



INTLREG
INTERNATIONAL REGISTER OF SHIPPING

RULES AND REGULATIONS FOR CLASSIFICATION OF STEEL VESSELS

Part 5 Machinery Equipment Installation and Piping System

This page is intentionally left blank

**PART 5A Machinery Equipment
Installation and Piping System**
(For ships with $L \geq 100\text{m}$)

This page is intentionally left blank

CHANGES HISTORY

Refer Changes history in Part 1

CONTENTS

CHAPTER 1 GENERAL	9
SECTION 1 GENERAL CLASSIFICATION	10
SECTION 2 CERTIFICATION OF MACHINERY	15
SECTION 3 PLANS OF MACHINERY	22
SECTION 4 MISCELLANEOUS REQUIREMENTS	24
SECTION 5 SEA TRIALS	27
CHAPTER 2 PRIME MOVER	29
SECTION 1 DIESEL ENGINES	30
SECTION 2 TURBOCHARGERS	109
SECTION 3 GAS TURBINES	119
SECTION 4 STEAM TURBINES.....	132
CHAPTER 3 REDUCTION GEARS	143
SECTION 1 GENERAL REQUIREMENTS.....	144
SECTION 2 MATERIALS.....	149
SECTION 3 DESIGN OF GEARS.....	151
SECTION 4 CONSTRUCTION	165
SECTION 5 PIPING SYSTEMS.....	168
SECTION 6 TESTING, INSPECTION AND CERTIFICATION OF GEARS	170
SECTION 7 SPARE PARTS	182
CHAPTER 4 PROPULSION SHAFTING	184
SECTION 1 GENERAL REQUIREMENTS.....	185
SECTION 2 MATERIALS.....	188
SECTION 3 DESIGN AND CONSTRUCTION.....	190
SECTION 4 ALIGNMENT AND VIBRATIONS OF PROPULSION SHAFT	201
SECTION 5 TESTING, INSPECTION AND CERTIFICATION	209
SECTION 6 INSTALLATIONS AND TRIALS	211
CHAPTER 5 PROPELLERS	215
SECTION 1 GENERAL REQUIREMENTS.....	216
SECTION 2 MATERIALS	219
SECTION 3 DESIGN	221
SECTION 4 INSPECTION, TESTING AND CERTIFICATION	233
SECTION 5 INSTALLATION AND TRIAL.....	235

CHAPTER 6 STEERING GEARS	237
SECTION 1 GENERAL REQUIREMENTS.....	238
SECTION 2 MATERIALS.....	241
SECTION 3 SYSTEM ARRANGEMENTS.....	243
SECTION 4 MECHANICAL COMPONENT DESIGN	246
SECTION 5 HYDRAULIC SYSTEM	250
SECTION 6 ELECTRICAL SYSTEMS, CONTROLS, INSTRUMENTATION AND COMMUNICATIONS	254
SECTION 7 INSTALLATION, TESTS AND TRIALS	260
SECTION 8 ADDITIONAL REQUIREMENTS	263
SECTION 9 CERTIFICATION	267
CHAPTER 7 THRUSTERS, WATERJETS AND DYNAMIC POSITIONING SYSTEMS	269
SECTION 1 GENERAL REQUIREMENTS.....	270
SECTION 2 THRUSTER MATERIALS	274
SECTION 3 DESIGN OF THRUSTERS	276
SECTION 4 CONTROLS, INSTRUMENTATION AND COMMUNICATIONS.....	283
SECTION 5 MISCELLANEOUS REQUIREMENTS FOR THRUSTER ROOMS	285
SECTION 6 CERTIFICATION AND TRIAL.....	287
SECTION 7 WATERJETS	289
SECTION 8 DYNAMIC POSITIONING SYSTEMS	298
CHAPTER 8 MACHINERY PIPING SYSTEM	307
SECTION 1 GENERAL REQUIREMENTS.....	308
SECTION 2 METALLIC PIPING	319
SECTION 3 PLASTIC PIPING	359
SECTION 4 PIPING SYSTEMS FOR INTERNAL COMBUSTION ENGINES	378
SECTION 5 PIPING SYSTEMS FOR STEAM PLANTS	395
SECTION 6 OTHER PIPING SYSTEMS	412
CHAPTER 9 SHIP PIPING SYSTEMS	423
SECTION 1 GENERAL.....	424
SECTION 2 GRAVITY DRAIN SYSTEMS.....	426
SECTION 3 BILGE SYSTEM.....	433
SECTION 4 BALLAST SYSTEMS.....	442
SECTION 5 TANK VENTS AND OVERFLOWS.....	445
SECTION 6 MEANS OF SOUNDING.....	455
SECTION 7 FUEL OIL STORAGE AND TRANSFER SYSTEMS.....	460
SECTION 8 LUBRICATING OIL STORAGE AND TRANSFER SYSTEMS.....	471
SECTION 9 ADDITIONAL MEASURES FOR OIL POLLUTION PREVENTION.....	475

CHAPTER 10 BOILERS AND PRESSURE VESSELS	478
SECTION 1 GENERAL REQUIREMENTS	479
SECTION 2 MATERIALS	486
SECTION 3 DESIGN	488
SECTION 4 FABRICATION, TESTING AND CERTIFICATION	524
SECTION 5 BOILER ACCESSORIES	526
SECTION 6 BOILER CONTROL	534
SECTION 7 THERMAL OIL HEATERS	539
SECTION 8 INCINERATORS	542
SECTION 9 PRESSURE VESSEL AND HEAT EXCHANGER ACCESSORIES	544
SECTION 10 INSTALLATION AND SHIPBOARD TRIALS	546
CHAPTER 11 PROPULSION REDUNDANCY	549
SECTION 1 GENERAL REQUIREMENTS	550
SECTION 2 CLASSIFICATION NOTATIONS AND SURVEYS	553
SECTION 3 SINGLE FAILURE CONCEPT	556
SECTION 4 PROPULSION AND STEERING CAPABILITY	558
SECTION 5 SYSTEM DESIGN	560
SECTION 6 FIRE PRECAUTIONS AND OPERATIONAL MANUAL	564
SECTION 7 TEST AND TRIAL	566
CHAPTER 12 RUDDER STOCKS AND SHAFTS	568
SECTION 1 RUDDER STOCKS	569
SECTION 2 RUDDER SHAFTS	578
CHAPTER 13 FIRE SAFETY	583
SECTION 1 GENERAL	584
SECTION 2 FIRE PREVENTION	598
SECTION 3 SUPPRESSION OF FIRE	618
SECTION 4 ESCAPE AND OPERATIONAL REQUIREMENTS	675
SECTION 5 ALTERNATIVE DESIGN ARRANGEMENTS AND SPECIAL REQUIREMENTS	688
ANNEX 1 INTERNAL COMBUSTION ENGINE APPROVAL APPLICATION FORM AND DATA SHEET	7057
ANNEX 2 SAMPLE TEMPLATE FOR CONFIRMATION OF THE LICENSOR'S ACCEPTANCE OF LICENSEE'S MODIFICATIONS	7156

All rights reserved

International Register of Shipping (hereafter referred as the Society) has copyrights of these rules and they fall under its ownership rights. Consequently, only the Society is entitled to offer and/or perform classification or other services on the basis of and/or pursuant to these rules without Society prior written consent, which can include issuance of certificates and/or declarations of conformity, wholly or partly. Also Society cannot be held accountable for the resultant consequences of using rules other than those specified by Society.

