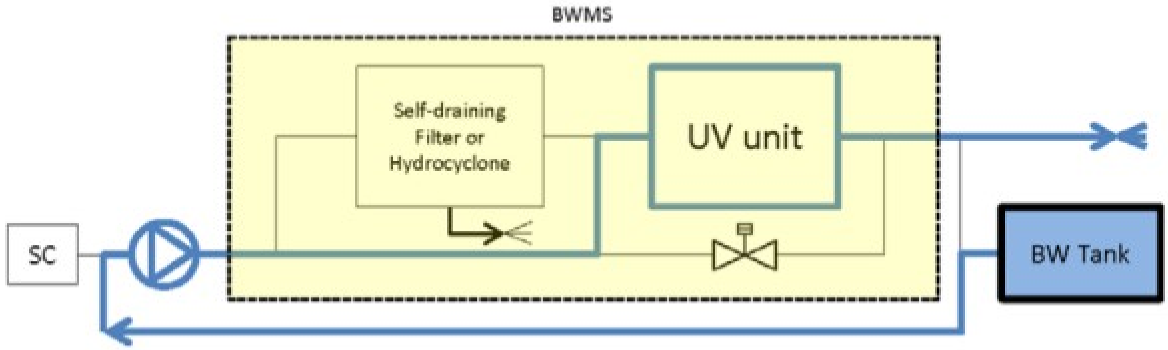
3. Installation of one single BWMS on tankers

3.1 BWMS technology group 1 (In-line UV, including UV + AOT and UV + TiO_2

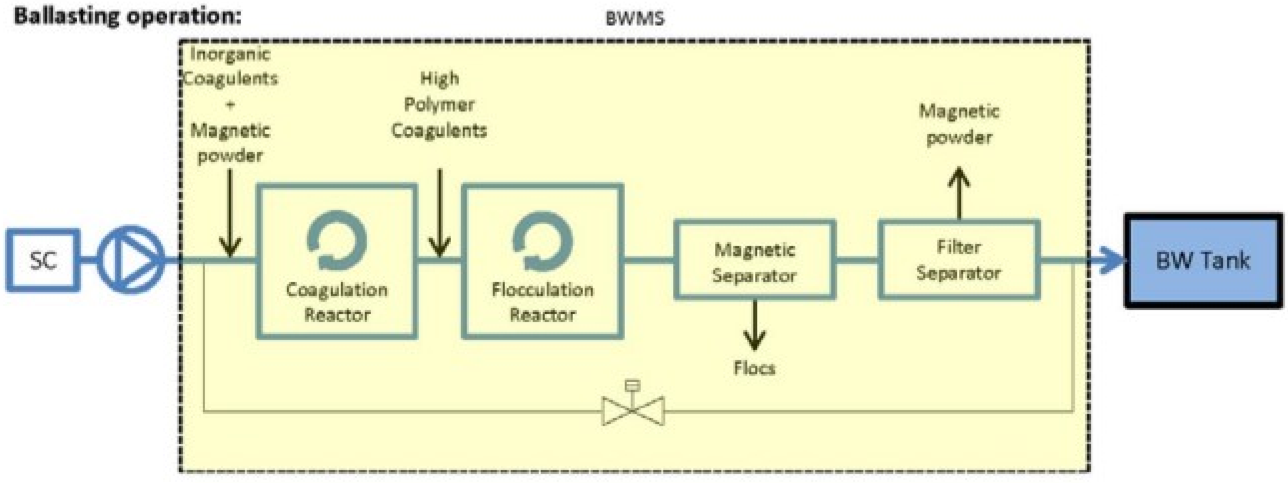
Ballasting operation:



De-ballasting operation:



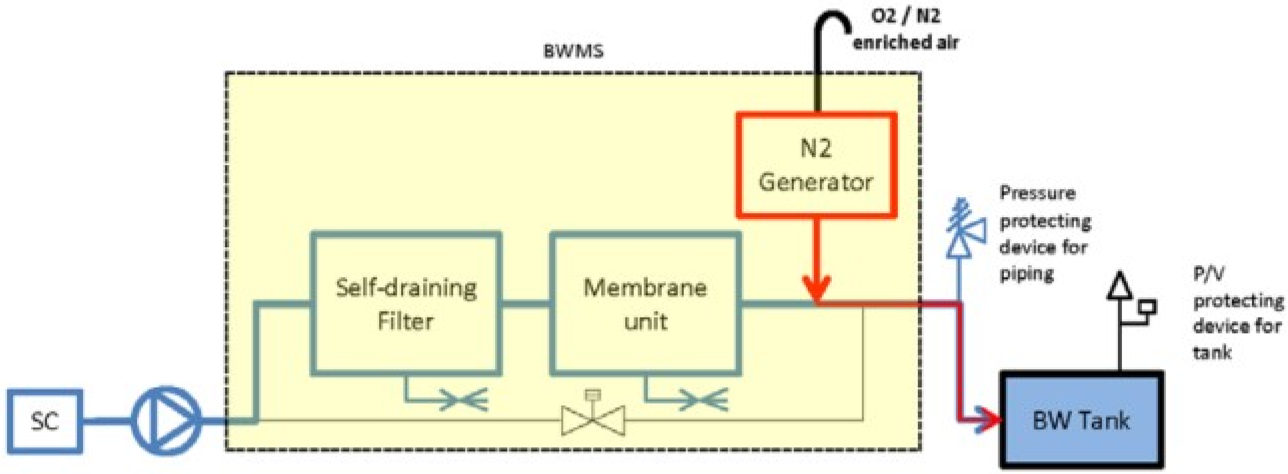
3.2 BWMS technology group 2 In-line UV flocculation



De-ballasting operation: no requirement for after-treatment

3.3 BWMS technology group no. 31 In-line membrane separation and de-oxygenation (injection of N_2 from N_2 generator)

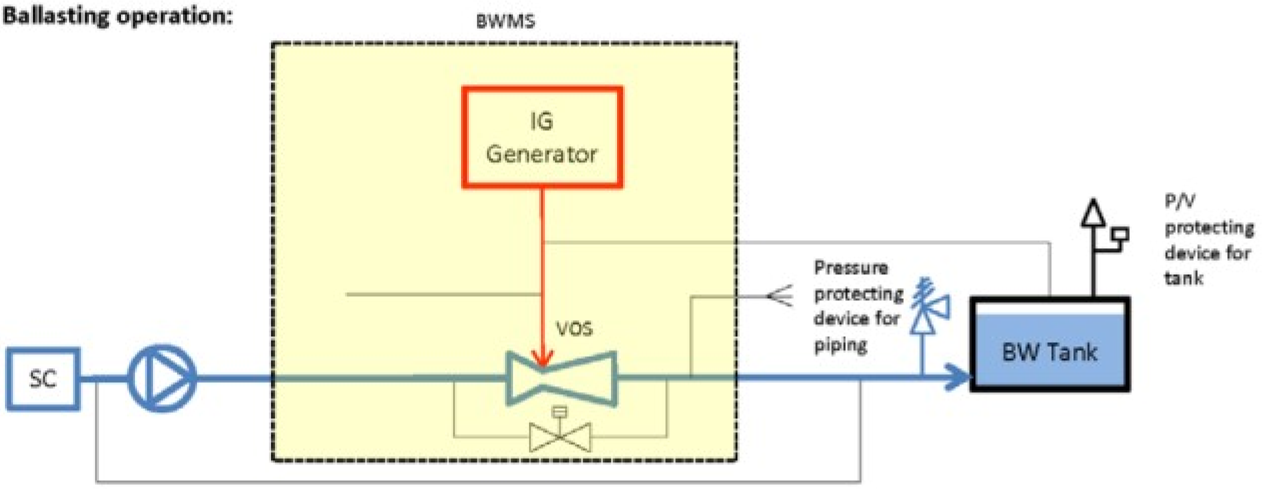
Ballasting operation:



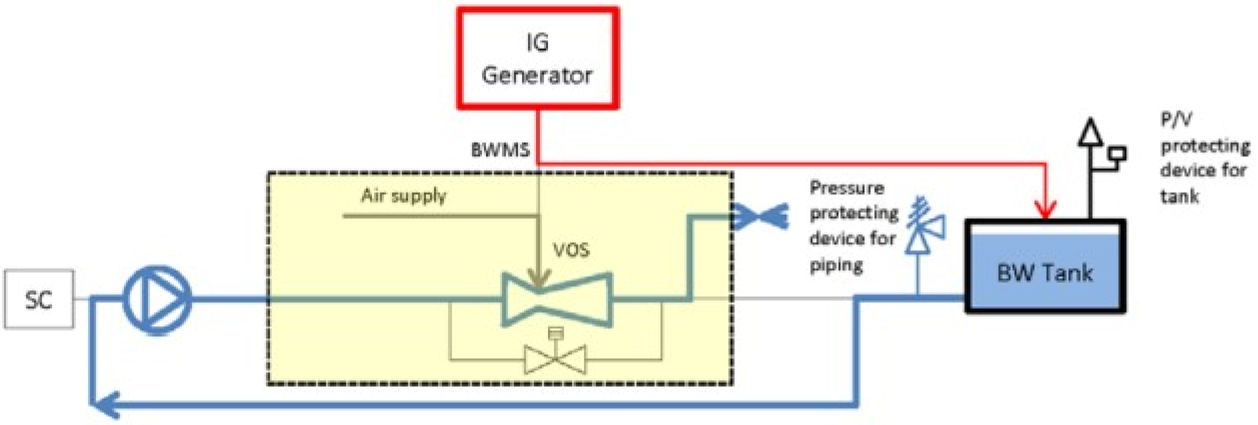
De-ballasting operation: no requirement for after-treatment

3.4 BWMS technology group no. 3b In-line de-oxygenation (injection of inert gas from either an oil-fired inert gas generator or inert gas from treatment of the flue gas from main or auxiliary boilers)

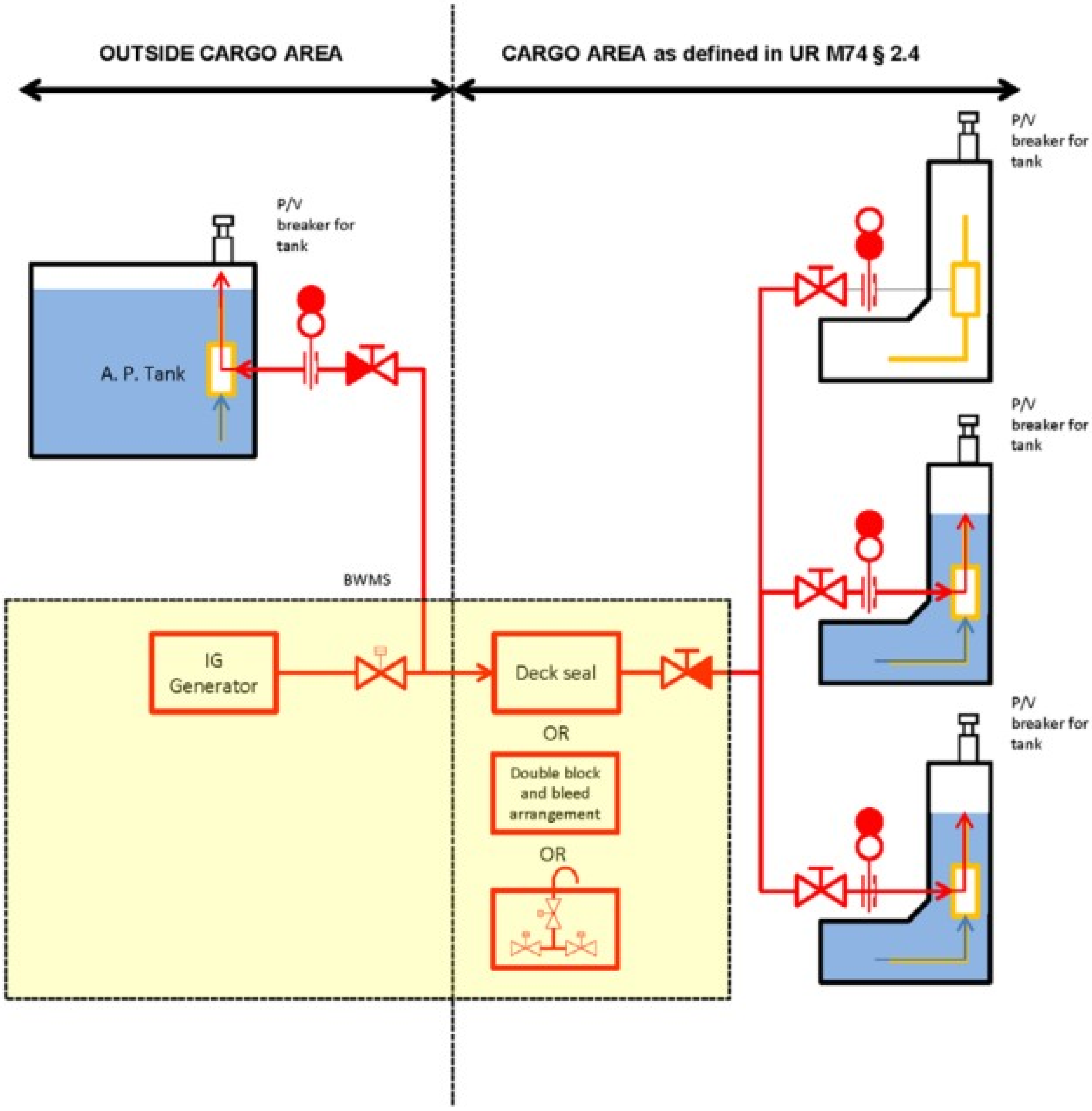
Ballasting operation:



De-ballasting operation:

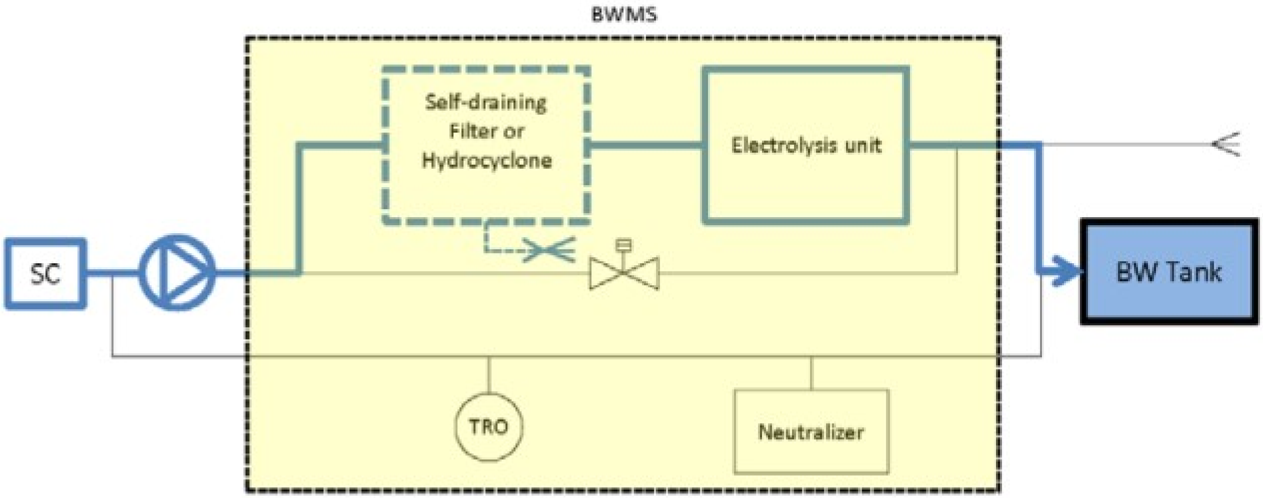


3.5 BWMS technology group no. 3c In-line de-oxygenation with IGG

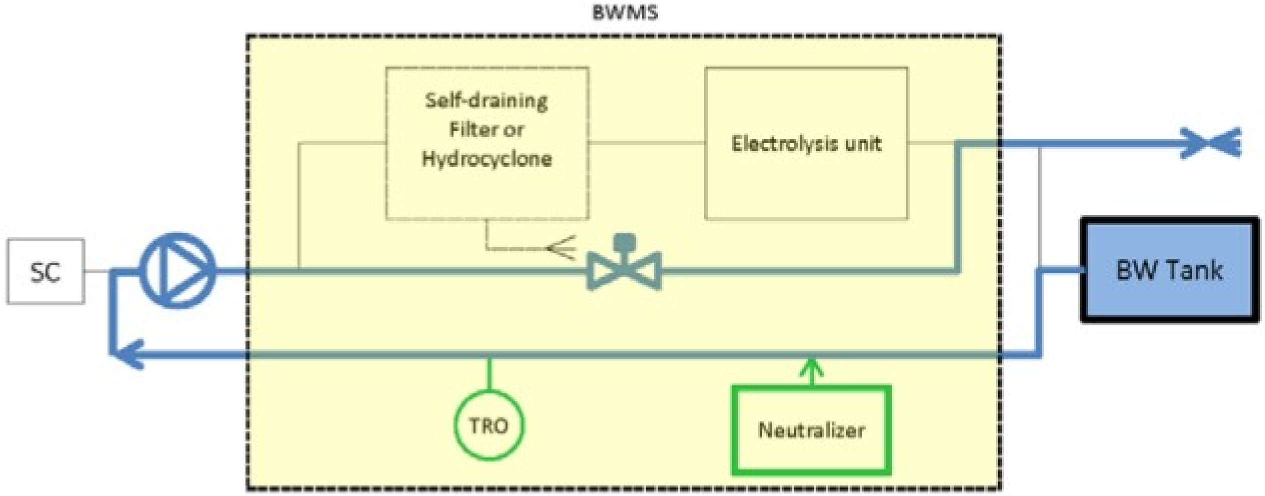


3.6 BWMS technology group no.4 In-line full flow electrolysis

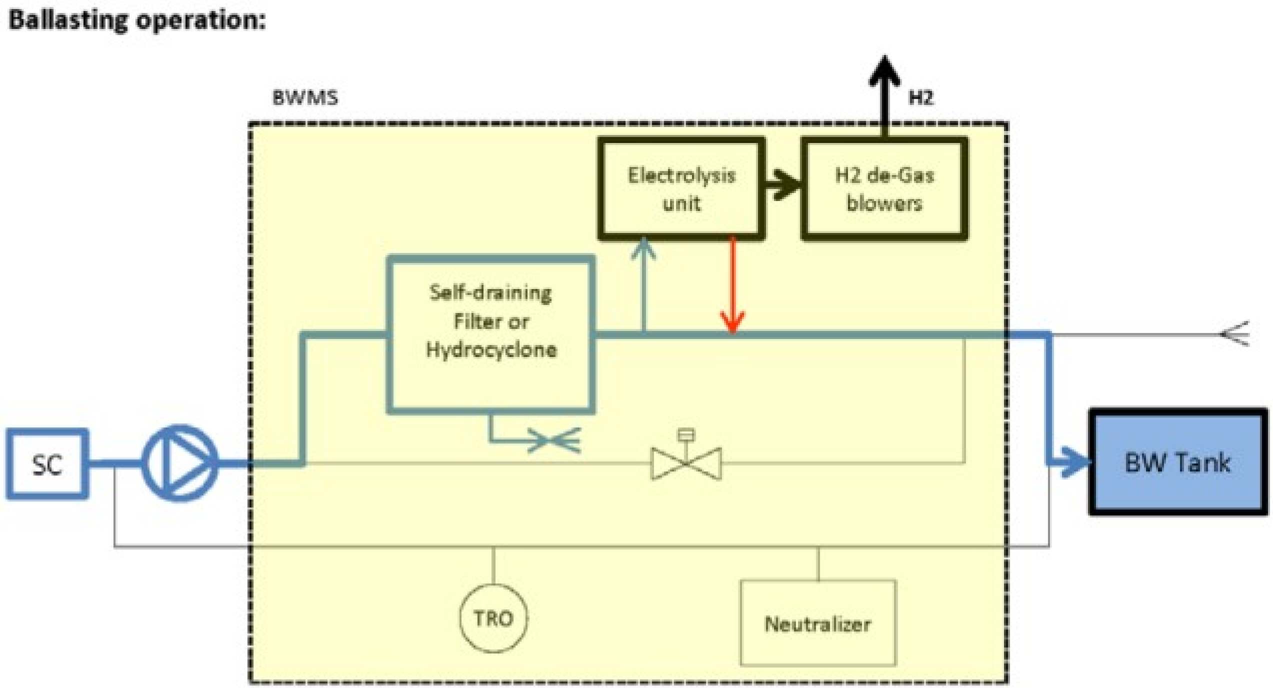
Ballasting operation:

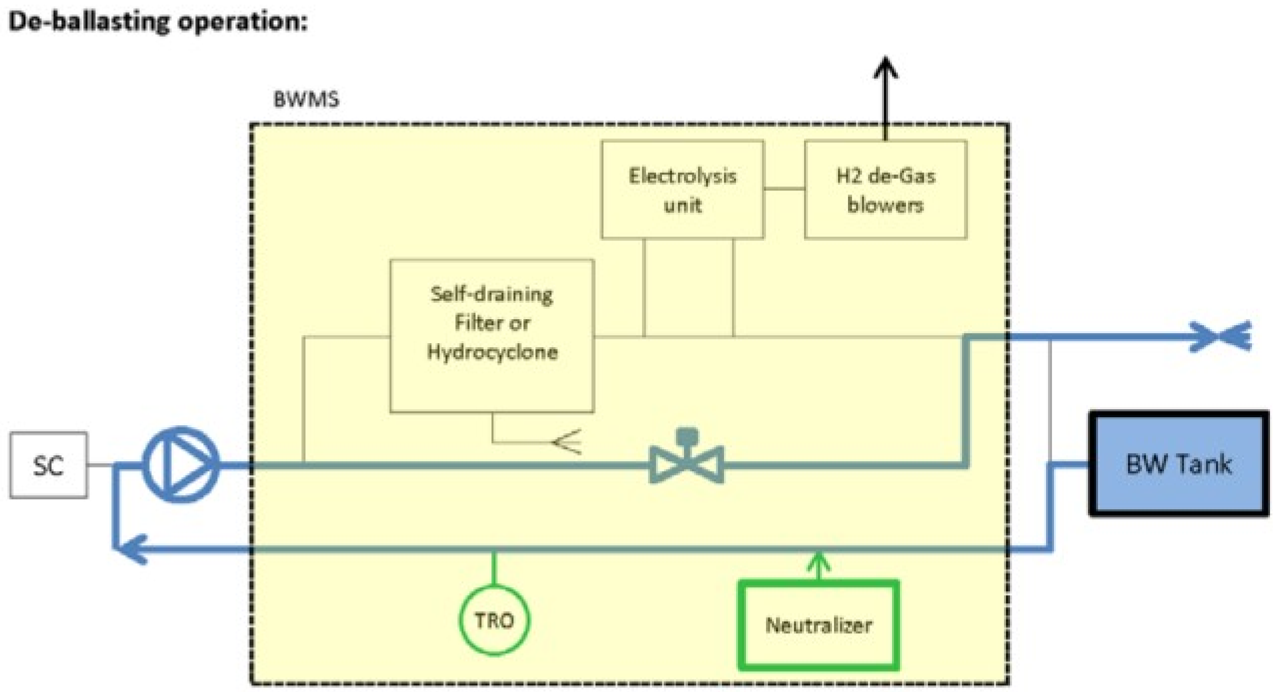


De-ballasting operation:

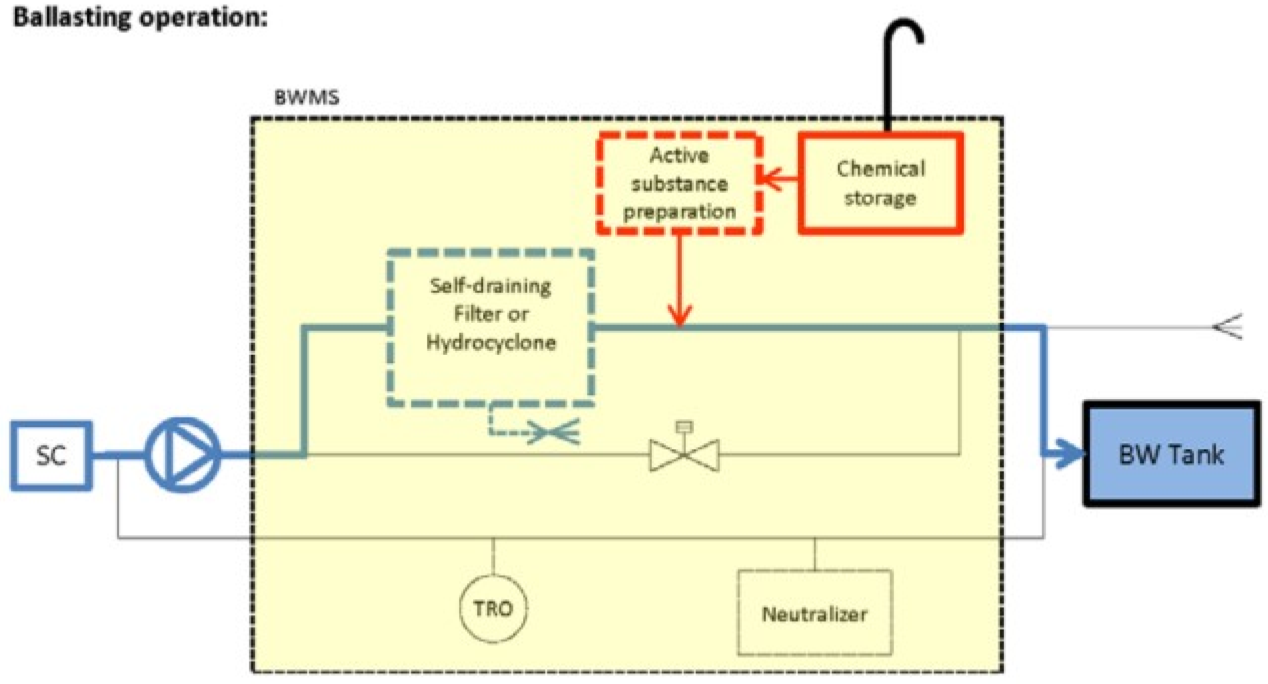


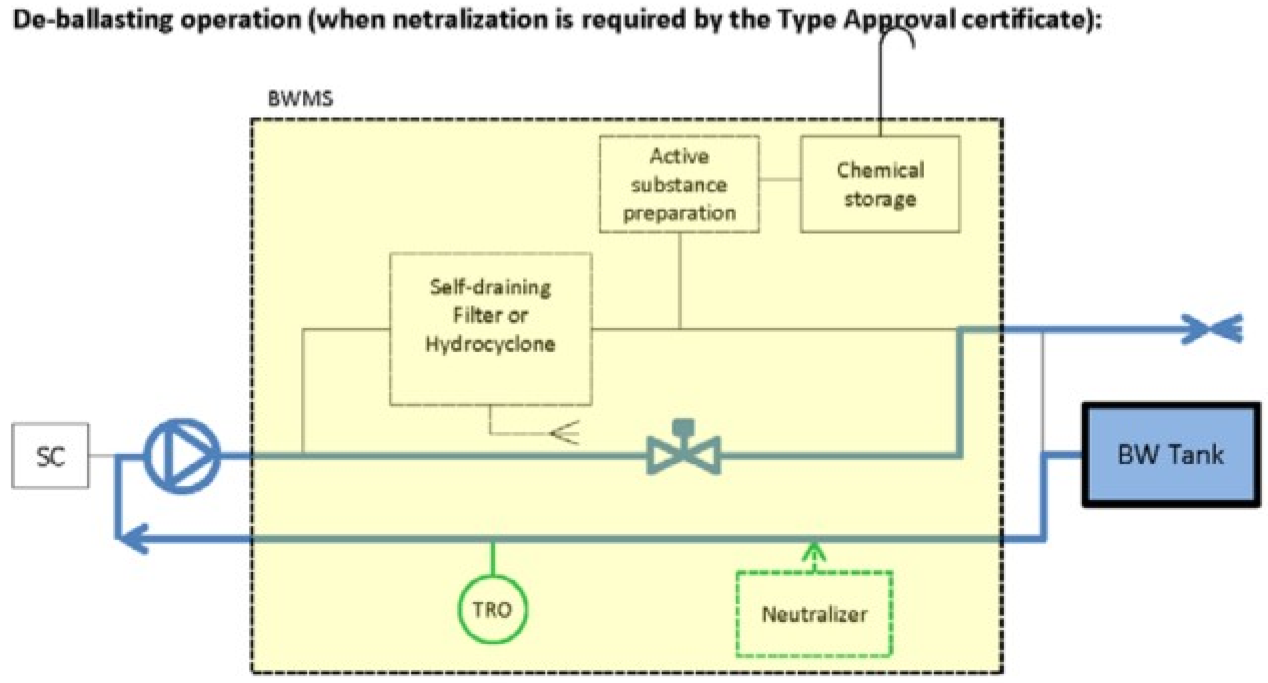
3.7 BWMS technology group no.5 In-line side-stream electrolysis (electro-chloronization)



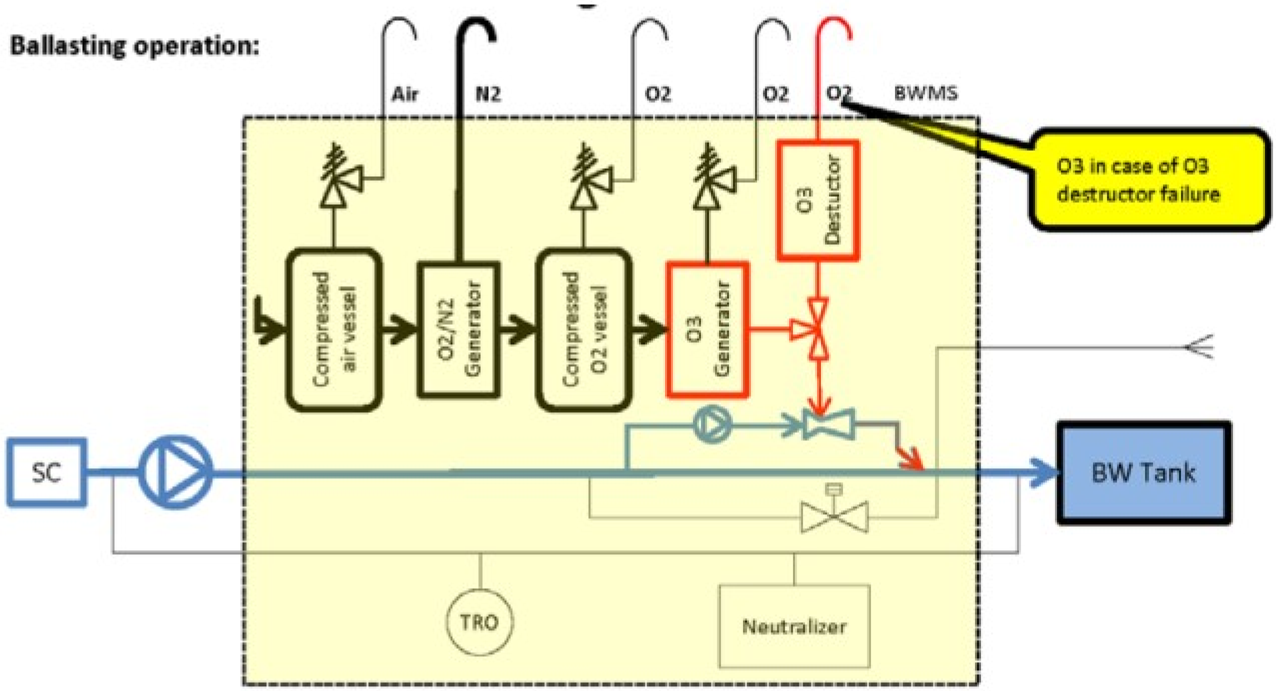


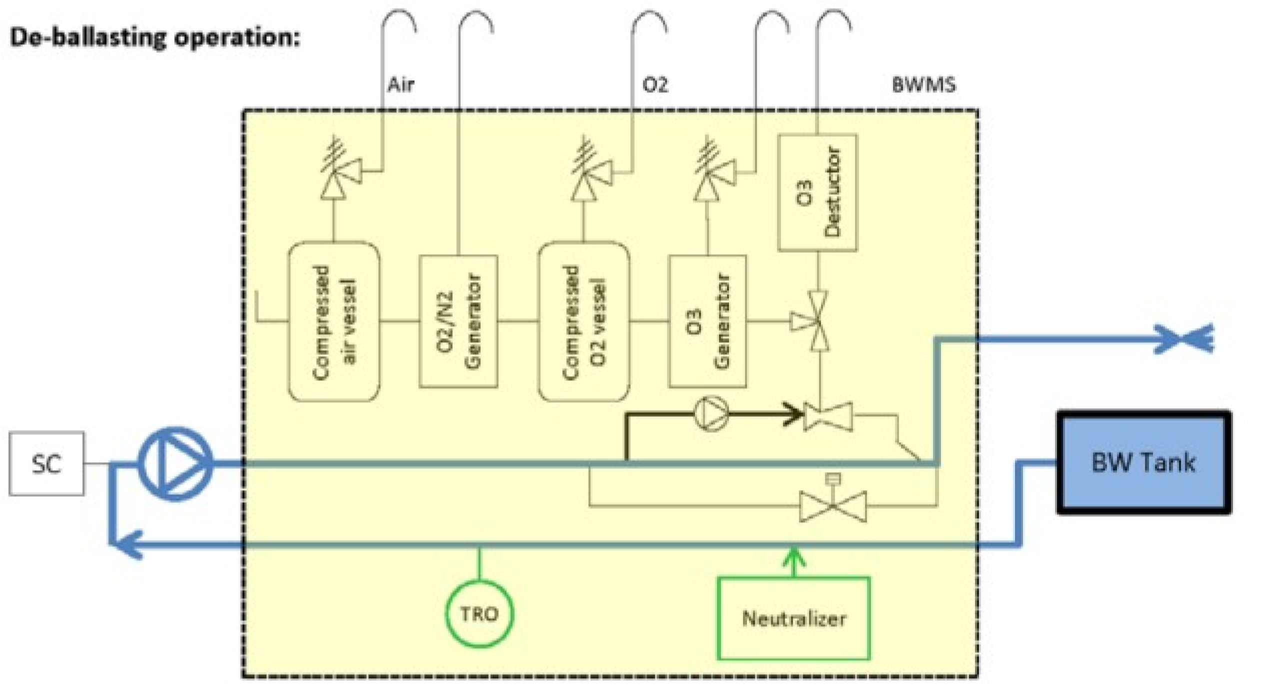
3.8 BWMS technology group no.6 In-line chemical injection



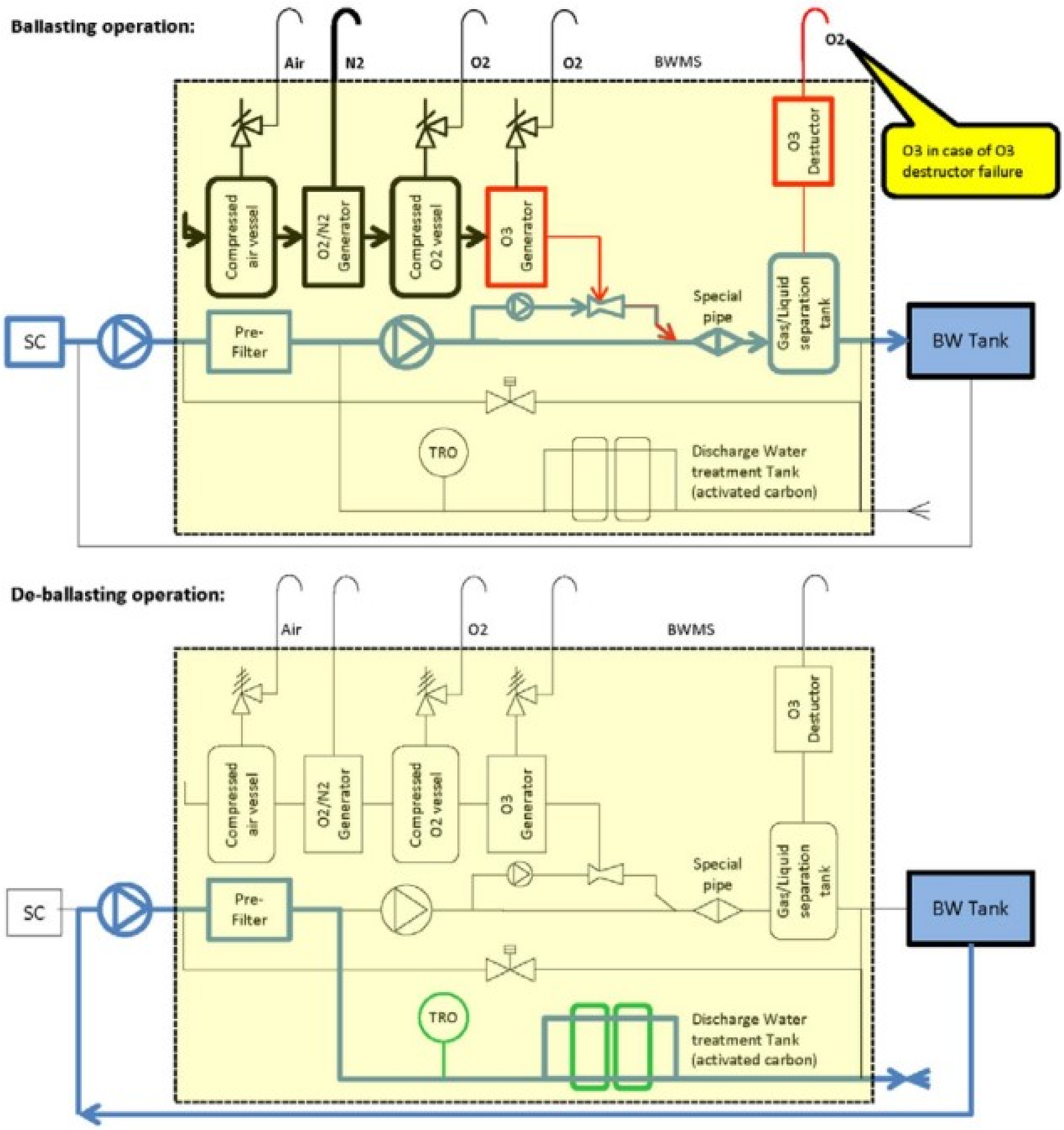


3.9 BWMS technology group no.7a In-line side-stream ozone injection without gas/liquid separation tank and without discharge water treatment tank