CHAPTER 1 GENERAL

CONTENTS

SECTION 1 GENERAL CLASSIFICATION.....

SECTION 2 CERTIFICATION OF MACHINERY.....

SECTION 3 PLANS OF MACHINERY.....

SECTION 4 MISCELLANEOUS REQUIREMENTS.....

SECTION 5 SEA TRIALS.....

10

15

22

24

27

SECTION 1 GENERAL CLASSIFICATION

Contents

1.1. Scope..... 11

1.2. General Definitions 12

1.3. Classification notations..... 13

1.4. Alternative standards 14

1.1. Scope

1.1.1. Chapters mentioned in Part-5A contain classification requirements for machinery. These requirements are organized in two broad segments

- 1) a) Equipments Requirements
- 2) b) System Requirements

Table 1.1.1 shows the overhaul organization of Part: 5A

Part 5A provides the minimum requirements for machinery of self-propelled vessels of 100 meters in length and over. Compliance with Part 5A is a condition for classification of all such vessels, and for assigning the appropriate machinery class notations indicated in Sect [1.3] of this Chapter . Additional requirements as determined by the Society may be applicable for particular ship types based on the vessel type assigned in the class notation.

Additional requirements as determined by the Society may be applicable for particular ship types based on the vessel type assigned in the Class Notation.

Table 1.1.1: Organization of Part: 5A

PART 5A: MACHINERY EQUIPMENT, INSTALLATION AND PIPING SYSTEM			
Chapter 1	CLASSIFICATION OF MACHINERY		
EQUIPMENT REQUIREMENTS		SYSTEM REQUIREMENTS	
Chapter 2	PRIME MOVERS	Chapter 8	MACHINERY PIPING SYSTEM
Chapter 3	REDUCTION GEARS	Chapter 9	SHIP PIPING SYSTEMS
Chapter 4	PROPELLER SHAFTING		
Chapter 5	PROPELLERS		
Chapter 6	STEERING GEAR		
Chapter 7	THRUSTERS, WATERJETS AND DYNAMIC POSITIONING SYSTEMS		
Chapter 10	BOILERS AND PRESSURE VESSELS		
Chapter 11	PROPULSION REDUNDANCY		
Chapter 12	RUDDER STOCKS AND SHAFTS		
Chapter 13	FIRE SAFETY		

1.1.2 Fundamental intent of machinery rules

- a) Propulsion and maneuvering capability

Part 5A of the rule is intended to assure that the propulsion and maneuvering capability of the vessel through specification of pertinent design, testing and certification requirements for propulsion, maneuvering and other equipment and their associated systems. Please refer Table 1.1.1 for equipment and systems included in the scope

- b) Machinery hazards

Part 5A of the Rules is also intended to identify and address hazards associated with machinery aboard a vessel, particularly those hazards which are capable of causing personal injury, flooding, fire or pollution.

- c) Cargo hazards
In Part 6, hazards associated with cargoes carried (such as oil, dangerous goods, etc.) or to the specialized operations of the vessel (such as navigating in ice) are addressed.

1.1.3 Application

Requirements in Part 5A are mainly for those vessels which are under construction; but they are also applicable to alterations that are made to existing vessels, as far as practicable.

1.2. General Definitions

Definitions of terms used are defined in the chapter, sections or subsections where they appear. The following terms are used throughout Part 5A of INTLREG Rules.

1.2.1 Machinery Space

Any space that contains oil fuel units, boilers, propulsion machinery, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, air conditioning and ventilation machinery, refrigerating machinery, stabilizing machinery or other similar machinery, including the trunks to the space is known as Machinery Space. Machinery space is to include "machinery space of category A", which, as defined in , Ch-13, Sec-1, [1.3.31], is a space and trunks to that space which contains:

- Internal combustion machinery used for main propulsion; or
- Internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW (500 hp); or
- Any oil-fired boiler (including similar oil-fired equipment such as inert gas generators, incinerators, waste disposal units, etc.) or Oil Fuel Unit (Refer definition in Ch-13, Sec-1, [1.3.34].

1.2.2 Control Station

A location where controllers or actuator are fitted, with monitoring devices, as appropriate, for purposes of effecting desired operation of specific machinery.

Control Station is defined exclusively for purposes of, "Fire Safety", as intended by SOLAS, in Ch-13, Sec-3[.3.4.9].

Centralized Control Station is used in Part 6, Chapter 8, Sec 3 to refer to the space or the location where the following functions are centralized:

- Controlling propulsion and auxiliary machinery;
- Monitoring propulsion and auxiliary machinery; and
- Monitoring the propulsion machinery space.

1.2.3 Dead Ship Condition

Dead ship condition means a condition under which:

- a) The main propulsion plant, boilers and auxiliary machinery are not in operation due to the loss of the main source of electrical power, and
- b) In restoring propulsion, the stored energy for starting the propulsion plant, the main source of electrical power and other essential auxiliary machinery is assumed to not be available.

1.2.4 Blackout

Blackout means that the main and auxiliary machinery installations, including the main power supply, are out of operation but the services for bringing them into operation (e.g. compressed air, starting current from batteries, etc.) are available.

1.2.5 Hazardous Area

Hazardous areas are the areas where flammable or explosive gases, vapors or dust are usually present or likely to be present. However, hazardous areas are more specifically defined for certain machinery installations, storage spaces and cargo spaces that can cause such hazard, e.g.:

- Helicopter refueling facilities, refer Part 6, Ch-3, sec-6, [6.9.3];
- Paint stores, Refer Part 6, Ch-3, sec-6, [6.9.1];
- Cargo oil tanks and other spaces of oil carriers; Refer Part 7B;
- Ro-Ro cargo spaces; Refer Part 7B, Ch-2

1.2.6 Toxic or Corrosive Substances

Toxic substances (solid, liquid or gas) are those with the common property that can cause death or serious injury or harm to human health, if swallowed or inhaled, or by skin contact.

Corrosive substances (solid or liquid) are those, excluding saltwater, which in their original state possess the natural ability to cause irreversible damage through chemical action by coming into contact with living tissues, the vessel or its cargoes, when escaped from their containment.

1.2.7 Essential Services

Services essential for the operation of the propulsion machinery, steering and the supply of electrical power are to be arranged so to that the ship will retain not less than 50 per cent of the prime mover capacity and 50 per cent of the installed propulsion systems and retain steering capability in the event of a single failure in any of the services, where required by the respective class notations. Also refer Part-6, Ch-1, Sec-2, [2.2].

1.3. Classification notations

1.3.1. Classification notations are assigned to a vessel in order to indicate compliance with particular portions of the Rules. The following classification notations define compliance with specific requirements of the Rules for machinery:

- a) **IM** indicates that a vessel complies with all machinery requirements given in Part 6, other than the requirements associated with the other classification notations below. **IM** is mandatory for all self-propelled vessels.
- b) **CCS** indicates that in a self-propelled vessel, in lieu of manning the propulsion machinery space locally, it is intended to monitor the propulsion machinery space and to control and monitor the propulsion and auxiliary machinery from a continuously manned Centralized Control Station. Where such a centralized control station is installed, the provisions of Part 6 Ch-8, Sec-1, [1.2.1] are to be complied with. Upon verification of compliance, **CCS** will be assigned.
- c) **DP** indicates that a vessel, self-propelled or non-self-propelled, is fitted with a Dynamic Positioning System. **DP** is assigned only when requested by the owners and approved by the committee.

- d) **UM** indicates that a self-propelled vessel is fitted with various degrees of automation and with remote monitoring and control systems to enable the propulsion machinery space to be periodically unattended and the propulsion control to be effected primarily from the navigation bridge. Where periodically unattended propulsion machinery space is intended, the provisions of Part 6, Ch-8, Sec-1, [1.2.2] are to be complied with. Upon verification of compliance, **UM** will be assigned.
 - e) **APS** Indicates that a self-propelled vessel is fitted with athwart ship thrusters. APS is optional for all self-propelled vessels fitted with such thrusters and signifies compliance with applicable requirements of Section: Part: 5A Chapter:7, Section 1, (1.2.1)
 - f) **PAS** indicates that a non-self-propelled vessel is fitted with thrusters for the purpose of assisting the movement or maneuvering. PAS is only assigned when requested by the Owner and signifies compliance with applicable requirements of Section: Part: 5A, Chapter:7, Section 1, (1.2.2)
 - g) This notation followed by letters within parenthesis describes the type of tail shaft fitted:
 - TS (OG): Vessel fitted with approved oil gland
 - TS (CL): Vessel fitted with continuous shaft liner
 - TS (ES): Vessel fitted with exposed steel shaft
 - TS (NC): Vessel fitted with non-corrosive steel shaft
 - TS (CM): Vessel fitted with approved oil gland and has extended tail shaft survey based on Condition Monitoring..
 - h)  This distinguishing mark, when prefixed to class notations (machinery) signifies that the main and auxiliary machinery installed in the vessel are manufactured under special survey of the society to the extent required by the Rules
 - i) * This distinguishing mark, when prefixed to class notations (machinery) signifies that the main and auxiliary machinery installed in the vessel are manufactured under special survey of a recognized class society
- 1.3.2. The above class notations, where preceded by the symbol  (Big Asterisks; e.g.,  **IM**), signify that compliance with these Rules was verified by INTLREG during construction of the vessel. This includes survey of the machinery at the manufacturer's plant (where required), during installation on board the vessel and during trials. Where an existing vessel, not previously classed by INTLREG, is accepted for class, these class notations are assigned without .

1.4. Alternative standards

- 1.4.1. Where items of machinery are manufactured as individual or series produced units the Committee will be prepared to give consideration to the adoption of a survey procedure based on quality assurance concepts utilizing regular and systematic audits of the approved manufacturing and quality control processes and procedures as an alternative to the direct survey of individual items.
- 1.4.2. In order to obtain approval, the requirements of Part 1, Ch-1, Sec-11 are to be complied with.
- 1.4.3. Where it is proposed to depart from the requirements of the Rules, the Committee will be prepared to give consideration to the circumstances of any special case.
- 1.4.4. Any novelty in the construction of the machinery, boilers or pressure vessels is to be reported to the Committee

SECTION 2 CERTIFICATION OF MACHINERY

Contents

2.1 General requirements.....	16
2.2 Type Approval Program	16
2.3 Non-mass produced machinery	16
2.4 Details of certification of some representative products	17

2.1 General requirements

- 2.1.1. To varying degrees, the Rules defines the extent of evaluation required for products, machinery, equipment and their components on the basis of the criticality level of each of those items. There are three basic evaluation constituents:
- Design review; type/prototype testing, as applicable;
 - Survey during construction and testing at the plant of manufacture; an
 - Survey during installation on board the vessel and at trials.
- 2.1.2 Where design review is required by the Rules, a letter will be issued by INTLREG upon satisfactory review of the plans to evidence the acceptance of the design. In addition to, or independent of, design review, INTLREG may require survey and testing of forgings, castings and component parts at the various manufacturers' plants, as well as survey and testing of the finished product. A certificate or report will be issued upon satisfactory completion of each survey to evidence acceptance of the forging, casting, component or finished product. Design review, survey and the issuance of reports or certificates constitute the certification of machinery.
- 2.1.3 On the basis of the intended service and application, some products do not require certification because they are not directly related to the scope of classification or because normal practices for their construction within the industry are considered adequate. Such products may be accepted based on the manufacturers' documentation on design and quality.
- 2.1.4 Generally for all items of machinery, surveys during installation on board the vessel and at trials are required. This is not considered a part of the product certification process. However, there may be instances where letters or certificates that are issued for items of machinery that contain conditions which during installation, tests or trials, must be verified.
- 2.1.5 Refer to [2.1.3]
- 2.1.6 Refer to [2.1.4]

2.2 Type Approval Program

Under the INTLREG Type Approval Program, products that can be consistently manufactured to the same design and specification may be Type Approved. The INTLREG Type Approval Program is a voluntary option for demonstrating the compliance of a product with the Rules or other recognized standards. It may be applied for upon the request of the designer or manufacturer.

Generally, the INTLREG Type Approval Program covers Product Type Approval, but is also applicable for a more expeditious procedure towards Unit-Certification, as specified in Part 1, Ch-1, Sec-11, [11.1.3.4 (a)]. Refer Part 1, Ch-1, Sec-11, for "INTLREG Type Approval Program".