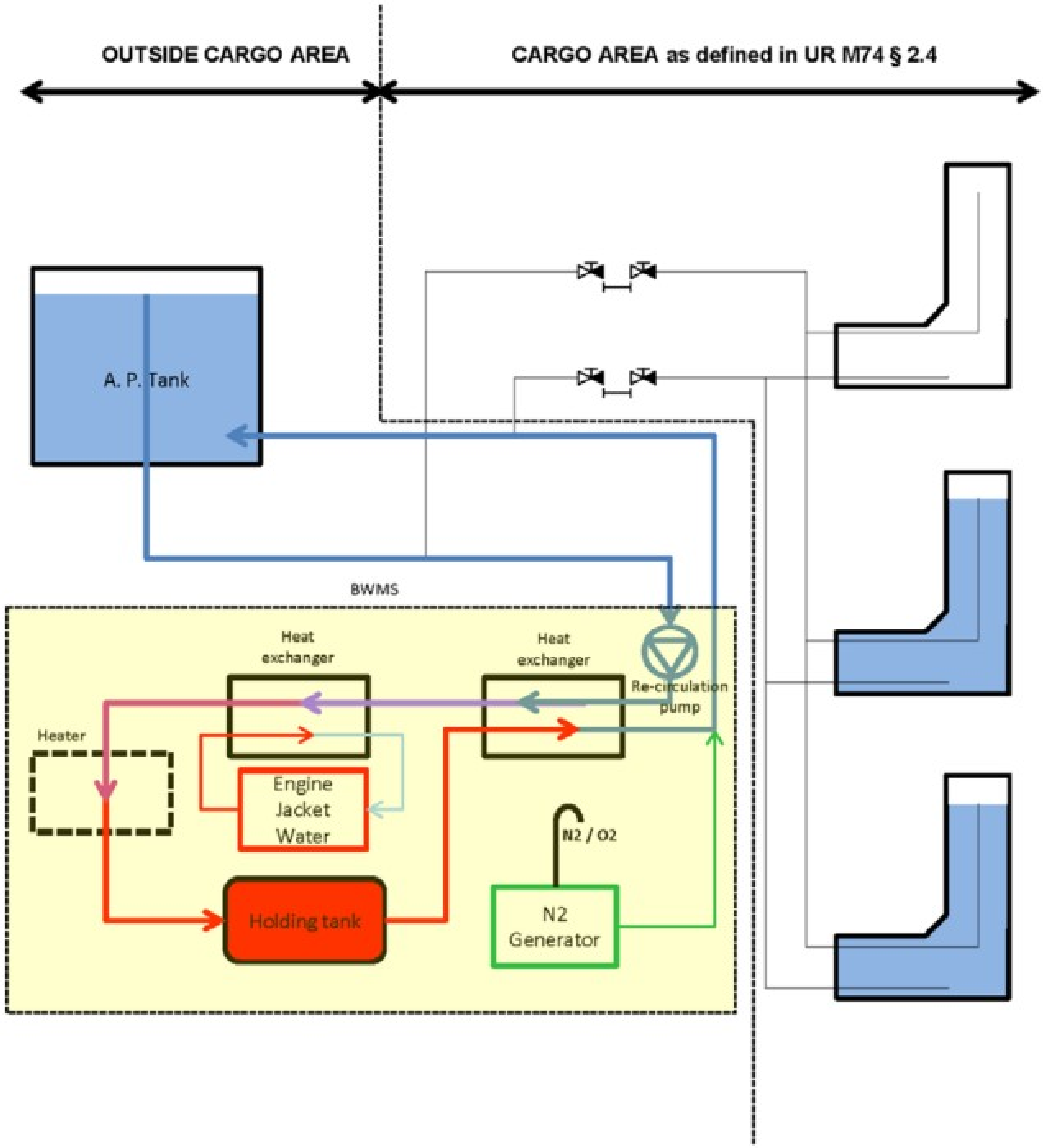




3.10 BWMS technology group no.7b In-line side-stream ozone injection with gas/liquid separation tank and with discharge water treatment tank



3.11 BWMS technology group no.8 In-line pasteurization + de-oxygenation with N_2 generator



F. Requirements for the use of crude oil or slops as fuel for tanker boilers

1. This subsection applies to tankers where crude oil or slops are used as fuel for boilers, except for the requirement(s) in this subsection which create conflict with the statutory requirements related to alternative design and arrangements required by SOLAS II-1/55 that do not need to be complied with (i.e statutory requirements take precedence over this subsection).

2. In tankers crude oil or slops may be used as fuel for main or auxiliary boilers according to the following requirements. For this purpose all arrangement drawings of a crude oil installation with pipeline layout and safety equipment are to be submitted for approval in each case.

3. Crude oil or slops may be taken directly from cargo tanks or flow slop tanks or from other suitable tanks. These tanks are to be fitted in the cargo tank area and are to be separated from non-gas-dangerous areas by means of cofferdams with gas-tight bulkheads.

4. The construction and workmanship of the boilers and burners are to be proved to be satisfactory in operation with crude oil.

The whole surface of the boilers shall be gas-tight separated from the engine room. The boilers themselves are to be tested for gas-tightness before being used. The whole system of pumps, strainers, separators and heaters, if any, shall be fitted in the cargo pump room or in another room, to be considered as dangerous, and separated from engine and boiler room by gas-tight bulkheads. When crude oil is heated by steam or hot water the outlet of the heating coils should be led to a separate observation tank installed together with above mentioned components. This closed tank is to be fitted with a venting pipe led to the atmosphere in a safe position according to the rules for tankers and with the outlet fitted with a suitable flame proo f wire gauze of corrosion resistant material which is to be easily removable for cleaning.

5. Electric, internal combustion and steam (when the steam temperature is higher than 22°C) prime movers of pumps, of separators (if any), etc., shall be fitted in the engine room or in another non-dangerous room.

Where drive shafts pass through pump room bulkhead or deck plating, gas-tight glands are to be fitted.

The glands are to be efficiently lubricated from outside the pump room.

6. Pumps shall be fitted with a pressure relief bypass from delivery to suction side and it shall be possible to stop them by a remote control placed in a position near the boiler fronts or machinery control room and from outside the engine room.

7. When it is necessary to preheat crude oil or slops, their temperature is to be automatically controlled and a high temperature alarm is to be fitted.

8. The piping for crude oil or slops and the draining pipes for the tray defined in 10. are to have a thickness as follows:

Table 15.3: Fixed Fire Extinguishing System

External diameter of pipes [d_e]			Thickness [t]
	$d_e \leq$	82,5 mm	$t \geq$ 6,3 mm
88,9 mm	< $d_e \leq$	108 mm	$t \geq$ 7,1 mm
114,3 mm	< $d_e \leq$	139,7 mm	$t \geq$ 8 mm
152,4 mm	$\leq d_e$		$t \geq$ 8,8 mm

Their connections (to be reduced to a minimum) are to be of the heavy flange type. Within the engine room and boiler room these pipes are to be fitted within a metal duct, which is to be gas-tight and tightly connected to the fore bulkhead separating the pump room and to the tray. This duct (and the enclosed piping) is to be fitted at a distance from the ship's side of at least 20% of the vessel's beam amidships and be at an inclination rising towards the boiler so that the oil naturally returns towards the pump room in the case of leakage or failure in delivery pressure. It is to be fitted with inspection openings with gas-tight doors in way of connections of pipes within it, with an automatic closing drain-trap placed on the pump room side, set in such a way as to discharge leakage of crude oil into the pump room.

In order to detect leakages, level position indicators with relevant alarms are to be fitted on the drainage tank defined in 10. Also a vent pipe is to be fitted at the highest part of the duct and is to be led to the open in a safe position. The outlet is to be fitted with a suitable flame proof wire gauze of corrosion-resistant material which is to be easily removable for cleaning.

The duct is to be permanently connected to an approved inert gas system or steam supply in order to make possible:

— injection of inert gas or steam in the duct in case of fire or leakage

— purging of the duct before carrying out work on the piping in case of leakage.

9. In way of the bulkhead to which the duct defined in 8. is connected, delivery and return oil pipes are to be fitted on the pump room side, with shut-off valves remotely controlled from a position near the boiler fronts or from the machinery control room. The remote control valves should be interlocked with the hood exhaust fans (defined in 11.) to ensure that whenever crude oil is circulating the fans are running.

10. Boilers shall be fitted with a tray or gutterway of a height to the satisfaction of BKI and be placed in such a way as to collect any possible oil leakage from burners, valves and connections.

Such a tray or gutterway shall be fitted with a suitable flame proof wire gauze, made of corrosion resistant material and easily dismountable for cleaning. Delivery and return oil pipes shall pass through the tray or gutterway by means of a tight penetration and shall then be connected to the oil supply manifolds.

A quick closing master valve is to be fitted on the oil supply to each boiler manifold. The tray or gutterway shall be fitted with a draining pipe discharging into a collecting tank in pump room. This tank is to be fitted with a venting pipe led to the open in a safe position and with the outlet fitted with wire gauze made of corrosion resistant material and easily dismountable for cleaning.

The draining pipe is to be fitted with arrangements to prevent the return of gas to the boiler or engine room.

11. Boilers shall be fitted with a suitable hood placed in such a way as to enclose as much as possible of the burners, valves and oil pipes, without preventing, on the other side, air inlet to burner register.

The hood, if necessary, is to be fitted with suitable doors placed in such a way as to enable inspection of and access to oil pipes and valves placed behind it. It is to be fitted with a duct leading to the open in a safe position, the outlet of which is to be fitted with a suitable flame wire gauze, easily dismountable for cleaning. At least two mechanically driven exhaust fans having spark proof impellers are to be fitted so that the pressure inside the hood is less than that in the boiler room. The exhaust fans are to be connected with automatic change over in case of stoppage or failure of the one in operation

The exhaust fan prime movers shall be placed outside the duct and a gas-tight bulkhead penetration shall be arranged for the shaft.

Electrical equipment installed in gas dangerous areas or in areas which may become dangerous (i.e. in the hood or duct in which crude-oil piping is placed) is to be of certified safe type.

12. When using fuel oil for delivery to and return from boilers fuel oil burning units in accordance with this Rule shall be fitted in the boiler room. Fuel oil delivery to, and returns from, burners shall be effected by means of a suitable mechanical interlocking device so that running on fuel oil automatically excludes running on crude oil or vice versa.

13. The boiler compartments are to be fitted with a mechanical ventilation plant and shall be designed in such a way as to avoid the formation of gas pockets.

Ventilation is to be particularly efficient in way of electrical plants and machinery and other plants which may generate sparks. These plants shall be separated from those for service of other compartments and shall be in accordance with the requirements of these Rules.

14. A gas detector plant shall be fitted with intakes in the duct defined in 8., in the hood duct (downstream of the exhaust fans in way of the boilers) and in all zones where ventilation may be reduced. An optical warning device is to be installed near the boiler fronts and in the machinery control room. An acoustical alarm, audible in the machinery space and control room, is to be provided.

15. Means are to be provided for the boiler to be automatically purged before firing.

16. Independent of the fire extinguishing plant as required in Section 12, an additional fire extinguishing plant is to be fitted in the engine and boiler rooms in such a way that it is possible for an approved fire extinguishing medium to be directed on to the boiler fronts and on to the tray defined in 10. The emission of extinguishing medium should automatically stop the exhaust fan of the boiler hood (see 9.).

17. A warning notice must be fitted in an easily visible position near the boiler front. This notice must specify that when an explosive mixture is signalled by the gas detector plant defined in 14. the watchkeepers are to immediately shut off the remote controlled valves on the crude oil delivery and return pipes in the pump room, stop the relative pumps, inject inert gas into the duct defined in 8. and turn the boilers to normal running on fuel oil.

18. One pilot burner in addition to the normal burning control is required.

Section 16 Torsional Vibrations

A. Definition

For the purposes of these requirements, torsional vibration loads are additional loads due to torsional vibrations. They result from the alternating torque which is superimposed on the mean torque.

For ships with ice classes, loads resulting from propeller/ ice interaction must be calculated separately, see Section 13.

B. Calculation of Torsional Vibrations

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 BKI for approval. To facilitate a smooth and efficient approval process, the drawings could be submitted in electronic format. The following data shall be included in the analysis:

Input Data

— equivalent torsional vibration system
moments of inertia and inertialess torsional elasticities/ stiffness for the complete system

— prime mover
engine type, rated power, rated speed, cycles per revolution, design (in-line/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/unconventional types of engines)

— vibration damper
type, damping coefficient, moments of inertia, dynamic stiffness

— elastic couplings
type, damping coefficient, moments of inertia dynamic 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 CP propellers)

Output Data/Results

- natural frequencies
  with their relevant vibration forms (modes)

- forced vibratory loads (torques or stresses)
  calculated torsional vibration torques/shear stresses in all important 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.

- maximum permissible time for passing through a barred speed range, in case prohibited ranges of operation are introduced for continuous running

2. The calculations are to be performed both for normal operation (uniform pressure distribution over all cylinders or small deviations in pressure distribution e.g. ± 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 generator, with clutches for engaged and disengaged branches.

4. The calculation of torsional vibrations shall also include the stresses / torques resulting from the superimposition of several harmonics (synthesized values) so far relevant for the overall assessment of the system, see also 1, output data.

5. If modifications are introduced into the system which have a substantial effect on the torsional vibration characteristics, the calculation of the torsional vibrations is to be adapted and re-submitted 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 Torsional Vibration Stresses

1. Shafting

1.1 The alternating torsional stress amplitude is understood as $(\tau_{max} - \tau_{min})/2$ as can be measured on a shaft in a relevant condition over a repetitive cycle.

Torsional vibration calculations are to include normal operation and operation with any one-cylinder misfiring (i.e. no injection but with compression) giving rise to the highest torsional vibration stresses in the shafting.

For continuous operation the permissible stresses (τ_1) due to alternating torsional vibration are not to exceed the values given by the following formulae:

$$\pm \tau_1 = C_W \cdot C_K \cdot C_D \cdot (3 - 2 \cdot \lambda^2) \quad [N/mm^2] \qquad (1)$$

for speed ratio values $\lambda < 0,9$

$$\pm \tau_1 = C_W \cdot C_K \cdot C_D \cdot 1.38 \quad [N/mm^2] \qquad (2)$$

for speed ratio values $0,9 \le \lambda \le 1,05$

For the passing of the barred speed range the torsional vibrations for steady state condition (τ_2) are not to exceed the value given by the formula:

$$\pm\,\tau_2 = 1{,}7 \cdot \frac{\tau_1}{\sqrt{c_K}} \qquad (3)$$

where:

τ_1 = permissible stress amplitude due to torsional vibration for continuous operation [N/mm^2]

τ_2 = permissible stress amplitude due to steady state torsional vibration in a barred speed range [N/mm^2]

ς_B = specified minimum ultimate tensile strength of the shaft material [N/mm^2]

C_D = size factor

= $0{,}35 + 0{,}93 \cdot d_o 0{,}2$

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 16.1.

d_o = shaft diameter [mm]

λ = speed ratio = n/n_0

n = speed under consideration [rpm]

n_0 = nominal speed at rated power [rpm]

R_m = tensile strength of shaft material [N/mm^2]

C_W = material factor

$$= \frac{R_m + 160}{18} \qquad (4)$$

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 $R_m \geq 500\ N/mm^2$. Otherwise, materials having a specified minimum ultimate tensile strength $R_m \geq 400\ N/mm^2$ may be used.

For the purpose of the formulas (1), (2), (3), (4) the tensile strength calculation value applied must not exceed the following limits:

R_m = $600\ N/mm^2$

— for propeller shafts in general
— for all other shafts particularly intermediate shafts, made of forged, low alloy carbon or carbon manganese steel

R_m = $800\ N/mm^2$

for all shafts except propeller shafts made of forged high alloy steels. Formulas (4) should be applied in conjunction with such steels and special design features only.

Table 16.1: Form factor for intermediate and propeller shafts

k	C_K	Type of shafts
		Intermediate shafts with
1,0	1,0	Integral coupling flange [1] and straight sections
1,0	1,0	Shrink fit coupling [2]
1,10	0,60	Keyway, tapered connection [3,4]
1,10	0,45	Keyway, cylindrical connection [3,4]
1,10	0,50	Radial hole [5]
1,20	0,30 [7]	Longitudinal slot [6]
		Thrust shafts external to engines
1,10	0,85	on both sides of thrust collar [1]
1,10	0,85	in way of bearing when a roller bearing is used
		Propeller shafts
1,22	0,55	Flange mounted, or keyless taper fitted propellers [8]
1,26	0,55	Key fitted propellers [8]
1,15	0,80	Between forward end of aft most bearing and forward stern tube seal

Notes:

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.

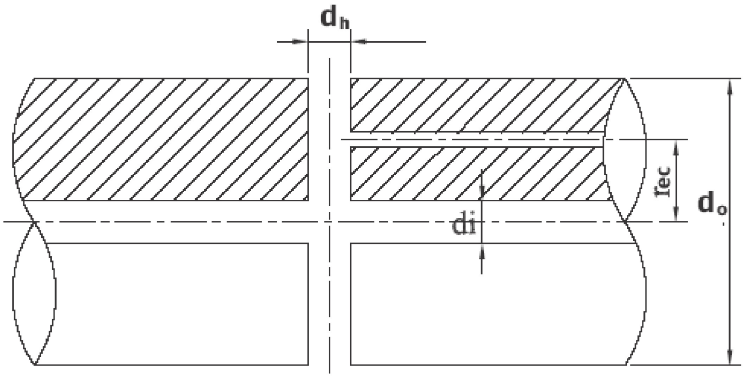
1 Fillet radius is not to be less than $0{,}08 \cdot d_o$.