2.3 Non-mass produced machinery

In accordance with the procedure described in [2.1] of this section, non-mass produced critical machinery, such as propulsion boilers, slow speed diesel engines, turbines, steering gears, and similar critical items are to be individually unit certified. However, it shall be considered to grant Type Approval to such machinery that is in the categories of Acceptable Quality System (AQS) and Recognized Quality System (RQS). Normally for all products, the category of Product Quality Assurance (PQA) will not be available, and such limitations will be indicated in Table 1.2.1 through Table 1.2.6. Where Type Approval is granted in each instant, in addition to quality assurance and quality control assessment of the manufacturing facilities, INTLREG will require some degree of product specific survey during manufacture.

2.4 Details of certification of some representative products

Based on the basic requirements of the Rules for machinery, abbreviated certification requirements of representative machinery are detailed in Table 1.2.1 through Table 1.2.6. The applicability of the Type Approval Program for each of these machinery items are also provided by the tables.

The tables contain six product categories as follows:

- i) Prime movers
- ii) Propulsion, maneuvering and mooring machinery
- iii) Fire safety equipment
- iv) Electrical and control equipment
- v) Boilers, pressure vessels, fired equipment
- vi) Piping system components

Table: 1.2.1, Certification Details – Prime Movers

Prime Movers (Refer note 1)	Individual Unit Certification (Refer note 2)	Type Approval Program (Refer note 3)					
		Product Design Assessment			Manufacturing Assessment		
		Design Review	Type Exam.	Type Test	AQS	RQS	PQA
1. Diesel engines with cylinder bore; >300mm	d, m, s, t	x	x	x	o	o	NA
2. Diesel engines; steam turbines; gas turbines; $\geq 100\text{kW}$ (135hp)	d, m, s, t	x	x	x	o	o	o
3. Diesel engines; steam turbines; gas turbines, <100kW (135hp)	g	x	o	x	o	o	NA
4. Turbochargers for engines $\geq 100\text{kW}$ (135hp) and bore $\geq 300\text{mm}$ (11.8in.)	d, m, s, t	x	x	x	o	o	o
5. Turbochargers for engines $\geq 100\text{kW}$ (135hp) and bore < 300mm (11.8in.)	d, t	x	x	x	o	o	NA

Notes:

- For full certification details, refer to Chapter 2 of this part.
- Refer also [2.1] of this section. Notations used in this column are:
 - d* – Design review by INTLREG.
 - m* – Material tests witnessed by Surveyor.
 - s* – Survey at the plant of manufacture including witnessing acceptance tests on production unit.
 - t* – type/prototype testing conducted on an actual sample or a prototype model is required, as applicable.
 - g* – Certification by INTLREG not required; acceptance based on manufacturer's guarantee.
- For description of Type Approval Program, Refer Part 1, Ch-1, Sec-11. Notations used in these columns are:
 - x* – Indicates the particular element of the program is applicable.
 - o* – Indicates the particular element of the program is optional.
 - NA* – indicates the particular element of the program is not applicable.

Table 1.2.2: Certification Details – Propulsion, Maneuvering and Mooring Machinery

Propulsion, Maneuvering and Mooring Machinery		Individual Unit Certification (Refer note 1)	Type Approval Program (Refer note 2)					
			Product Design Assessment			Manufacturing Assessment		
			Design Review	Type Exam.	Type Test	AQS	RQS	PQA
1.	Propulsion shafts, couplings, coupling bolts (Refer note 3)	d, m, s	x	NA	NA	o	o	NA
2.	Cardan shafts, standard couplings and coupling bolts	d, m, s	x	x	x	o	o	o
3.	Gears and Clutches ≥ 5590 kW (7500 hp)	d, m, s	x	x	x	o	o	NA
4.	Gears and clutches, ≥ 100 kW (135 hp)	d, m, s	x	x	x	o	o	o
5.	Gears and clutches, < 100 kW (135 hp)	g	o	o	x	o	o	NA
6.	Propellers, fixed and controllable pitch (Refer note 3)	d, m, s	x	NA	NA	o	o	NA
7.	Propulsion thrusters	d, m, s	x	x	x	o	o	o
8.	Steering gears	d, m, s	x	x	x	o	o	NA
9.	Athwartship thrusters	d, m, s	x	x	x	o	o	o
10.	Positioning thrusters (Refer note 4)	g	x	x	x	o	o	NA
11.	Dynamic positioning thrusters with DP notation	d, m, s, t	x	x	x	o	o	NA

Notes:

1. Refer also [2.1] of this section. Notations used in this column are:
d – Design review by INTLREG.
M – Material tests to be witnessed by Surveyor.
s – Survey at the plant of manufacture, and witness acceptance tests on production unit.
t – Type/prototype testing conducted on an actual sample or a prototype model is required, as applicable.
g – Certification by INTLREG not required; acceptance is based on manufacturer's guarantee.
2. For description of Type Approval Program, Refer Part 1, Ch-1, Sec-11. Notations used in these columns are:
x – Indicates the particular element of the program is applicable.
o – Indicates the particular element of the program is optional.
NA – indicates the particular element of the program is not applicable.
3. Typically made to custom designs. However, manufacturing facilities may be quality assurance approved, Refer [2.3] of this section.
4. Thrusters in this category would be those not normally relied upon for maneuvering assistance.

Table:1.2. 3, Certification Details – Electrical and Control Equipment

Electrical and Control Equipment (Refer note 1)		Individual Unit Certification (Refer note 2)	Type Approval Program (Refer note 3)					
			Product Design Assessment			Manufacturing Assessment		
			Design Review	Type Exam.	Type Test	AQS	RQS	PQA
1.	Generators and motors for essential services ≥ 100 kW (135 hp)	d, s, t	x	x	x	o	o	o
2.	Motors ≥ 100 kW (135 hp) for LNG cargo or vapor handling services. (Refer Relevant Part in Special type ships)	d, s, t	x	x	x	o	o	o
3.	Generators and motors for essential services < 100 kW (135 hp)	g	o	o	x	o	o	NA
4.	Motors < 100 kW (135 hp) for LNG cargo or vapor handling services. (Refer Relevant Part in Special type ships)	g	o	o	x	o	o	NA
5.	Propulsion generators and motors	d, m, s, t	x	x	x	o	o	NA
6.	Switchboards (propulsion, main and emergency) (Refer note 4)	d, s	x	NA	NA	o	o	o
7.	Motor controllers for essential services ≥ 100 kW (135 hp)	d, s	x	x	NA	o	o	o
8.	Motor controllers ≥ 100 kW (135 hp) for LNG cargo or vapor handling services. (Refer Relevant Part in Special type ships)	d, s	x	x	NA	o	o	o
9.	Motor control centers for essential services ≥ 100 kW (135 hp)	d, s	x	x	NA	o	o	o
10.	Motor control centers ≥ 100 kW (135 hp) for LNG cargo or vapor handling services. (Refer Relevant Part in Special type ships)	d, s	x	x	NA	o	o	o
11.	Battery charging and discharging boards for essential, emergency or transitional source of power. (Refer Part-6, Ch-3, Sec-4)	d, s	x	x	NA	o	o	o
12.	Power transformers and converters of low voltage	g	x	x	x	o	o	NA
13.	Power transformers and converters for high voltage systems exceeding 1 kV	d, s	x	x	x	o	o	o
14.	Cables	d-1, t	x	x	x	o	o	o
15.	Propulsion cables	d-1, s, t	x	x	x	o	o	NA
16.	Circuit breakers & fuses	g	NA	x	x	o	o	NA
17.	Certified safe equipment	t	NA	x	x	o	o	NA
18.	Governors	t	NA	x	x	o	o	NA
19.	Control, monitoring and safety system devices, including computers, programmable logic controllers, etc., for UM and CCS notations	t	x	x	x	o	o	o
20.	Complete assembly or subassembly units for UM and CCS notations	d, s, t	x	x	x	o	o	NA