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 $0{,}2 \cdot d_o$ 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 $0{,}3 d_o$.
The intersection between a radial and an eccentric (rec) axial bore (see below) is not covered in this Section.



6 Subject to limitations as slot length (l)/outside diameter < 0,8 and inner diameter (di)/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 Footnote C or by direct application of FE calculation. In which case:
c_K = 1,45/scf
Note that the scf is defined as the ratio between the maximum local principal stress and √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.

Footnotes:

A. Shafts complying with this Section satisfy the following

1 Low cycle fatigue criterion (typically < 104), i.e. the primary cycles represented by zero to full load and back to zero, including reversing torque if applicable. This is addressed by the formula in M68.4.

2 High cycle fatigue criterion (typically » 107), i.e. torsional vibration stresses permitted for continuous operation as well as reverse bending stresses. The limits for torsional vibration stresses are given in M68.5.The influence of reverse bending stresses is addressed by the safety margins inherent in the formula in M68.4.

3 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 M68.5.

B. 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 0,08 . d_o (geometric stress concentration of approximately 1,45).

$c_K = \frac{1,45}{scf}$ and $k = \left[\frac{scf}{1,45}\right]^x$

where the exponent x considers low cycle notch sensitivity.

— The notch sensitivity. The chosen values are mainly representative for soft steels (σ_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.

C. Stress concentration factor of slots

The stress concentration factor (scf) at the end of slots can be determined by means of the following empirical formulae using the symbols in note 6:

$$scf = \alpha_{t(hole)} + 0,8 \cdot \frac{(l - e/d)}{\sqrt{\left(1 - \frac{d_i}{d}\right) \cdot \frac{e}{d}}}$$

This formula applies to:

— slots at 120 or 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.

$\alpha_{t(hole)}$ represents the stress concentration of radial holes (in this context e = hole diameter) and can be determined as:

$$\alpha_{t(hole)} = 2,3 - 3 \cdot \frac{e}{d} + 15 \cdot \left(\frac{e}{d}\right)^2 + 10 \cdot \left(\frac{e}{d}\right)^2 \cdot \left(\frac{d_i}{d}\right)^2$$

or simplified to $\alpha_{t(hole)}$ = 2.3

Where the stress amplitudes exceed the limiting values of τ_1 for continuous operation, including one-cylinder misfiring conditions if intended to be continuously operated under such conditions, restricted speed ranges are to be imposed which are to be passed through rapidly.

Restricted speed ranges in normal operating conditions are not acceptable above λ = 0,8.

Restricted speed ranges in one-cylinder misfiring conditions of single propulsion engine ships are to enable safe navigation. The limits of the barred speed range are to be determined as follows:

1) The barred speed range is to cover all speeds where the acceptance limits (τ_1) are exceeded. For controllable pitch propellers with the possibility of individual pitch and speed control, both full and zero pitch conditions have to be considered.

2) Additionally, the tachometer tolerance has to be added. At each end of the barred speed range the engine is to be stable in operation.

3) In general, and subject to 1) the following formula may be applied, provided that the stress amplitudes at the border of the barred speed range are less than τ_1 under normal and stable operating conditions.

$$\frac{16 \cdot n_c}{18 - \lambda_c} \leq n \leq \frac{(18 - \lambda_c) \cdot n_c}{16}$$

n_c = critical speed in revolutions per minute (resonance speed) [rpm]
λ_c = critical speed ratio = n_c / n_o

1.2 In the speed range 0,9 ≤ λ ≤ 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 BKI, 90% of the mean torque may be permitted provided that the torque is only transmitted in the connection by friction only or integrally forged flanges are applied.

1.3 For 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 shear stresses remain below the τ_2 value for λ = 0,6 calculated by formula (4). 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.

2. Crankshafts

2.1 Crankshafts applied for engines for ships classed by BKI shall be approved on the basis of the Section 2.C. For application of this guideline a gas pressure distribution in the cylinder over the crank angle is submitted by the maker of the engine. The maker 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/mm^2 for medium and high-speed engines and between 25 and 40 N/mm^2 for two strokes engines, but special confirmation of the value considered for judgment by BKI is necessary.

For further details see also Section 2.C.1.

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 to Section 2.C, 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 to the BKI Guideline 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 must be suitable for use for diesel engines. BKI 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 dismounted with reasonable ease for checking purpose. 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.

3. Gears

3.1 In the service speed range 0,9 ≤ λ ≤ 1,05, no alternating torque higher than 30% of the mean nominal torque for this stage shall normally occur in any loaded gear's mesh. 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 BKI, 30% of the design torque of the concerned gear's mesh may be applied as the load limit.

3.2 When passing through resonant speeds below the operational speed range during starting and stopping of the plant, the alternating torque in the gear shall not exceed twice the nominal mean torque for which the gear has been designed.

3.3 Load reversal due to alternating torques is normally permitted only while passing through the lower speed range up to λ ≤ 0,35.

If, in special cases, gear hammering in the λ ≤ 0,35 speed range 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 3.4.

3.4 In installation 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 carriers). For the loaded parts of the gear system the provisions in accordance to 3.1 apply.

Higher alternating torques may be approved by BKI if proof is submitted that design measures have been introduced considering these higher loads, see 3.1.

4. Flexible couplings

4.1 Flexible couplings shall be designed to withstand the torsional vibration loads which occur during 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 5.

4.2 Flexible couplings shall be capable of transmitting for a reasonable time the increased alternating torques which occur 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, continuous operation is not allowed shall be indicated in accordance with E.2.

5. Shaft-driven generators

5.1 In installation 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 shall be 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 exited resonant speed 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°. The electrical vibration amplitude is obtained by multiplying the mechanical vibration amplitude by the number of pole pairs. Whether BKI 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 investigating the torsional vibration loadings.

In the assessment of their dynamic loads, the limits as defined by the respective makers are to be considered in addition to the criteria as stated in 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. Dismounting of such units shall generally not lead to substantial overloading o the main system in terms of exceeding the τ_2 limit for shafting systems, the maximum torque for flexible couplings or the like.

6.2 In special cases, the calculations of forced torsional vibrations, including those for disturbed operation (dismounted unit), as stated in B.1. will be required to be submitted to BKI. In such cases BKI reserves the right to stipulate the performance of confirmatory measurements (compare D), including such as related to disturbed operation.

D. Torsional Vibration Measurements

1. During the ship's sea trials, the torsional vibrations of the propulsion plant are to be measured over the whole operating range. Measuring investigations shall 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 shall 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.

Measurements are required by BKI for all plants with a nominal torque exceeding 40 kNm. For other plants not meeting this condition, BKI reserve the right to ask for measurements depending on the calculation results. The requirement for measurements will be communicated to the yard/engine supplier with the approval letter for the torsional vibration calculation.

Where measurements of identical propulsion plants (specifically sister vessels) are available, further torsional vibration measurements for repeat ships may, with the consent of BKI, be dispensed with.

In case that the measuring results are not conclusive enough in respect to the calculations, BKI reserve the right to ask for further investigations or new approval of a revised and adapted calculation model.

2. Where existing propulsion plants are modified, BKI reserve the right to require a renewed investigation of the torsional vibration characteristics.

E. Prohibited Ranges of Operation

1. Operating ranges, which due to 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 stations. See also D.2.

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(s) is (are) to be selected in a way that stresses in the shafting's 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, 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 also C.4 and C.5).

2. Measures necessary to avoid overloading of the propulsion plant under abnormal operating conditions are to be displayed on instruction plates to be affixed to all engine control stations.

F. Auxiliary Machinery

1. Essential auxiliary machinery such as diesel generators, bow thrusters and AC generating sets shall be designed in a way that the operating speed range is free of unacceptable stresses due to torsional vibrations in accordance with C.

2. Generators

2.1 For diesel generator sets with a mechanical output of more than 150 kW torsional vibration calculations must be submitted to BKI for approval. The investigations must include natural frequencies as well as forced vibration calculations. The speed range 90% to 105% of the nominal speed must be investigated under full load conditions.

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 Rule nominal torque is the torque which can be calculated by applying the actual data of the diesel engine (nominal output/nominal speed).

The compliance of the limit of 250% within the speed range 90% to 105% of the nominal speed shall be proven. The calculation for this speed range shall be carried out by using the excitation corresponding to the nominal torque of the engine.

Exceeding the limit of 250% 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 set as defined above must not be exceeded.

3. Bow thruster

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 must be submitted to BKI for approval. The torsional vibration calculation must focus 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 shall take care that relevant excitation forces (e.g. propeller blade frequency or similar) may not lead to unacceptable torsional vibration loadings. In special cases BKI may require the submission of corresponding calculations.

4. AC Generating Sets

4.1 The generating set shall show torsional vibration levels which are compatible with the allowable limits for the alternator, shafts, coupling and damper.

4.2 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. When the engine power is 110 kW or above, torsional vibration calculations are to be submitted to BKI for approval.

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

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

— the generating set manufacturer's name or mark.

— the set serial number.

— the set date of manufacture (month/year).

— the rated power (both in kW and KVA) with one of the prefixes Continuous Power (COP), Prime Power (PRP) or, only for emergency Generating sets, Limited-Time running power (LTP) as defined in ISO 8528-1:2018.

— the rated power factor.

— the set rated frequency (Hz).

— the set rated voltage (V).

— the set rated current (A).

— the mass (kg).

Section 17 Spare Parts

A. General

1. Spare parts in general are not mandatory for retention of BKI. It is, however, assumed that an inventory of spare parts sufficient to meet the needs posed by the ship's plans of operation is maintained on board. 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

These Rules are considered to be complied with if the range of spare parts corresponds to the tables given below and allowing for the extend of the installed systems and components in question at the time of commissioning.

2. Depending on the design and arrangement of the engine plant, the intended service and operation of the ship, and also the manufacturer's recommendations, a different volume of spare parts may be agreed between the ship-owners and BKI.

Where the volume of spare parts is based on special arrangements between the ship-owners and BKI, technical documentation is to be provided.

A list of the relevant spare parts is to be carried on board.

3. In the case of propulsion systems and essential auxiliary machinery which are not included in the following tables, the requisite range of spare parts is to be established in each individual case between shipyard/ ship-owners and BKI.

4. The list of spare parts specified in this Section are applicable to the ships for unrestricted services. All other ships are to be agreed between the ship owner and BKI.

B. Risk Assessment Approach for Determining the Spare Part Provision of Main Internal Combustion Engine

1. The risk assessment approach may be used to assess the required spare parts of main internal combustion engine to be carried on board.

2. Assessment of the recommended spare parts to be carried onboard ship through risk assessment can provide a flexible and adaptable means to satisfy the core requirement for spare parts and associated maintenance, namely, the avoidance of sudden operational failures to equipment, components and systems which may result in hazardous situations or unsafe events.

3. The Guidance for Marine Industry (Pt.1, Vol.AC) Section 2, R-26 may be used as reference.

4. In cases where a risk assessment approach has not been taken, requirement in Table 17.1 to o 17.5 sets out a generic example of the typical minimum recommended spare parts for conventionally fuelled main internal combustion engines

C. Volume of Spare Parts

1. Recognising the complexity and diversity of machinery, equipment and systems providing essential services, a recommended list of spare parts may not always be relevant. In such circumstances, a risk-based approach should be taken in order to determine the spare parts to be carried onboard.

2. In cases where a risk assessment approach is not followed, the list of spare parts in accordance with the Table 17.1 to 17.5 are a generic example of the typical minimum recommended spare part for each type of application.

Table 17.1: generic example of the typical minimum recommended spare parts for conventionally fuelled main internal combustion engines of ships for unrestricted service

Item	Spare parts	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, fully equipped and ready for installation, including gaskets	1
4. Cylinder cover	Cylinder cover, complete with valves, joint rings and gaskets.	1
	Cylinder cover bolts and nuts, for one cylinder	1/2 set
5. Cylinder Valves	Exhaust valves, complete with casings, seats, springs and other fittings for one cylinder	2 set
	Air inlet valves, complete with casings, seats, springs and other fittings for one cylinder	1 set
	Starting air valve, complete with casting, 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 lubricator	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

Table 17.1: generic example of the typical minimum recommended spare parts for conventionally fuelled main internal combustion engines of ships for unrestricted service(Continued)

Item	Spare parts	Number recommended
13. Scavenge blower (including turbo chargers)	Rotors, rotor shafts, bearings, nozzle rings and gear wheels or equivalent working parts if 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
16. Control alarm and safety system	Parts essential for safe engine operation	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 ship operator.
2. It is assumed that the new 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 17.2: A generic example of the typical minimum recommended spare parts for auxiliary internal combustion engine driving electric generators for essential services on board ships for unrestricted service

Item	Spare parts	Number recommended
1. Main bearings	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 casing, 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
9. Control, alarm and safety system	Parts essential for safe engine operation	1 set

Notes:
1. The availability of other spare parts should be specially considered and decided upon by the ship operator.
2. It is assumed that the new 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 17.3: A generic example of the typical minimum recommended spare parts for main steam turbines of ships for unrestricted service

Item	Spare parts	Number recommended
1. Turbine shaft	Carbon sealing rings, where fitted, with springs for each size sealing rings and type of gland	1 set
2. Oil filters	Strainer baskets or inserts, for filters of special design, of each type and size	1 set
3. Control, alarm and safety system	Parts essential for safe turbine operation	1 set

Notes:

1. The availability of other spare parts should be specially considered and decided upon by the ship operator.
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-turbine installations, the minimum recommended spare parts are only necessary for one turbine.

Table 17.4: A generic example of the typical minimum recommended spare parts for auxiliary steam turbines driving electric generators for essential services of ships for unrestricted service

Item	Spare parts	Number recommended
1. Turbine shaft	Carbon sealing rings, where fitted, with springs, for each size and sealing rings 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
3. Control, alarm and safety system	Parts essential for safe turbine operation	1 set

Notes:

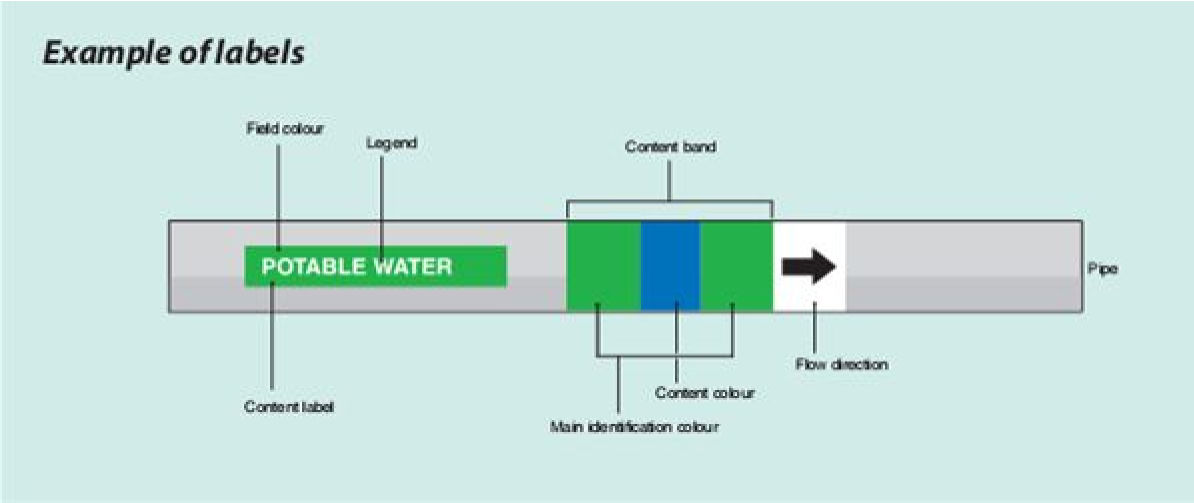
1. The availability of other spare parts should be specially considered and decided upon by the ship operator.
2. It is assumed that the crew has on board the necessary tools and equipment.
3. When the recommended spares are utilized, it is recommended that new spares are supplied as soon as possible.
4. Where the number of generators of adequate capacity fitted for essential services exceeds the required number, spare parts may be omitted.

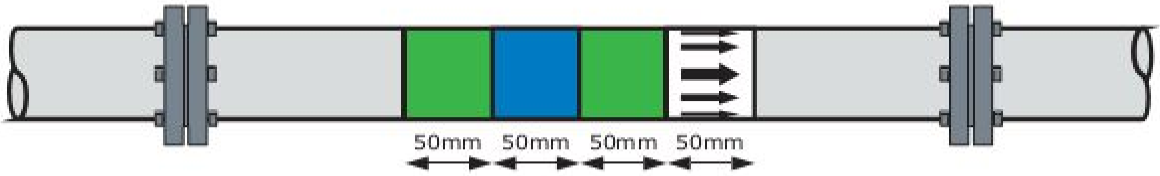
Table 17.5: A generic example of the typical minimum recommended spare parts for essential auxiliary machinery of ships for unrestricted service

<table>
<tr><td colspan="3">1. Auxiliary internal combustion engines and steam turbines driving essential service machinery other than generators</td></tr>
<tr><td colspan="3">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.</td></tr>
<tr><td colspan="3">2. Pumps</td></tr>
<tr><th>Item</th><th>Spare parts</th><th>Number recommended [1]</th></tr>
<tr><td rowspan="2">a. Piston pumps</td><td>Valve with seats and springs, each size fitted</td><td>1 set</td></tr>
<tr><td>Piston rings, each type and size for one piston</td><td>1 set</td></tr>
<tr><td rowspan="2">b. Centrifugal pumps</td><td>Bearing of each type and size</td><td>1</td></tr>
<tr><td>Rotor sealings of each type and size</td><td>1</td></tr>
<tr><td rowspan="2">c. Gear type pumps</td><td>Bearings of each type and size</td><td>1</td></tr>
<tr><td>Rotor sealings of each type and size</td><td>1</td></tr>
<tr><td colspan="3">3. Compressors for essential service</td></tr>
<tr><th colspan="2">Spare parts</th><th>Number recommended</th></tr>
<tr><td colspan="2">Suction and delivery valves complete of each size fitted in one unit</td><td>1/2 set</td></tr>
<tr><td colspan="2">Piston rings of each type and size fitted for one piston</td><td>1 set</td></tr>
<tr><td colspan="3">4. General</td></tr>
<tr><td colspan="3">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 spares are supplied as soon as possible.</td></tr>
<tr><td colspan="3">Notes:
1. When a sufficiently rated standby pump is available, the spare parts may be dispensed with.</td></tr>
</table>

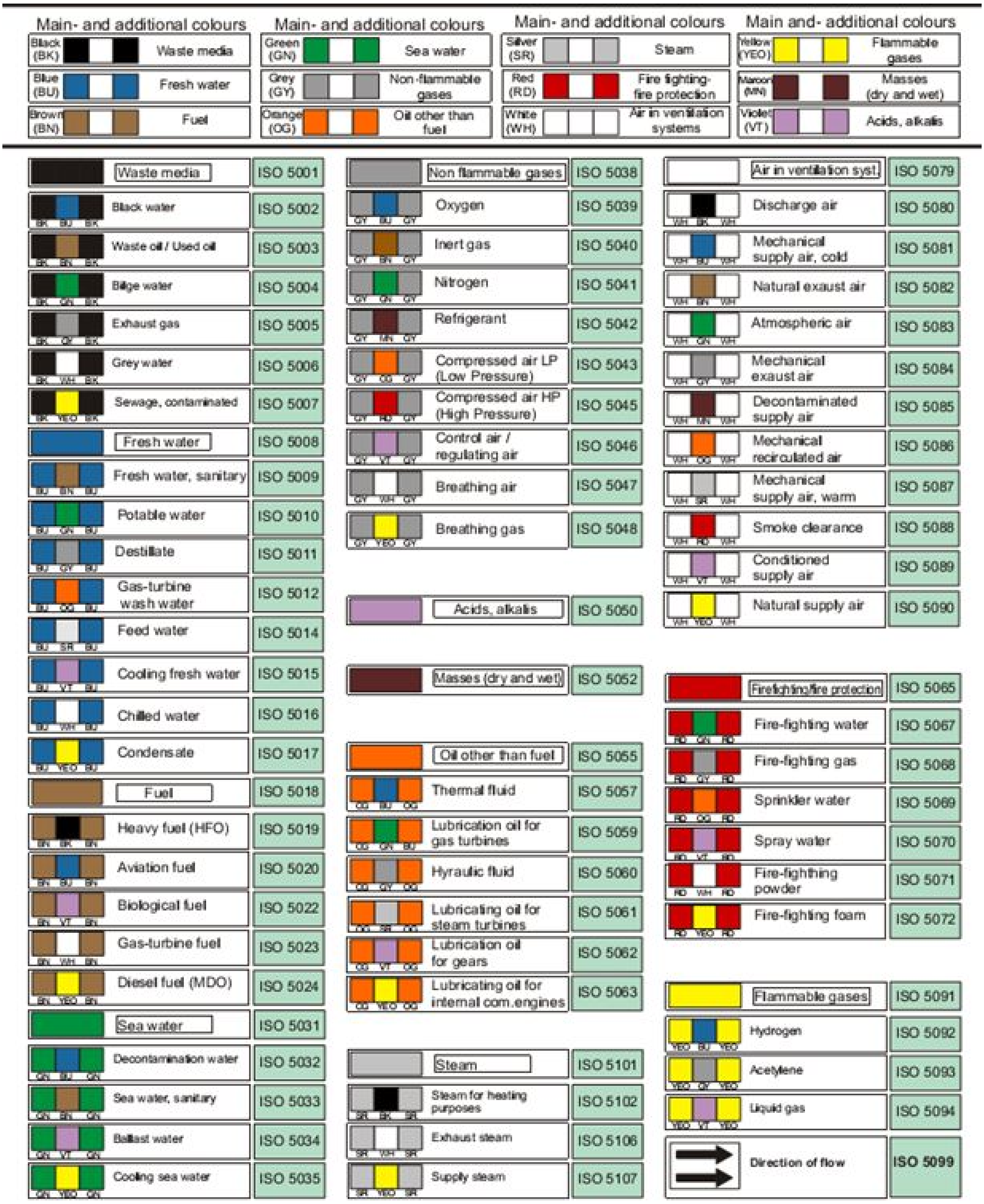
Annex A Pipe Marking

A. Marking Arrangement





B. Marking Type



Annex B Installations of BWMS on-board Ships

A. General

1. Application

1.1 This requirement details fire safety, in addition to that required by SOLAS II-2, related to the installation of Ballast Water Management Systems onboard any ship.

Rquirement in this Annex is to be read in conjunction with Section 11.0.1.6 - Ballast water treatment plants.

1.2 The requirements of this Annex apply for BWMS technologies as listed in Table A.1. BWMS with alternative technologies are to be specially considered by BKI.

2. Definitions

2.1 Airlock

An airlock is a space enclosed by gastight steel bulkheads with two gastight doors spaced not more than 2.5 m apart. The doors shall be self-closing without any holding back arrangement. Air locks shall have mechanical ventilation and shall not be used for other purposes. An audible and visual alarm system to give a warning on both sides of the air lock shall be provided to indicate if more than one door is moved from the closed positions. The air lock space shall be monitored for dangerous gas as defined in Section 11.O.1.6.3.2.

2.2 Ballast Water Management System (BWMS)

Ballast Water Management System means any system defined in Section 11.O.1.6.3.1.

Table A.1: Categorization of BWMS technologies

BWM's technology category		1	2a	3a	3b	3c	4	5	6	7a	7b	8
Characteristics		In-line UV or UV + Advanced Oxidation Technology (AOT) or UV TiO2 or UV + Plasma	In-line Flocculation	In-line membrane separation and de-oxygenation (injection of N2 from a N2 Generator)	In-line de-oxygenation (injection of Inert Gas from Inert Gas Generator)	In-tank de-oxygenation with Inert Gas Generator	In-line full flow electrolysis	In-line side streamelectrolysis (2)	In-line (stored) chemical injection	In-line side-stream ozone injection without gas/liquid separation tank and without discharge treatment tank	In-line side-stream ozone injection with gas/liquid Separation tank and discharge water treatment tank	In-tank pasteurization and de-oxygenation with N_2 generator
Des-infection when ballasting	Making use of active substance		X			In-tank technology: No treatment when ballasting or de-ballasting	X	X	X	X	X	In-tank technology: No treatment when ballasting or de-ballasting
	Full flow of ballast water is passing through the BWMS	X	X	X	X		X				X	
	Only a small part of ballast water is passing through the BWMS to generate the active substance							X				
After treatment when deballasting	Full flow of ballast water is passing through the BWMS	X									X	
	Injection of neutralizer						X	X	X	X	X	
	Not required by the Type Approval Certificate issued by the Administration		X	X								
Example of dangerous gas as defined in 1.6.3.4			(1)	O_2 N_2	CO_2 CO		H_2 Cl_2	H_2 Cl_2	(1)	O_2 O_3 N_2		O_2 N_2

Note:

(1) To be investigated on a case by case basis based on the result of the IMO (GESAMP) MEPC report for Basic and Final approval in accordance with the G9 Guideline.

(2) In-line side stream electrolysis may also be applied in-tank in circulation mode (no treatment when ballasting or de-ballasting)

Taking into consideration future developments of BWMS technologies, some additional technologies may be considered in this Table 1 by identifying their characteristics in the same manner as for the above BWMS categories 1, 2, 3a, 3b, 3c. 4, 5, 6, 7a. 7b and 8.

2.3 Ballast Water Management Room (BWMR)

A Ballast Water Management Room is any space containing equipment belonging to the Ballast Water Management System. A space containing remote controls for the BWMS or a space dedicated to the storage of liquid or solid chemicals for BWMS need not be considered as a BWMR for the purposes of this Annex.

2.4 BWMS storing, Introducing or generating chemicals.

In general, BWMS storing, introducing or generating chemicals refer to:

- In-line flocculation (cat.2 as per Table A.1)
- Chemical injection In-line flocculation (cat.6 as per Table A.1) and
- BWM technologies using neutralizers injection (cat.4, 5, 6, 7 as per Table 1)

BWMS that do not store, introduce or generate toxic or flammable chemicals may be specially considered as detailed in Table A.2)

Table A.2: Requirements that may be reduced for BWMS storing, introducing or generating chemicals depending on the chemicals.

Requirement	Conditions to be met before reducing the requirement
B.3.4	The stored chemicals are neither toxic nor flammable
C.1.1	The BWMS does not use any flammable or toxic chemical substances
C.3.1	No dangerous chemical gas as defined in Section 11.0.1.6.2.3 will be generated by the BWMS
F.1.1	No toxic chemical is stored and no toxic gas will be generated by the BWMS
G.1. G.3. G.6.	No toxic chemical is used or will be generated by the BWMS

The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guidelines) and ”safety hazard” as listed in Ch.17 of IMO IBC code are to be considered for this purpose.

Note:

Chemicals include additives for BWMS

B. Fire categorization

1. General

BWMR shall be classified as follows for the purpose of applying the requirements of SOLAS Chapter II-2:

- BWMR containing oil-fired inert gas generators (i.e. BWMS cat.3b and 3c as per Table 1.A) shall be treated as machinery spaces of category A
- Other BWMR shall be considered as other machinery spaces and shall be categorized, depending on the ship type (10) or (11) according to SOLAS II-2/9.2.2.3 or (7) according to SOLAS II-2/9.2.2.4, I1-2/9.2.3 and 11-2/9.2.4

2. BWMS located in the cargo area of tankers

Notwithstanding the above, where a BWMS is located in the cargo area of a tanker as allowed by UR M74, the BWMR shall be categorized as (8), a cargo pump-room, according to SOLAS 11-2/9.2.4.2.2 for determining the extent of fire protection to be provided.

Note:

The cargo area of a tanker is defined in:

- *for tankers to which regulation 1.6.1 of SOLAS Chapter II-2 as amended by IMO resolutions up to MSC.421(98) (hereinafter the same) applies, regulation 3.6 of SOLAS Chapter II-2;*
- *for chemical tankers, Paragraph 1.3.6 of the IBC Code as amended by IMO resolutions up to MSC.460(101);*

— *for gas carriers, Paragraph 1.2.7 of the IGC Code as amended by IMO resolutions up to MSC.441(99); and*

— *for offshore support vessels, Paragraph 1.3.1 of the IMO Resolution A.673(16) as amended by Resolution MSC.236(82) or Paragraph 1.2.7 of the IMO Resolution A. 1122(30), as applicable.*

3. Storage of chemicals

3.1 Spaces where the storage of liquid or solid chemicals for BWMS is intended shall be categorized as store-rooms for the purpose of applying the requirements of SOLAS Chapter II-2, i.e.:

2) On passenger ships carrying more than 36 passengers:

   — ”Other spaces in which flammable liquids are stowed” as defined in SOLAS II-2/9.2.2.3.2.2(14), if flammable products are stored

   — ”Store-rooms, workshops, pantries, etc.” as defined in SOLAS II-2/9.2.2.3.2.2(13) otherwise

3) On other ships:

   — ”Cargo pump-rooms” as defined in SOLAS II-2/9.2.4.2.2.2(8) if located in the cargo area of a tanker

   — ”Service spaces (low risk)” as defined in SOLAS II-2/9.2.2.4.2.2(5), SOLAS II-2/9.2.3.3.2.2(5) or II-2/9.2.4.2.2.2(5) if the surface area is less than 4m2 and if no flammable products are stored

   — ”Service spaces (high risk)” as defined in SOLAS I -2/9.2.2.4.2.2(9), SOLAS II-2/9.2.3.3.2.2(9) or II-2/9.2.4.2.2.2(9) otherwise

Note:
It is understood that only chemical injection (cat.6 as per Table 1), in-line flocculation (cat.2 as per Table 1) and technologies using neutralizer injection (cat.4, 5, 6 and 7 as per Table 1) will require chemical or additive storage.

3.2 Where the storage of chemicals is foreseen in the same room as the ballast water management machinery, this room shall be considered both as a store-room and as a machinery space in line with 1.

3.3 When the chemical substances are stored inside integral tanks, the ship’s shell plating shall not form any boundary of the tank.

3.4 Tanks containing chemicals shall be segregated from accommodation, service spaces, control stations, machinery spaces not related to the BWMS and from drinking water and stores for human consumption by means of a cofferdam, void space, cargo pump-room, empty tank, oil fuel storage tank, BWMR or other similar space. On-deck stowage of permanently attached deck tanks or installation of independent tanks in otherwise empty hold spaces should be considered as satisfying this provision.

C. BWMR location and boundaries

1. BWMS using chemical substances

1.1 For BWMS storing, introducing or generating chemicals, the BWMR and chemical substance storage rooms are not to be located in the accommodation area. Any ventilation exhaust or other openings from these rooms shall be located not less than 3 m from entrances, air inlets and openings to accommodation spaces.

This requirement need not apply in case the BWMS is located in the engine room.

2. Ozone-based BWMS

2.1 Ozone-based BWMS - i.e. cat.7a and 7b - shall be located in dedicated compartment, separated from any other space by gastight boundaries. Access to the BWMR from any other enclosed space shall be through airlock only, except if the only access to that space is from the open deck.

Access to the ozone based BWMR may be provided through the engine room only provided:

— Access from the engine room to the BWMR is through airlock and,

— An alarm repeater is provided in the BWMR, which will repeat any alarm activated in the engine room.

2.2 A sign shall be affixed on the door providing personnel with a warning that ozone may be present and with the necessary instructions to be followed before entering the room.

3. General

3.1 BWMR containing equipment for BWMS of the following types shall be equipped with tested gastight and self-closing doors without any holding back arrangements:

— BWMS storing, introducing or generating chemical substances

— De-oxygenation based on inert gas generator

— Electrolysis

— Ozone injection

Doors leading to the open deck need however not to be self-closing.

D. Fire fighting

1. Fixed fire-extinguishing system

1.1 Where fitted, fixed fire extinguishing systems shall comply with the relevant provisions of the Fire Safety Systems Code

1.2 Ozone-based BWMS

BWMR containing equipment related to ozone-based BwMS shall be provided with a fixed fire extinguishing system suitable for category A machinery spaces and capable of manual release.

1.3 Where a fixed fire-extinguishing system is provided in the BWMR, it should be compatible with the BWMS and the chemical products that are used, produced or stored in the BWMR. Specific attention shall be paid to potential chemical reactions between the fire extinguishing medium and chemical products used for water treatment.

Especially, water-based fire-extinguishing systems should be avoided in case of sulfuric acid storage.

1.4 Foam fixed fire-extinguishing system

For all kinds of BWMS, in case a foam fire extinguishing system is installed in the BWMR, its efficiency shall not be impaired by chemicals used by the BWMS where relevant.

1.5 Where a fixed fire-extinguishing system is installed in the BWMR, automatic shutdown of the BWMS upon release of the fixed fire extinguishing system shall be arranged. Any need for cooldown necessary for safe shutdown to be considered in the shutdown sequence.

1.6 Where BWMS that includes air or O_2 storage is located in a room covered by a fixed gas fire-extinguishing system, air or O_2 storage shall be taken into account for the gas capacity calculation, unless the discharge pipe from safety valves for air or O_2 storage are led directly to outside the room.

2. Portable fire-fighting equipment

2.1 There shall be at least one portable fire extinguisher that complies with the provisions of the Fire Safety Systems Code and suitable for electrical fires in the BWMR containing UV-type BWMS.

E. Fire prevention

1. Equipment protection

1.1 Overcurrent or overvoltage protection is to be installed to protect UV type BWMS.

1.2 Electrolysis reactors are to be provided with at least with two independent means of monitoring operation. The monitoring system shall initiate audible and visual alarms and automatic shutdown of the BWMS in the event that an anomaly is detected. Requirements for shutdown arrangement are clarified in Section 11.O.1.6.4.1.9.

Note:

If a pressure relief valve is also provided, the vent of this valve is to be led to a safe location on the open deck, as clarified in Section 11.O. The valve should be positioned to optimally remove gas from the electrolysis reactor.

2. Fire detection

2.1 A fixed fire detection and fire alarm system complying with the provisions of the Fire Safety Systems Code shall be installed in spaces containing an inert gas generator or an ozone generator.

2.2 A section of fire detectors which covers a control station, a service space or an accommodation space is not to include a BWMR containing equipment related to ozone based BWMS.

F. Ventilation

1. Ventilation arrangement

1.1 The ventilation systems for BWMR containing BWMS of the following types shall be independent of the ventilation systems serving any other spaces:

- BWMS storing, introducing or generating chemical substances
- De-oxygenation, including pasteurization and de-oxygenation (cat.3 and cat.8 as per Table 1.A)
- Electrolysis
- Ozone injection

1.2 The ventilation exhaust for BWMR containing a nitrogen generator shall be located in the lower part of the room in order to efficiently evacuate dangerous gases - as defined in Section 11.O.1.6.3.2 - heavier than air.

1.3 The ventilation exhaust for BWMR containing electrolysis systems shall be located so as to be able to efficiently evacuate dangerous gases as defined in Section 11.O.1.6.3.2 - that could be generated during the electrolysis process. Due regard shall be paid to the expected quantity and density of such gases when designing the ventilation exhaust.

1.4 The following requirements apply to ventilation ducts serving BWMR for ozone-based BWMS:

- The part of the ducts located outside of the BWMR shall be made of steel having a thickness of at least 3 mm for ducts with a free cross-sectional area of less than 0.075 m^2, at least 4 mm for ducts with a free cross-sectional area of between 0.075 m^2 and 0.45 m^2, and at least 5 mm for ducts with a free cross-sectional area of over 0.45 m^2; and
- The ducts shall be suitably supported and stiffened

- The outside openings of the ducts shall be fitted with protective screens of not more than 13 mm square mesh.

1.5 The ventilation system for BWMR containing ozone-based BWMS or ventilation system for hydrogen de gas arrangement as required by Section 11.O.1.6.5.1 5) shall be interlocked with the BWMS such that:

- In case of loss of ventilation (primary and secondary), a visual and audible alarm shall be triggered both inside and outside the BWMR and at a place where a responsible member of the crew is on duty. If the ventilation is not restored after a pre-set time, the BWMS shall then be automatically shut down. Any need for cooldown necessary for safe shutdown is to be considered in the shutdown sequence.
- It shall not be possible to start the BWMS without the ventilation running

For ventilation systems serving BWMR and containing or conveying a dangerous gas, relevant requirements in Section 11.O.1.6.5 are to be satisfied.

2. Ventilation rate

2.1 An adequate power ventilation system shall be provided in enclosed BWMR.

2.2 The ventilation capacity shall be at least 30 air changes per hour where explosive or toxic gases may be generated during operation of the BWMS. The IMO reports issued during the basic and final approval procedures of the BWMS that make use of active substances (G9 Guidelines) and "safety hazard" as listed in Ch.17 of IBC code are to be used as references for identifying those cases.

2.3 The ventilation capacity may be reduced as follows:

— Flocculation-type BWMS	6 air changes per hour
— De-oxygenation, incl. pasteurization and de-oxygenation (cat.3 and cat.8 as per Table A.1)	6 air changes per hour
— Full flow electrolysis	6 air changes per hour
— Side-stream electrolysis	20 air changes per hour
— Ozone injection	20 air changes per hour
— Chemical injection	6 air changes per hour

Note:
More stringent ventilation capacity requirements may arise from other regulations e.g. IBC Code requirements for spaces located in the cargo area.