Notes:

1. For full certification details, Refer Part-6 for electrical equipment and control, monitoring and safety system equipment.

2. Refer also [2.1] of this section. Notations used in this column are:

d – design review by INTLREG.

d-1 – reviewed for compliance with a recognized standard.

m – material tests to be witnessed by Surveyor.

s – survey at the plant of manufacture including witnessing acceptance tests of production unit.

t – type/prototype testing conducted on an actual sample or a prototype model is required, as applicable.

g – certification by INTLREG not required; acceptance is based on manufacturer's guarantee.

3. For description of Type Approval Program, Refer Part 1, Ch-1, Sec-11. Notations used in these columns are:

x – indicates the particular element of the program is applicable.

o – indicates the particular element of the program is optional.

NA – indicates the particular element of the program is not applicable.

4. This equipment is generally made to custom design; but manufacturing facilities may be quality assurance approved, Refer [2.3] of this section.

Table:1.2.4, Certification Details – Fire Safety Equipment

Fire Safety Equipment (Refer note 1)		Individual Unit Certification (Refer note 2)	Type Approval Program (Refer note 3)					
			Product Design Assessment			Manufacturing Assessment		
			Design Review	Type Exam.	Type Test	AQS	RQS	PQA
1.	Fire detection and alarm system components	d, t	x	x	x	o	o	NA
2.	Fixed fire extinguishing system components	d, t	x	x	x	o	o	NA
3.	Fireman's outfit	t	x	x	x	o	o	NA
4.	Fire hoses	t	x	x	x	o	o	NA
5.	Portable fire extinguishers	t	x	x	x	o	o	NA
Notes 1. For certification details, Refer Part-6 2. Refer also [2.1] of this section. Notations used in this column are: <i>d</i> – Design review by INTLREG. <i>s</i> – Survey at the plant of manufactures and witness acceptance tests of production unit. <i>t</i> – Type/prototype testing conducted on an actual sample or a prototype model is required, as applicable; or type approval by Flag Administration. 3. For description of Type Approval Program, Refer Part 1, Ch-1, Sec 11 Notations used in these columns are: <i>x</i> – Indicates the particular element of the program is applicable. <i>o</i> – Indicates the particular element of the program is optional.								

Table: 1.2.5: Certification Details – Boilers, Pressure Vessels and Fired Equipment

Boilers, Pressure Vessels and Fired Equipment (Refer note 1)		Individual Unit Certification (Refer note 2)	Type Approval Program (Refer note 3)					
			Product Design Assessment			Manufacturing Assessment		
			Design Review	Type Exam.	Type Test	AQS	RQS	PQA
1.	Group I boilers and pressure vessels	d, m, s	x	x	NA	o	o	NA
2.	Group II pressure vessels	d, s	x	x	NA	o	o	o
3.	Inert gas generators, incinerators	d	x	x	x	o	o	NA
Notes: 1. For grouping of boilers and pressure vessels, Refer Ch-10, Sec-1, [1.4] & [1.5]. 2. Refer also [2.1] of this section. Notations used in this column are: <i>d</i> – design review by INTLREG <i>m</i> – material tests to be witnessed by Surveyor <i>s</i> – survey at the plant of manufacture and witness acceptance tests of production unit 3. For description of Type Approval Program, Refer Part 1, Ch-1, Sec-11 Type Approval Programs are generally applicable to mass produced boilers and pressure vessels (Refer Ch-10, Sec-1, [1.6.2]). Notations used in these columns are: <i>x</i> – indicates the particular element of the program is applicable <i>o</i> – indicates the particular element of the program is optional <i>NA</i> – indicates the particular element of the program is not applicable								

Table 1.2.6: Certification Details – Piping System Components

Piping System Components (Refer note 1)		Individual Unit Certification (Refer note 2)	Type Approval Program (Refer note 3)					
			Product Design Assessment			Manufacturing Assessment		
			Design Review	Type Exam.	Type Test	AQS	RQS	PQA
1.	Pumps related to propulsion diesel engines (bore >300 mm) (11.8 in.) and gas turbines and gears—fuel, cooling water, lube. Oil services	s	x	x	x	o	o	o
2.	Pumps related to propulsion steam plant and gears—fuel oil, lube. Oil, condensate, main circulating, feed water services	s	x	x	x	o	o	o
3.	Hydraulic pumps of steering gears, controllable pitch propellers, anchor windlass	s	x	x	x	o	o	o
4.	Pumps for fire main, ballast, bilge, liquid cargoes	s	x	x	x	o	o	o
5.	Air compressors	g	x	x	x	o	o	NA
6.	Steel pipes, classes I and II	m, s	x	NA	NA	o	o	o
7.	Steel pipes, class III	g	x	NA	NA	x	x	NA
8.	Pipe fittings—flanges, elbows, tees, flexible joints, etc., and valves; classes I & II	d-1	x	NA	NA	o	o	NA
9.	Pipe fittings—flanges, elbows, tees, flexible joints, etc., and valves; class III	g	x	NA	NA	o	o	NA
10.	Plastic pipes and pipe joints	d-2, t, s (Refer note 4)	x	x	x	o	o	o
11.	Hoses	d-2, t	x	x	x	o	o	NA
12.	Vent heads, pressure vacuum valves	d-2, t	x	x	x	o	o	NA
13.	Gauges, detectors and transmitters	d-2	x	x	x	o	o	NA
14.	Fluid power cylinders and systems, including valve actuators	d-1	x	x	x	o	o	NA
Notes 1. For full certification details, refer Chapter-8, Sec-3, [1.4] and Chapter-8, Sec-2 for metallic piping and Chapter-8, Sec-3 for plastic piping. 2. Refer also [2.1] of this section. Notations used in this column are: d-1 – verification for compliance with recognized standard or design review by INTLREG. d-2 – reviewed for suitability for proposed installation. m – material tests witnessed by Surveyor. s – survey at the plant of manufacture, including witnessing acceptance tests of production unit. t – type/prototype testing conducted on an actual sample or a prototype model is required, as applicable. Where, for plastic pipes, the manufacturer does not have a certified quality system in accordance with Part 1, Ch-1, Sec-11 or ISO 9001 (or equivalent), and that ensures testing is carried to demonstrate the compliance of plastic pipes, fittings and joints with Chapter-8, Sec-3, as applicable, testing is to be witnessed by Surveyor. g – certification by INTLREG not required; acceptance is based on manufacturer's documentation. 3. For description of Type Approval Program, Refer Part 1, Ch-1, Sec-11. Notations used in these columns are: x – indicates the particular element of the program is applicable. o – indicates the particular element of the program is optional. NA – indicates the particular element of the program is not applicable. 4. Where the manufacturer does not have a certified quality system, Refer Chapter 8 sec 3[3.4]. 5. Other than steering gear actuators.								