G. Personal equipment

1. Suitable protection equipment shall be available onboard for the protection of the crew members who are engaged in the servicing, maintenance and repair of BWMS storing, introducing or generating chemicals, as recommended by the product manufacturers. The protection equipment shall consist of large aprons, special gloves with long sleeves, suitable footwear, coveralls of chemical-resistant materials, and tight fitting goggles or face shields or both. The protective clothing and equipment shall cover all skin so that no part of the body is unprotected. This protection equipment is to be provided separately without taking into account equipment required by other mandatory requirements.

2. Work clothes and protective equipment shall be kept in easily accessible places and in special lockers. Such equipment shall not be kept within accommodation spaces, with the exception of new, unused equipment and equipment which has not been used since undergoing a thorough cleaning process. Notwithstanding the above, storage rooms for such equipment within accommodation spaces if adequately segregated from living spaces such as cabins, passageways, dining rooms, bathrooms, etc.

3. When a BWMS storing, introducing or generating chemicals is installed on board, suitably marked decontamination showers and an eyewash shall be available in a convenient location in close proximately to the BWMS and the chemical store room(s).

4. An emergency escape breathing apparatus (EEBD) is to be provided in the BWMR. This emergency escape breathing apparatus may be one of the EEBDs provided in accordance with the requirements of SOLAS II-2/13.

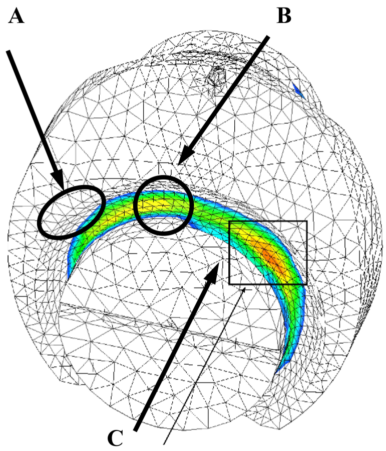
An EEBD need not be required for BWMS of cat.1 as per Table A.1.

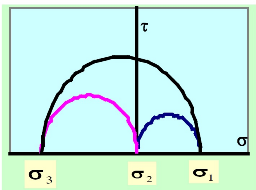
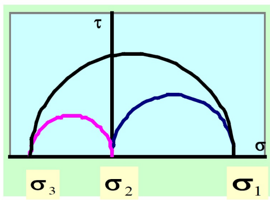
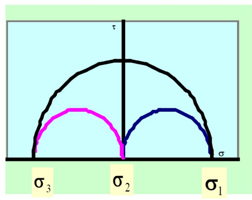
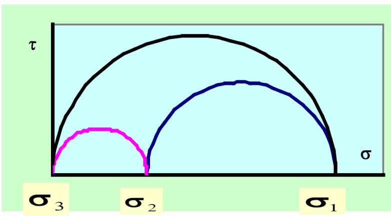
5. A personal ozone detector, calibrated as per the manufacturer's specifications, shall be provided for each person engaged in the servicing, maintenance and repair of BWMS utilizing ozone.

6. A two-way portable radiotelephone apparatus dedicated for the BWMS service, maintenance and repair shall be provided, in addition to those required by SOLAS for fire-fighting purposes. This two-way radiotelephone apparatus is to be properly identified in order to avoid mix-up with the apparatus intended for fire-fighting operations. Where the BWMS may release explosive gases, this two-way radiotelephone apparatus shall be of a certified safe type suitable for use in zone 1 hazardous areas, as defined in IEC Publication 60079. Where the BWMS stores, utilizes or introduces chemicals, the apparatus shall undergo deep cleaning or de-contamination after use.

A two-way portable radiotelephone apparatus need not be required for BWMS of cat.1 as per Table A.1.

Annex C Definition of Stress Concentration Factor in Crankshaft Fillets



Loading	Stress	Max $\lVert\sigma_3\rVert$	Max σ_1	
Torsional loading	Location of maximal stresses	**A**	**C**	**B**
	Typical principal stress system Mohr's circle diagram with $\sigma_2 = 0$	 $\lVert\sigma_3\rVert > \sigma_1$	 $\sigma_1 > \lVert\sigma_3\rVert$	 $\sigma_1 \approx \lVert\sigma_3\rVert$
	Equivalent stress and **S.C.F.**	$\tau_{equiv} = \frac{\sigma_1 - \sigma_3}{2}$ $S.C.F. = \frac{\tau_{equiv}}{\tau_n}$ for α_T, β_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.**	$\sigma\ equiv = \sqrt{\sigma_1{}^2 + \sigma_2{}^2 - \sigma_1 . \sigma_2}$ $S.C.F. = \frac{\sigma\ equiv}{\sigma_n}$ for $\alpha_B, \beta_B, \beta_Q$		

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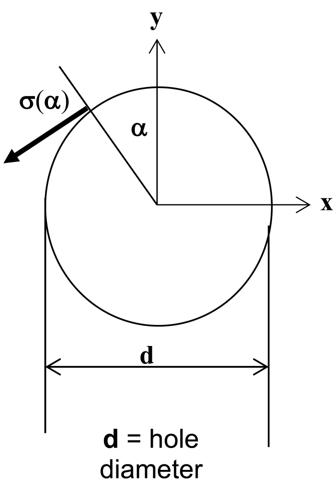
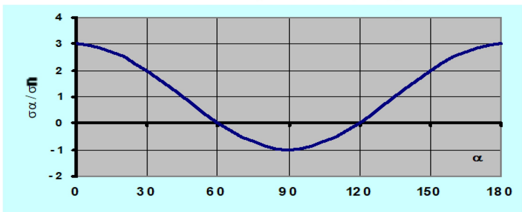
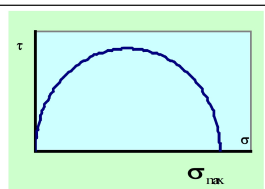
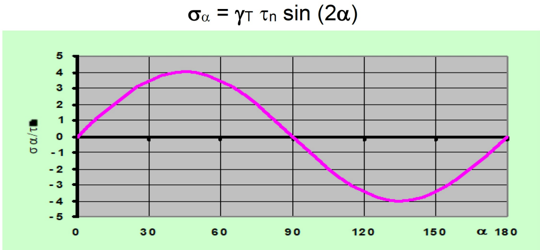
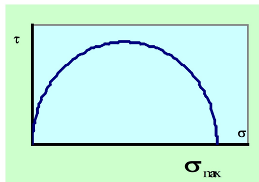
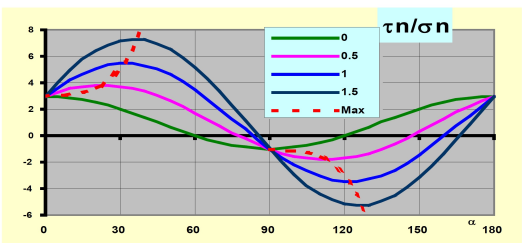
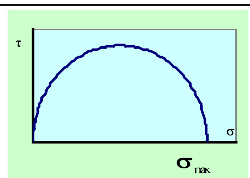
Annex D Stress Concentration Factor and Stress Distribution at the Edge of Oil Drillings



Stress type	Nominal stress tensor	Uniaxial stress distribution around the edge	Mohr's circle diagram
Tension	$\begin{bmatrix}\sigma_n & 0\\ 0 & 0\end{bmatrix}$	$\sigma_\alpha = \sigma_n \gamma_B / 3\,[1+2\cos(2\alpha)]$ 	 $\gamma_B = \sigma_{max}/\sigma_n$ for $\alpha = k\pi$
Shear	$\begin{bmatrix}0 & \tau_n\\ \tau_n & 0\end{bmatrix}$	$\sigma_\alpha = \gamma_T \tau_n \sin(2\alpha)$ 	 $\gamma_T = \sigma_{max}/\tau_n$ for $\alpha = \frac{\pi}{4} + k\frac{\pi}{2}$
Tension + shear	$\begin{bmatrix}\sigma_n & \tau_n\\ \tau_n & 0\end{bmatrix}$	$\sigma_\alpha = \frac{\gamma_B}{3}\sigma_n\left\{1+2\left[\cos(2\alpha)+\frac{3}{2}\frac{\gamma_T}{\gamma_B}\frac{\tau_n}{\sigma_n}\sin(2\alpha)\right]\right\}$ 	 $\sigma_{max} = \frac{\gamma_B}{3}\sigma_n\left[1+2\sqrt{1+\frac{9}{4}\left(\frac{\gamma_T}{\gamma_B}\frac{\tau_n}{\sigma_n}\right)^2}\right]$ for $\alpha = \frac{1}{2}tg^{-1}\left(\frac{3\gamma_T\tau_n}{2\gamma_B\sigma_n}\right)$

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Annex E Alternative Method for Calculation of Stress Concentration Factors in the Web Fillet Radii of Crankshafts by Utilizing Finite Element Method

A. 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 Guidance 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 Guidance or the alternative methods, Von Mises 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 semibuilt 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.

B. Model requirements

The basic recommendations and perceptions for building the FE-model are presented in Annex E.B.1. It is obligatory for the final FE-model to fulfill the requirement in Annex E.B.3.

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 .E.1.
- Drillings and holes for weight reduction have to be modeled.
- Sub-modeling may be used as far as the software requirements are fulfilled.

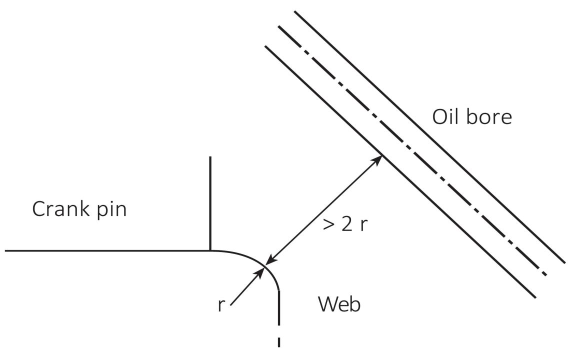

Figure E.1: Oil bore proximity to fillet

2. Material

This Guidance does not consider material properties such as Young's Modulus (E) and Poisson's ratio (ν). In FE analysis those material parameters are required, as strain is primarily calculated and stress is derived from strain using the Young's Modulus and Poisson's ratio. 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:

$$E = 2.05 \cdot 10^5 \text{ Mpa} \quad \text{and}$$

$$\nu = 0.3$$

3. Element mesh quality criteria

If the actual element mesh does not fulfil any ofthe following criteria at the examined area for SCF evaluation, then a second calculation with a refined mesh is to be performed.

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:

$$\text{min}(|\sigma_1|, |\sigma_2|, |\sigma_3|) < 0.03\text{max}(|\sigma_1|, |\sigma_2|, |\sigma_3|)$$

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, should differ less than by 5% from the 100% averaged nodal stress results at this node at the examined location.

C. Load cases

To substitute the analytically determined SCF in this Annex, the following load cases have to be calculated.

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.

For all nodes in both the journal and crank pin fillet principal stresses are extracted and the equivalent torsional stress is calculated:

$$\tau_{\text{equiv}} = \text{max}\left(\left|\frac{\sigma_1 - \sigma_2}{2}\right|, \left|\frac{\sigma_2 - \sigma_3}{2}\right|, \left|\frac{\sigma_1 - \sigma_3}{2}\right|\right)$$

The maximum value taken for the subsequent calculation of the SCF:

$$\alpha_T = \frac{\tau_{\text{equiv}\alpha}}{\tau_N}$$

$$\beta_T = \frac{\tau_{\text{equiv}\beta}}{\tau_N}$$

where τ_N is nominal torsional stress referred to the crankpin and respectively journal as per Section 2.C.5.2.2 with the torsional torque T:

$$\tau_N = \frac{T}{W_p}$$

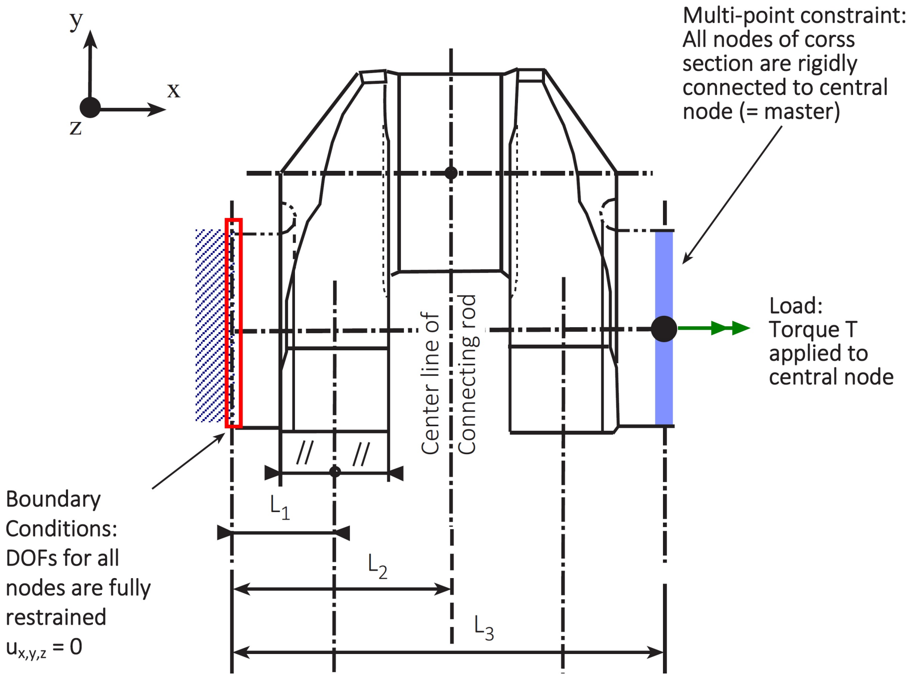

Figure E.2: Boundary and load conditions for the torsion load case

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.

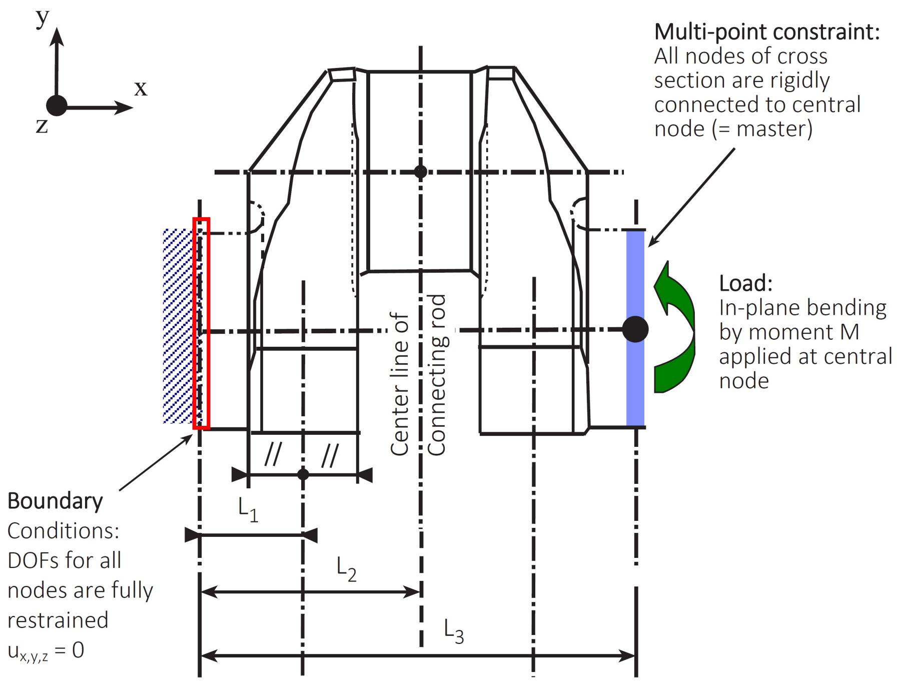

Figure E.3: Boundary and load conditions for the pure bending load case

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:

$$\alpha_B = \frac{\sigma_{equiv\alpha}}{\sigma_N}$$

$$\beta_B = \frac{\sigma_{equiv\beta}}{\sigma_N}$$

Nominal stress ς_N is calculated as per Section 2.C.5.1.2.1 with the bending moment M:

$$\sigma_N = \frac{M}{W_{eqw}}$$

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.

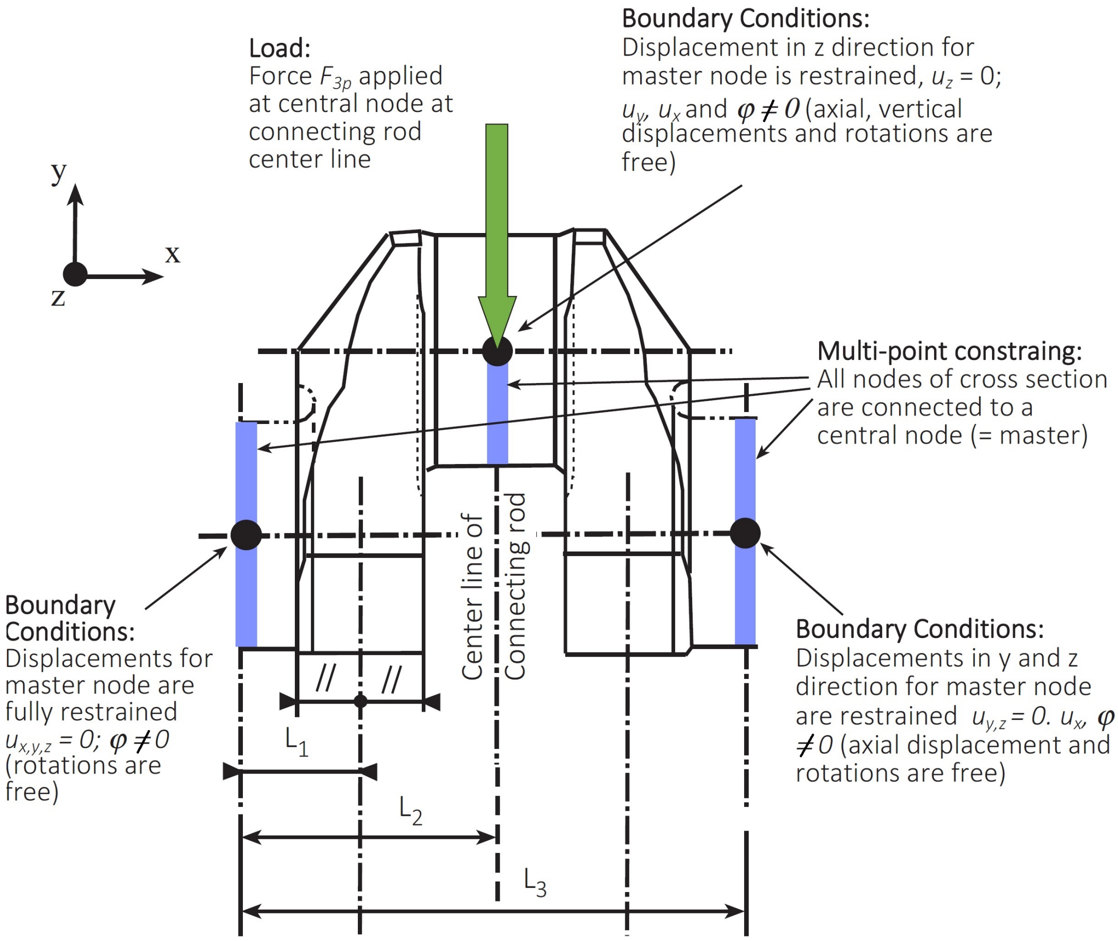

Figure E.4: Boundary and load conditions for the 3-point bending load case of an inline engine

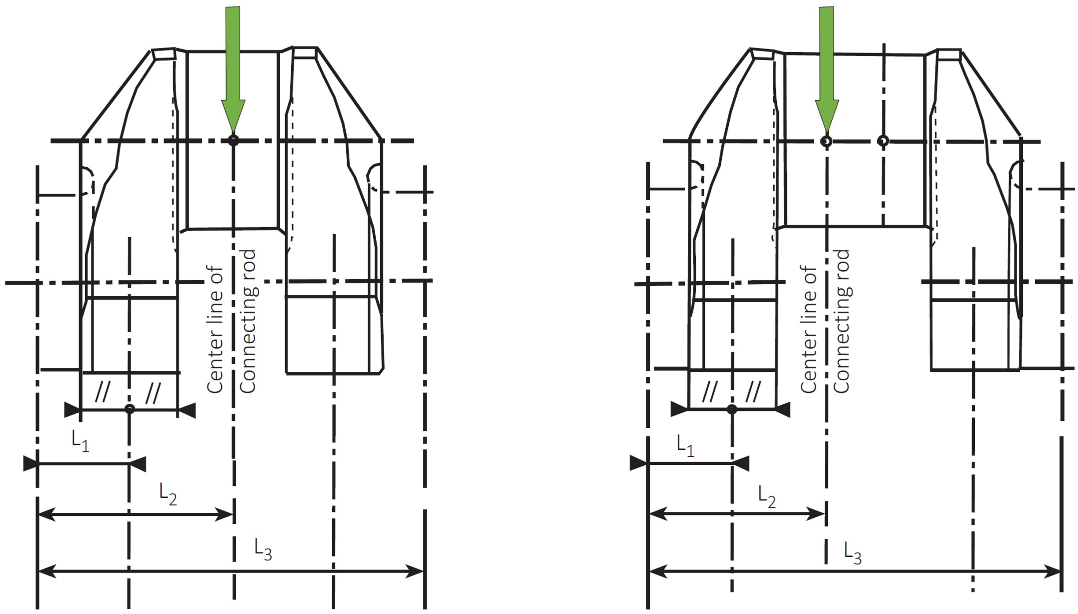

Figure E.5: Load applications for in-line and V-type engines

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.

3.1 Method 1

This method is analogue to the FVV investigation. The results from 3-point and 4-point bending are combined as follows:

$$\sigma_{3P} = \sigma_{\beta_B} + \sigma_{Q3P} \cdot \beta_Q$$

Where:

ς_{3P} = as found by the FE calculation.

ς_{N3P} = Nominal bending stress in the web center due to the force F_3P[N] applied to the centre line of the actual connecting rod, see Figure .E.5.

β_B = as determined in paragraph Annex E.C.3.2.

ς_{Q3P} = $(Q_{3P})/(B.W)$ where Q_{3P} is the radial (shear) force in the web due to the force F_{3P}[N] applied to the center line of the actual connecting rod, see also Figure .E.3 and Figure .E.4 in Guidance.

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 Annex E.C.3.1

When using this method, the radial force and stress determination in Guidance becomes superfluous. The alternating bending stress in the journal fillet as per Section 2.C.5.1.3 is then evaluated:

$$\sigma_{BG} = \pm \left|\beta_{BQ} \cdot \sigma_{BFN}\right|$$

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 Section 2.C.

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Annex F Guidance for Evaluation of Fatigue Tests

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.C, 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 Annex F.B.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:

$$\overline{S_a} = S_{a0} + d \cdot \left(\frac{A}{F} - \frac{1}{2}\right) \qquad \text{when } C = 1$$

$$\overline{S_a} = S_{a0} + d \cdot \left(\frac{A}{F} + \frac{1}{2}\right) \qquad \text{when } C = 2$$

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 = Σfi

A = Σi · fi

B = Σi^2 · fi

i is the stress level numbering

fi is the number of samples at stress level i

The formula for the standard deviation is an approximation and can be used when

$$\frac{B \cdot F - A^2}{F^2} > 0.3 \qquad \text{and} \qquad 0.5 \cdot < d < 1.5 \cdot s$$

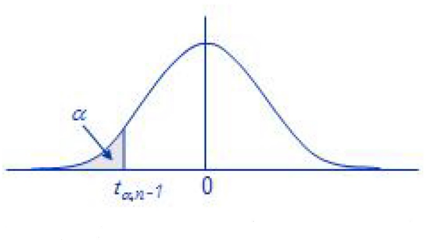
If any of these two conditions are not fulfilled, a new staircase test should be considered or the standard deviation should be taken quite large in order to be on the safe side.

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.



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 - α) · 100% confidence interval for the sample mean.

Figure F.1: Student's t-distribution

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:

$$P\left(S_a - t_{\alpha,n-1} \cdot \frac{s}{\sqrt{n}} < S_{aX\%}\right) = 1 - \alpha$$

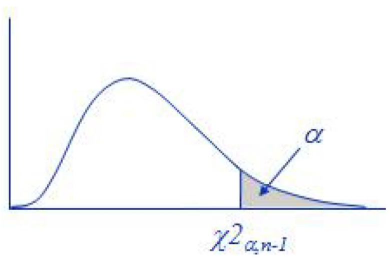
The resulting confidence interval is symmetric around the empirical mean of the sample values, and the lower endpoint can be found as:

$$S_{aX\%} = S_a - t_{\alpha,n-1} \cdot \frac{s}{\sqrt{n}}$$

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.



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 chi-square for (1 - α) · 100% confidence interval for the variance.

Figure F.2: Chi-square distribution

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:

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

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 .F.3.

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.

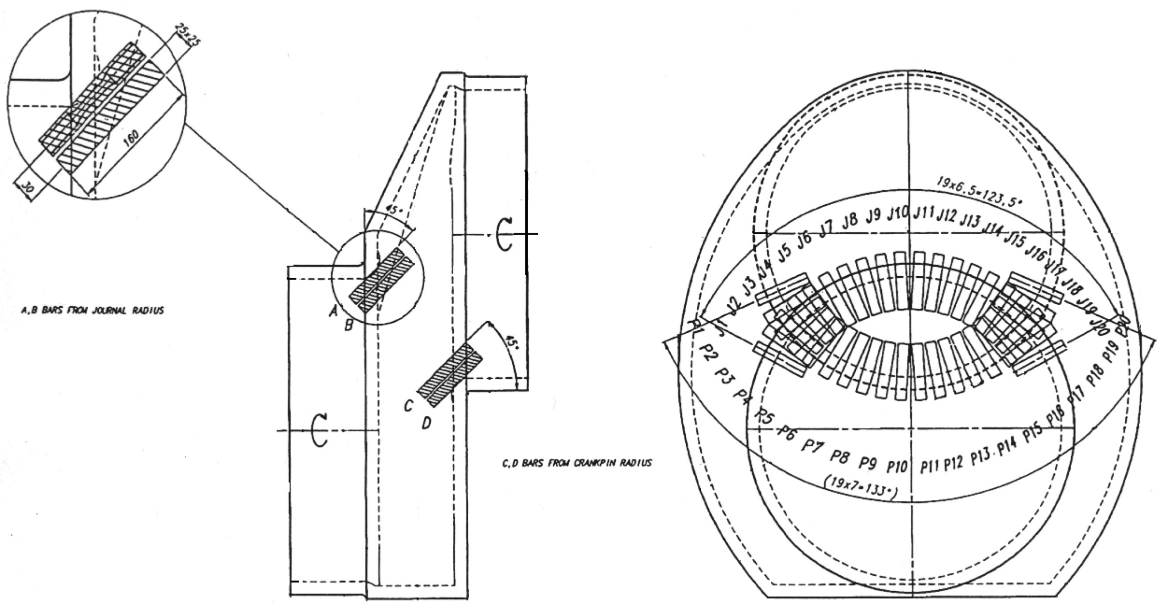


Figure F.3: Specimen locations in a crank throw

The (static) mechanical properties are to be determined as stipulated by the quality control procedures.

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 .F.3.

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 .F.3.

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 Annex E.C.1 to Annex E.C.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 .F.4 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.

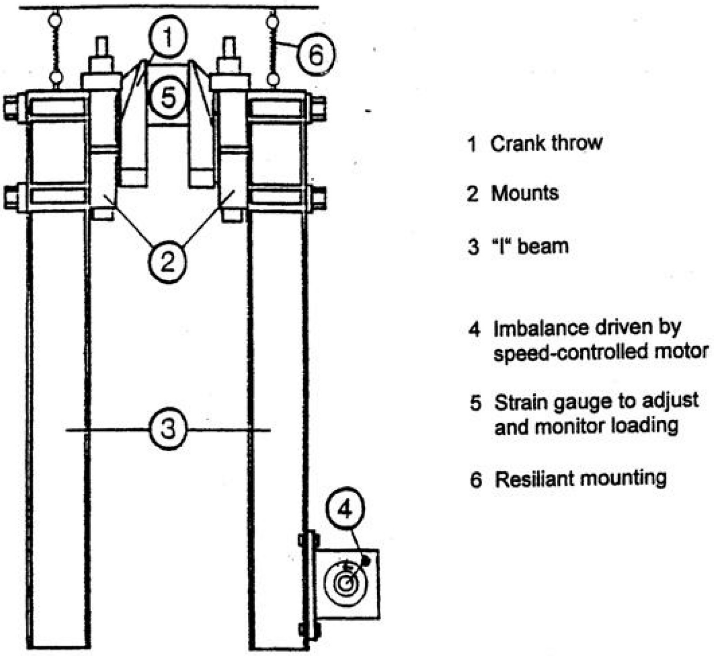


Figure F.4: An example of testing arrangement of the resonance tester for bending loading

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.

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 .F.5 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 sideway 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 sideway 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.

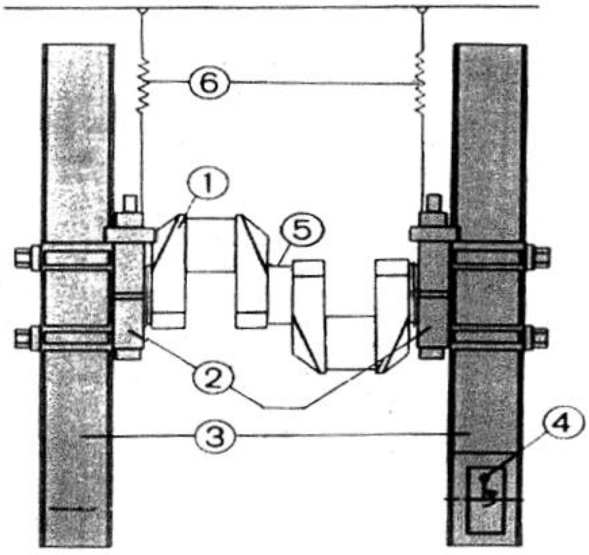


Figure F.5: An example of testing arrangement of the resonance tester for torsion loading with double crank throw section

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.C.10), the Gough-Pollard approach and the maximum principal equivalent stress formulation can be applied for the following cases:

At the crankpin fillet:

$$Q = \left(\sqrt{\left(\frac{\sigma_{BH} + \sigma_{add}}{\sigma_{DWCT}}\right)^2 + \left(\frac{\tau_H}{\tau_{DWCT}}\right)^2}\right)^{-1}$$

Where:

σ_{DWCT} fatigue strength by bending testing

τ_{DWCT} fatigue strength by torsion testing

for other parameters see Section 2.C.5.1.3, Section 2.C.5.2.3 and Section 2.C.7

Related to crankpin oil bore:

$$Q = \frac{\sigma_{DWOT}}{\sigma_{\upsilon}}; \qquad \sigma_{\upsilon} = \frac{1}{3} \cdot \sigma_{BO} \cdot \left(1 + 2 \cdot \sqrt{1 + \frac{9}{4} \cdot \left(\frac{\sigma_{TO}}{\sigma_{BO}}\right)^2}\right)$$

Where:

σ_{DWOT} fatigue strength by means of largest principal stress from torsion testing

At the journal fillet:

$$Q = \left(\sqrt{\left(\frac{\sigma_{BG} + \sigma_{add}}{\sigma_{DWJT}}\right)^2 + \left(\frac{\tau_G}{\tau_{DWJT}}\right)^2}\right)^{-1}$$

Where:

σ_{DWJT} fatigue strength by bending testing

τ_{DWJT} fatigue strength by torsion testing

for other parameters see Section 2.C.5.1.3, Section 2.C.5.2.3 and Section 2.C.7

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:

1) Material:
   - Similar material type
   - Cleanliness on the same or better level
   - The same mechanical properties can be granted (size versus hardenability
2) Geometry:
   - Difference in the size effect of stress gradient is insignificant or it is considered
   - Principal stress direction is equivalent. See Annex F.C.
3) Manufacturing:
   - Similar manufacturing process

Induction hardened or gas nitrited 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 th 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.

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Annex G Guidance for Calculation of Surface Treated Fillets and Oil Bore Outlets

A. Introduction

This annex 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.

Table G.1: Surface treatment methods and the characteristics they affect

Treatment method	Affecting
Induction hardening	Hardness and residual stresses
Nitriding	Chemistry, hardness and residual stresses
Case hardening	Chemistry, hardness and residual stresses
Die quenching (no temper)	Hardness and residual stresses
Cold rolling	Residual stresses
Stroke peening	Residual stresses
Shot peening	Residual stresses
Laser peening	Residual stresses
Ball coining	Residual stresses

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.

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 Annex G.E.1for 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.

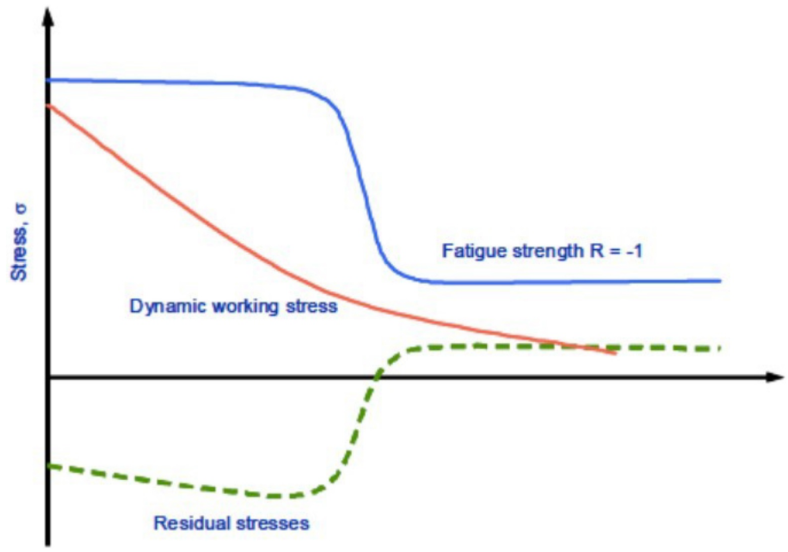

Figure G.1: Stresses as functions of depth, general principles

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 Annex E. 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.C.6.1 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 .G.2 for bending and respectively for torsion in Equation 3.2 and Figure .G.3.

$$\alpha_{B-local} = (\alpha_B - 1) \cdot e^{\frac{-2 \cdot t}{R_H}} + 1 - \left(\frac{2 \cdot t}{\sqrt{W^2 + S^2}} \right)^{\frac{0.6}{\sqrt{\alpha_B}}} \tag{3.1}$$

$$\alpha_{T-local} = (\alpha_T - 1) \cdot e^{\frac{-t}{R_H}} + 1 - \left(\frac{2 \cdot t}{D} \right)^{\frac{1}{\sqrt{\alpha_T}}} \tag{3.2}$$

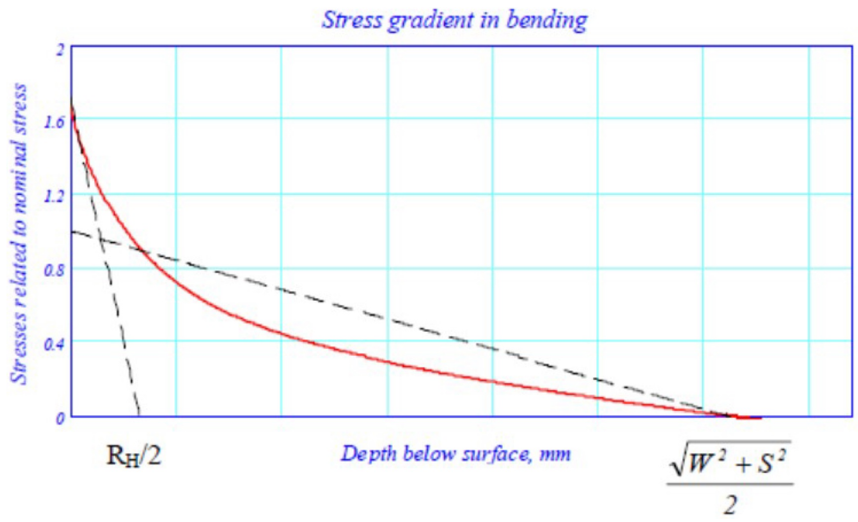

Figure G.2: Bending SCF in the crankpin fillet as a function of depth. The corresponding SCF for the journal fillet can be found by replacing R_H with R_G