SECTION 3 PLANS OF MACHINERY

Contents

3.1	Submission of Plans	23
3.2	Plans	23

3.1 Submission of Plans

Machinery and systems plans required by the Rules are generally to be submitted electronically by the manufacturer, designer or shipbuilder to INTLREG. However, hard copies will also be accepted. After review and approval of the plans, one copy will be returned to the submitter, one copy will be retained for the use of the INTLREG Surveyor, and one copy will be retained by INTLREG for record. Where so stated in the shipbuilding contract, the Owner may require the builder to provide copies of approved plans and related correspondence. Fee will be charged for the review of plans which are not covered by a contract of classification with the shipbuilder. In general, all plans are to be submitted and approved before proceeding with the work.

3.2 Plans

Machinery plans required to be submitted for review and approval by INTLREG is listed in each of the sections in Part 5A. In general, equipment plans are to contain performance data and operational particulars; standard of compliance where standards are used in addition to, or in lieu of, the Rules; construction details such as dimensions, tolerances, welding details, welding procedures, material specifications, etc.; and engineering calculations or analyses in support of the design. System plans are to contain a bill of material with material specifications or particulars, a legend of symbols used, system design parameters, and are to be in a schematic format. Booklets containing standard shipyard practices of piping and electrical installations are generally required to supplement schematic system plans.

SECTION 4 MISCELLANEOUS REQUIREMENTS

Contents

4.1. Construction survey notification	25
4.2. General Equations of Machinery	25
4.3. Astern propulsion power	25
4.4. Ambient temperature	25
4.5. Dead ship start	26
4.6. Inclination Requirement Of Machinery	26
4.7. Materials Containing Asbestos	26
4.8. Ventilation of machinery space	26

4.1. Construction survey notification

INTLREG must be informed with a notification that survey is desired during construction, prior to proceeding with the manufacture of machinery requiring test and inspection. Such notice is to contain all the required information related to identification of the items to be surveyed.

4.2. General Equations of Machinery

The equations for rotating parts of the machinery in this Part of INTLREG Rules are based upon strength considerations only and their application does not relieve the manufacturer from responsibility for the presence of dangerous vibrations and other considerations in the installation at speeds within the operating range.

4.3. Astern propulsion power**4.3.1. General**

In all normal circumstances, sufficient power for going astern is to be provided in order to secure proper control of the vessel. In free route astern, the astern power of the main propelling machinery must have the capability of maintaining at least 70% of the ahead rpm corresponding to the maximum continuous ahead power. For main propulsion systems with reversing gears, controllable pitch propellers or electric propulsion drive, running astern is not to lead to overload of the propulsion machinery. The ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, and so to bring the vessel to rest within a reasonable distance from maximum ahead service speed, is to be demonstrated and recorded during trials.

4.3.2. Steam turbine propulsion

For a period of at least 15 minutes steam turbines are to be capable of maintaining in free route astern at least 70% of the ahead revolutions, where they are used for main propulsion. In order to avoid overheating of the turbine due to the effects of "windage" and friction, the astern trial is to be limited to 30 minutes or is to be in accordance with manufacturer's recommendation.

4.4. Ambient temperature

The ambient temperature for vessels of unrestricted service, as indicated in Table 1.4.1, is to be considered in the selection and installation of machinery, equipment and appliances. On the other hand, for vessels of restricted or special service, the ambient temperature suitable for the special nature is to be considered.

Table 1.4.1: Ambient Temperatures for Unrestricted Service

Location		Temperature (°C)
Air	Enclosed spaces (Refer note 1, 2)	0 to +45
	Open deck (Refer note 1)	-25 to +45
Seawater		+32
Notes: 1. Electronic equipment is to be suitable for operations up to 55°C. 2. Electrical equipment in machinery spaces is to be designed for 45°C, except that electric generators and motors are to be designed for 50°C. Electrical equipment outside machinery space may be designed for 40°C.		

4.5. Dead ship start

As defined in Sec-1, [1.2.3]. Refer Part 6, Ch-2, sec-2, [2.2.2] for the required starting arrangements, means are to be provided to bring the machinery into operation from a “dead ship” condition.

4.6. Inclination Requirement of Machinery

To ensure proper operations, machinery installations are to be designed under the conditions as shown in Table 1.4.2.

4.7. Materials Containing Asbestos

Installation of materials which contain asbestos is prohibited.

Table 1.4.2: Design Angles of Inclination, in Degrees (Refer note 1)

Installations / Components :	Athwartship		Fore-and-Aft	
	Static	Dynamic	Static	Dynamic
Propulsion and auxiliary machinery	15	22.5	55 (Refer note 4)	7.5
Safety equipment				
Emergency power installation (Refer note 3)	22.5	22.5	10	10
Emergency fire pumps and their drives	22.5	22.5	10	10
Switchgear				
Electrical and electronic appliances and control systems	22.5 (Refer note 2)	22.55 (Refer note 2)	10	10
Notes: 1. Athwartship and fore-and-aft inclinations occur simultaneously. 2. Up to an angle of inclination of 45 degrees, switches and controls are to remain in their last set position. 3. In vessels designed for carriage of liquefied gases and of chemicals, the emergency power installation is to remain operable with the vessel flooded to its permissible athwartship inclination up to a maximum of 30 degrees. 4. Where the length of the vessel exceeds 100 m (328 ft), the fore-and-aft static angle of inclination may be taken as $500/L$ degrees, where L is the length of the vessel in meters ($1640/L$ degrees, where L is the length of the vessel in feet).				