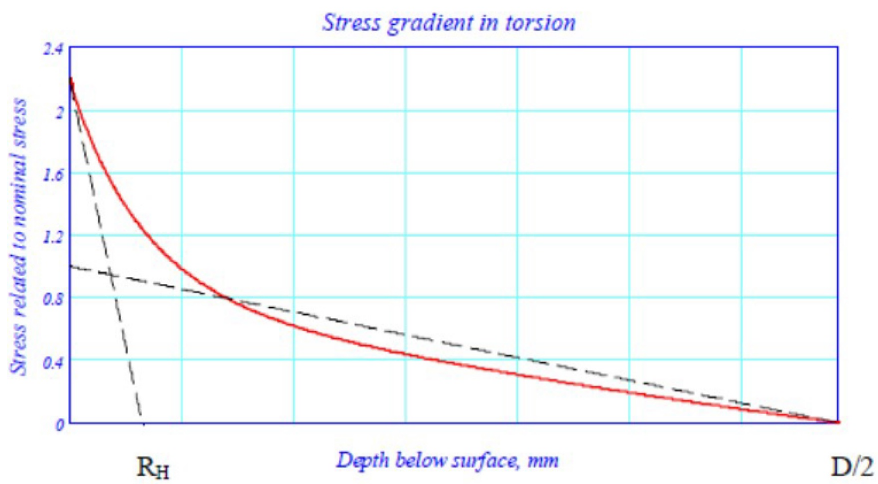

Figure G.3: Torsional SCF in the crankpin fillet as a function of depth. The corresponding SCF for the journal fillet can be found by replacing R_H with R_G and D with D_G

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 Annex E. 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 Annex E.C.1 – and the bending moment, with four-point bending as in Annex E.C.2

If no FEA is available, a simplified approach may be used. This can be based on the empirically determined SCF from Section 2.C.6 if within its applicability range. Bending and torsional stresses at the point of peak stresses are combined as in Section 2.C.6

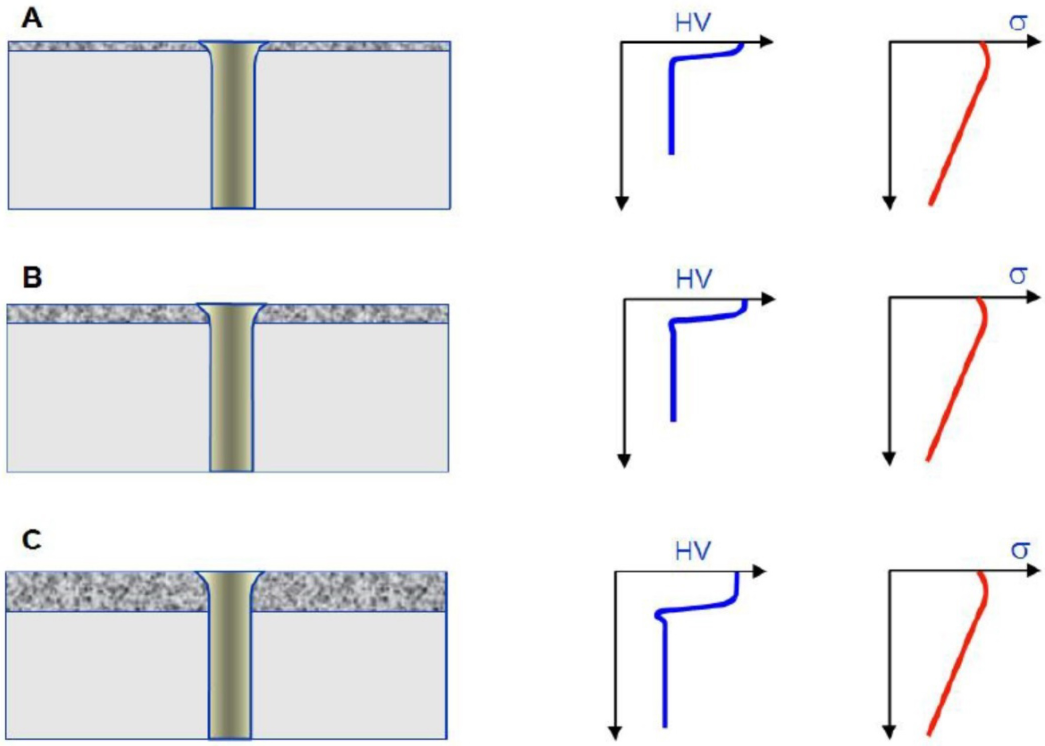

Figure G.4: Stresses and hardness in induction hardened oil holes

Figure .G.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 .G.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:

$$\gamma_{B\text{-local}} = (\gamma_B - 1) \cdot e^{\frac{-4 \cdot t}{D_O}} + 1 \qquad (3.3)$$

$$\gamma_{T\text{-local}} = (\gamma_T - 1) \cdot e^{\frac{-2 \cdot t}{D_O}} + 1 \qquad (3.4)$$

3. Acceptability criteria

Acceptance of crankshafts is based on fatigue considerations; Section 2.C. compares the equivalent alternating stress and the fatigue strength ratio to an acceptability factor of Q ≥ 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.

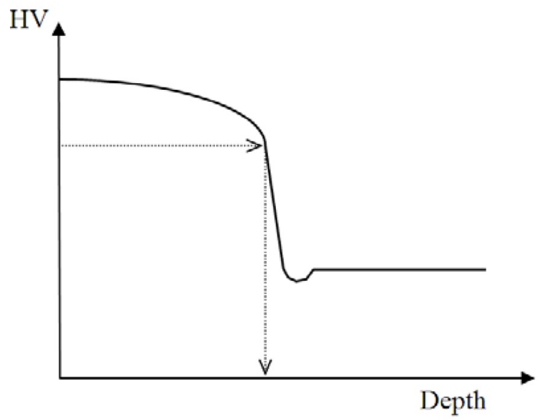

Figure G.5: Typical hardness as a function of depth. The arrows indicate the defined hardening depth. Note the indicated potential hardness drop at the transition to the core. This can be a weak point as local strength may be reduced and tensile residual stresses may occur

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 .G.6.

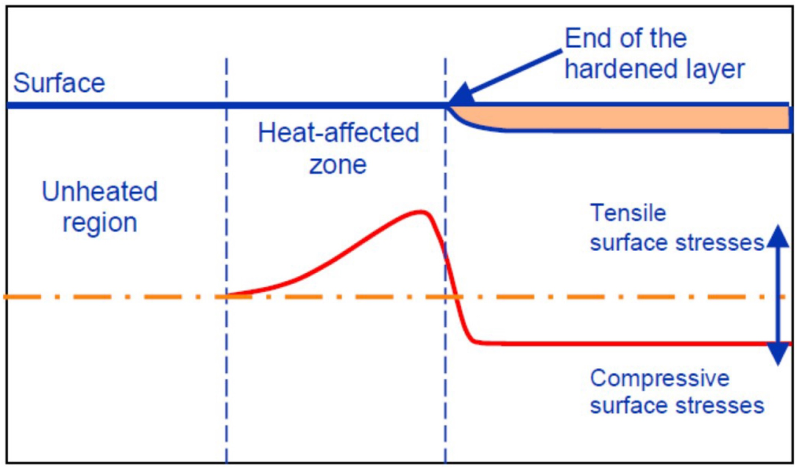

Figure G.6: Residual stresses along the surface of a pin and fillet

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 .G.5):
  - Constant hardness from the surface to the transition zone
  - 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 Annex F. 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:

$$\sigma_{Fsurface} = 400 + 0.5 \cdot (HV - 400) [MPa] \quad (4.1)$$

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 Section 2.C.9. For journal and respectively to crankpin fillet applies:

$$\sigma_{Ftransition,cpin} = \pm K \cdot (0.42 \cdot \sigma_B + 39.3) \cdot \left[0.264 + 1.073 \cdot Y^{-0.2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{X}}\right] \quad (4.2)$$

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: the equation does not include the influence of the residual stress.

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 .G.6 – the influence of the tensile residual stresses can be considered by subtracting a certain percentage, in accordance with Table .D.1., from the value determined by the above formula.

Table D.1: Surface treatment methods and the characteristics they affect

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%	

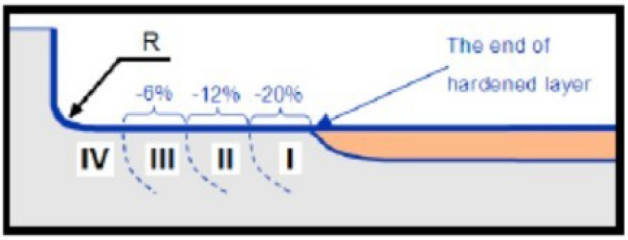

Figure G.7: Sketch of the location for the artificial transition point in the depth direction

2. 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 tN 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:

$$HV(t) = HV_{core} + (HV_{surface} - HV_{core}) \cdot \left(\frac{50}{HV_{surface} - HV_{core}}\right)^{\left(\frac{t}{t_N}\right)^2} \tag{5.1}$$

Where:

t	= The local depth
HV(t)	= Hardness at depth t
HV_{core}	= Core hardness (minimum)
$HV_{surface}$	= Surface hardness (minimum)
t_N	= Nitriding depth as defined above (minimum)

2.1 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 Annex F.

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:

$$\sigma_{Fsurface} = 450 MPa \tag{5.2}$$

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 Section 2.C.9 For crankpin and respectively to journal applies:

$$\sigma_{Ftransition,cpin} = \pm K \cdot (0.42 \cdot \sigma_B + 39.3) \cdot \left[0.264 + 1.073 \cdot Y^{-0.2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \cdot \sqrt{\frac{1}{X}}\right] \tag{5.3}$$

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.

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=1.2tN.

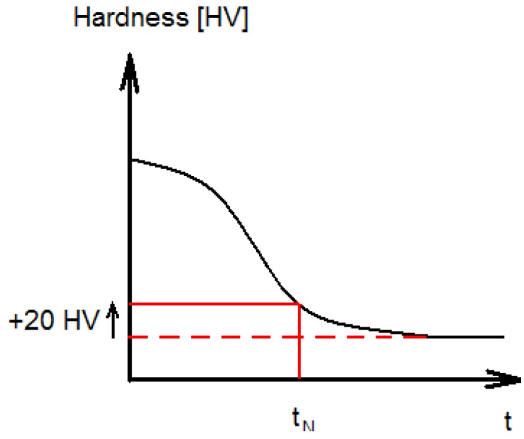

Figure G.8: Sketch of the location for the artificial transition point in the depth direction

E. 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 Annex F. 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 .G.9 as gradient load 2.

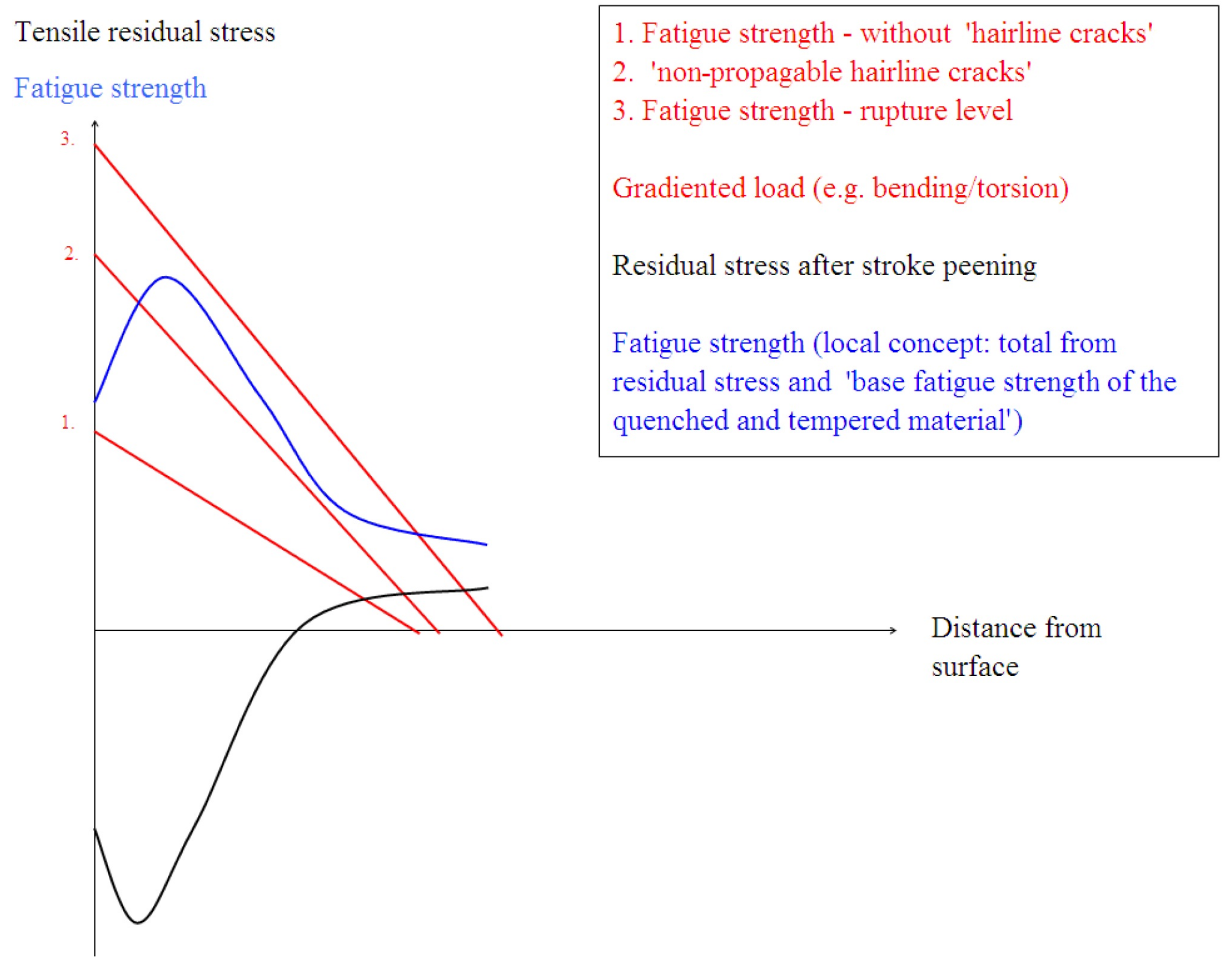

Figure G.9: Working and residual stresses below the stroke-peened surface. Straight lines 1...3 represent different possible load stress gradients.

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 base material. 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 ±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 ±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 ±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

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Annex H Guidance for Calculation of Stress Concentration Factors in the Oil Bore Outlets of crankshafts through utilisation of the Finite Element Method

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 Section 2.C, 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 Annex H.B.1. The final FE-model must meet one of the criteria in Annex H.B.2.

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

Section 2.C 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 Section 2.C, 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.

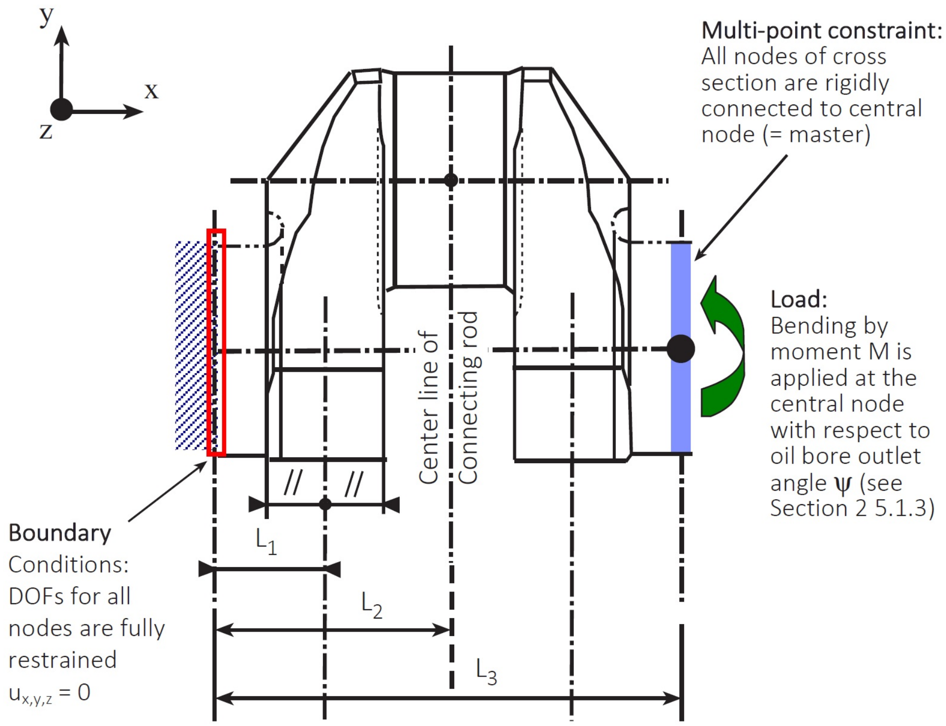

Figure 25.1: Boundary and load conditions for the torsion load case

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.C.5.2.2 with torque T:

$$\tau_N = \frac{T}{W_p}$$

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.

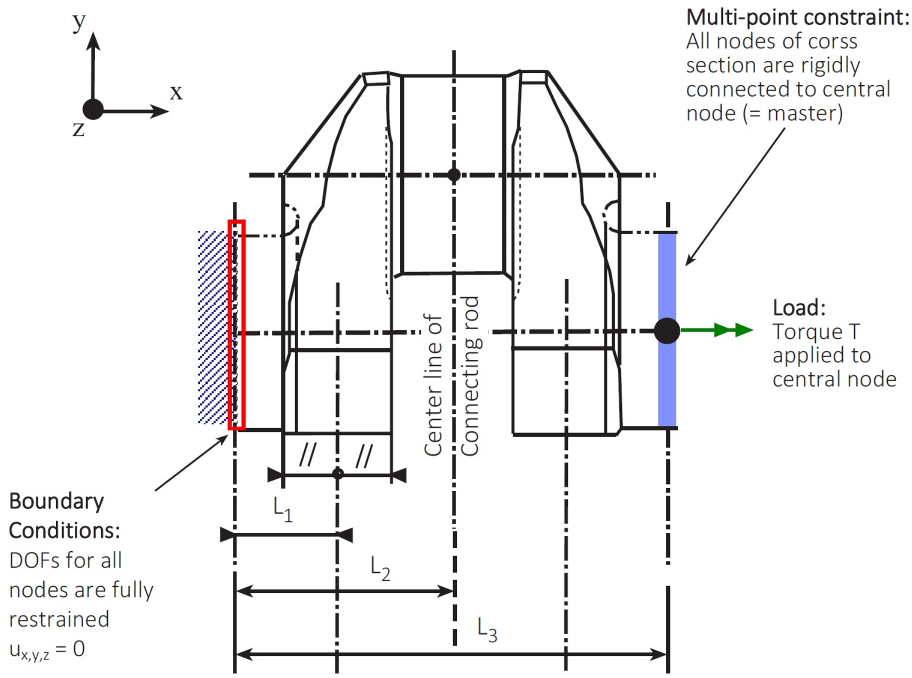

Figure 25.2: Boundary and load conditions for the pure bending load case

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.C.2.1.2.2 with bending moment M:

$$\sigma_N = \frac{M}{W_e}$$