4.8. Ventilation of machinery space

4.8.1. Adequate ventilation is to be provided for machinery spaces so as to simultaneously allow for crew attendance and for engines, boilers and other machinery to operate at rated power in all weather conditions, including heavy weather. The main propulsion machinery space is to be provided with mechanical means of ventilation.

4.8.2. Air supply is to be provided through ventilators which can be used in all weather conditions. In general, ventilators necessary to continuously supply the main propulsion machinery space and the immediate supply to the emergency generator room are to have coamings of sufficient height to eliminate the need to have closing arrangements. Refer Part 4, Ch-6, Sec-8.

4.8.3. However, lesser heights for machinery space and emergency generator room ventilator coamings may be accepted with provision of weather-tight closing appliances in accordance with Part 4, Ch-6, Sec-8 in combination with other suitable arrangements in order to ensure an uninterrupted and adequate supply of ventilation to these spaces, where due to the vessel size and arrangement this is not practicable. Refer also Ch-13, Sec-2, [2.1.2.2.2].

SECTION 5 SEA TRIALS

Contents

5.1. General.....	28

5.1. General

- 5.1.1. Where the assignment of a Class Notation or a Statement of Compliance is requested, an Initial Survey is to comprise sea trial or initial in-service testing, reporting and assessment against the criteria set out in these Rules.
- 5.1.2. A final underway trial is to be made of all machinery, steering gear, anchor windlass, stopping and maneuvering capability, including supplementary means for maneuvering, if any. As far as practicable, the vessel is required to be ballasted or otherwise arranged in order to simulate fully laden condition so as to allow propulsion machinery to discharge its rated power. In the presence of the Surveyor, the entire machinery installation is to be operated in order to demonstrate its reliability and sufficiency so as to function satisfactorily under operating conditions and its freedom from dangerous vibration and other detrimental operating phenomena at speeds within the operating range. To the satisfaction of the Surveyor, all automatic controls including tripping of all safety protective devices that affect the vessel's propulsion system, are to be tested under way or alongside the pier. References are also to be made to the following for more detailed requirements:
- Steering gear trial: Pt 5A, Chapter-6 Sect [6.2]
 - Anchor windlass trial: Part 4, Ch 3, Sect [6.3]
 - Remote propulsion control and automation trial: Part 6, Ch-8, sec-3 & Sect 7
 - Shipboard trials for diesel engines: Chapter-2, Sec-1, [1.10.]
- 5.1.3. Viscosity of the fuel used on the sea trial will be entered in the classification report.
- 5.1.4. On the basis of the sea trials, the following information is to be provided on board:
- Stopping time (Refer also Ch 7 Sect [6.2.3] of this chapter),
 - Vessel headings and distances recorded on sea trials, and
 - For vessels with multiple propellers, ability to navigate and maneuver with one or more propellers inoperative.
- 5.1.5. Reference may be made to **IMO Resolution A.209 (VII)** Recommendation on Information to be Included in the Maneuvering Booklet and **IMO Resolution A.601 (15)** Recommendation on the Provision and the Display of Maneuvering Information on board ships

CHAPTER 2 PRIME MOVER

CONTENTS

SECTION 1 DIESEL ENGINES 30

SECTION 2 TURBOCHARGERS 109

SECTION 3 GAS TURBINES 119

SECTION 4 STEAM TURBINES 132

SECTION 1 DIESEL ENGINES

Contents

1.1	General Requirements	31
1.2	Material Requirements	35
1.3	Design	35
1.4	Engine Accessories	52
1.5	Piping Systems for Diesel Engines	60
1.6	Installation of Diesel Engines	60
1.7	Calculation of Stress Concentration Factors in the Web Fillet Radii of Crankshafts by Utilizing Finite Element Method	61
1.8	Testing, Inspection and Certification of Diesel Engines	67
1.9	Certification, Approval Plans and Data for Diesel Engines	95
1.10	Shipboard Trials of Diesel Engines	104
1.11	Spare Parts	105

1.1 General Requirements

1.1.1. Application

In accordance with the requirements of this section, diesel engines having a rated power of 100 kW (135 hp) and over, intended for propulsion and for auxiliary services essential for propulsion, maneuvering and safety Refer: Part 5A-1-1/[1.1] of the vessel, are to be designed, constructed, tested, certified and installed.

Diesel engines having a rated power of less than 100 kW (135 hp) are not required to comply with the provisions of this section but are to be designed, constructed and equipped in accordance with good commercial and marine practice. Acceptance of such engines will be based on manufacturer's affidavit, verification of engine nameplate data, and subject to a satisfactory performance test after installation conducted in the presence of the Surveyor.

Diesel engines having a rated power of 100 kW (135 hp) and over, intended for services considered not essential for propulsion, maneuvering and safety, are not required to be designed, constructed and certified by IRES in accordance with the requirements of this section. They are to comply with safety features, such as crankcase explosion relief valve, over speed protection, etc., as provided in Part 5A-2-1 / [1.4], as applicable. After installation, they are subject to a satisfactory performance test conducted in the presence of the Surveyor

Piping systems serving diesel engines, such as fuel oil, lubricating oil, cooling water, starting air, crankcase ventilation and exhaust gas systems are addressed in Chapter: 8, Section: 4; hydraulic and pneumatic systems are addressed in Chapter 8/sect 6.

Requirements for turbochargers are provided in Section Chapter: 2, Section: 2

1.1.2. General Definitions

1.1.2.1. Slow-, Medium, High-Speed Diesel Engines

- *Slow-Speed Engines* means crosshead type diesel engines with a rated speed of less than 300 rpm.
- *Medium-Speed Engines* means trunk piston type diesel engines with a rated speed of 400 rpm and above, but less than 1400 rpm.
- *High-Speed Engine* means trunk piston type diesel engines with a rated speed of 1400 rpm or above.

1.1.2.2 Rated Power

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

1.1.3 Increased Power Rating

The rated power of an engine, which has been type tested as specified in Part 5A-2-1 / [1.1.3] and which has proven reliable in service, may be increased by not more than 10% of the type tested power rating without performing any new type test, subject to prior approval of relevant plans and particulars

1.1.4 Ambient reference conditions

The following ambient reference conditions are to be applied by the engine manufacturer for the purpose of determining the rated power of diesel engines used on vessels with unrestricted service. However, the engine manufacturer is not expected to provide simulated ambient reference conditions at any test.

Barometric pressure: 1 bar (1 Kg/cm², 15 psi)

Air temperature: 45°C (113°F)

Relative air humidity: 60%

Seawater Temperature (Charging air coolant inlet): 32°C (90°F)

1.1.5 Documents to be Submitted

For a tabulated listing, refer: Part 5A-2-1 / [1.9.2] of this section.

1.1.5.1 Engine Construction

Plans and particulars which need to be submitted for engineering construction are as follows:

- Engine transverse cross-section;
- Engine longitudinal section;
- Bedplate with welding details and procedures;
- Frame/column with welding details and procedures;
- Crankcase with welding details and procedures;
- Structural supporting and seating arrangements
- Arrangement of foundation bolts (for main engines only);
- Thrust bearing assembly;
- Thrust bearing bedplate;
- Cylinder cover, assembly or cylinder head (for each crank-throw);
- Cylinder jacket or engine block;
- Cylinder liner;
- Crankshaft, details Crankshaft, assembly;
- Thrust shaft or intermediate shaft (if integral with engine)
- Coupling bolts;
- Counterweights (if not integral with crankshaft);
- Connecting rod;
- Tie rod;
- Connecting rod, assembly and details;
- Crosshead, assembly and details;
- Piston rod, assembly and details;
- Piston, assembly and details;
- Camshaft drive, assembly;
- Arrangement of crankcase explosion relief valve and breather arrangement [only for engines having a cylinder bore of 200 mm (8 in.) and above]
- Main engine holding down arrangement (metal chocks).

1.1.5.2 Engine systems and appurtenances

- Starting air system;
- Fuel oil system;
- Lubricating oil system
- Cooling water system;
- Engine control and safety system;

- Hydraulic oil (for valve lift);
- Governor arrangements;
- Schematic diagram of the engine control and safety system;
- Shielding and insulation of exhaust pipes, assembly;
- Shielding of high pressure fuel pipes, assembly as applicable;
- Turbochargers and superchargers, Refer Part 5A-2-2 / [2.1.3];
- Couplings and clutches;
- Vibration damper assembly;
- Turning wheel assembly, if fitted
- Engine driven pump assembly;
- Scavenging pump and blower assemblies

1.1.5.3 Data

- Type designation of engine and combustion cycle;
- Number of cylinders;
- Rated power, kW (PS, hp);
- Rated engine speed, (rpm)
- ;Sense of rotation (clockwise/counter-clockwise);
- Firing order with the respective ignition intervals and, where necessary, V-angle, α_v ;
- Cylinder diameter, mm (in.);
- Stroke, mm (in.);
- Maximum cylinder pressure p_{max} , bar (Kgf/mm², psi);
- Mean effective pressure, bar (Kgf/mm², psi);
- Mean indicated pressure, bar (Kgf/mm², psi);
- Charge air pressure, bar (Kgf/mm², psi) (before inlet valves or scavenge ports, whichever applies).
- Nominal compression ratio;
- Connecting rod length LH, mm (in.);
- Oscillating mass of one crank gear, kg (lb.), (in case of V-type engines, where necessary, also for the cylinder unit with master and articulated type connecting rod or forked and inner connecting rod).
- Mass of reciprocating parts, kg (lb.);
- Digitalized gas pressure curve presented at equidistant intervals, bar (kgf/mm², psi) versus crank angle, (intervals equidistant and integrally divisible by the V-angle, but not more than 5 degrees CA).

For engines with articulated-type connecting rod:

- Distance to link point L_A , mm (in.);
- Link angle α_N (degree);
- Connecting rod length (between bearing centers) L_N , mm (in.)
- Tightening torques for pre-tensioned bolts and studs for reciprocating parts.
- Mass and diameter of flywheel and flywheel effect on engine.
- Operation and service manuals, including maintenance requirements for servicing and repair and details of any special tools and gauges that are to be used with their fittings / settings, together with any test requirements on completion of the maintenance Refer 5A-8 -2 / [2.5.4]

1.1.5.4 Materials

Crankshaft material:

- Material designation
- Mechanical properties of material (tensile strength, yield strength, elongation (with length of specimen), reduction of area, impact energy)
- Type of forging (open die forged (free form), continuous grain flow forged, close die forged (drop-forged), etc., with description of the forging process)
- Crankshaft heat treatment
- Crankshaft surface treatment
- Surface treatment of fillets, journals and pins (induction hardened, flame hardened, nitrided, rolled, shot peened, etc., with full details concerning hardening)
- Hardness at surface
- Hardness as a function of depth, mm (in.)
- Extension of surface hardening
- Material specifications of other main parts

1.1.5.5 Calculations and analyses

- Strength analysis for crankshaft and other reciprocating parts.
- Strength analysis for engine supports and seating arrangements
- Torsional vibration analysis for propulsion shafting systems for all modes of operation including the condition of one cylinder misfiring.
- Calculation demonstrating the adequacy of the bolting arrangement attaching tuning wheels or vibration dampers to the propulsion system to withstand all anticipated torsional vibration and operating loads.

1.1.5.6 Submittals by Licensee

- a. Plans lists: For each diesel engine that is manufactured under license, the licensee is to submit two listings of plans and data to be used in the construction of the engine:
 - One list containing drawing numbers and titles (including revision status) of the licensor's plans and data of the engine as approved by INTLREG (including approval information such as location and date at which they are approved) is to be included in one list; and
 - A second list, which is to contain the drawing numbers and titles (including revision status) of the licensee's plans and data, insofar as they are relevant to the construction of the engine. In the event that construction is based solely on the licensor's plans, this list will not be required.
- b. Plans for approval: Any design change made by the licensee is to be documented and the relevant plans and data are to be submitted by the licensee for the approval or for the information, as appropriate. The licensor's statement of acceptance of the modifications. Is to be included in the submittal.
- c. Plans for surveyor

A complete set of the licensee's or the licensee's plans and data, as approved by INTLREG, is to be made available to the Surveyor attending the licensee's plant

1.2 Material Requirements

1.2.1 Material specifications and tests

Material specifications are to be in accordance with that in Part 2, Chapter 2 or other specifications approved under [1.2.2.1] below. Except as noted in [1.2.2.3]below, materials intended for engines constructed under survey are to be tested and inspected in line with Table 2.1.1. The Surveyor is required to witness the material tests, wherever it is indicated in the table. Nondestructive tests given in Table 2.1.1 are to be executed by the manufacturer whose test records may be accepted by INTLREG.

Copies of material specifications or purchase orders are to be submitted to the Surveyor for information

1.2.2 Alternative materials and tests

1.2.2.1 Alternative specifications

Material manufactured to specifications other than those given in Part 2, Chapter 2 may be accepted, provided that their design is approved and that they are verified or tested in the presence of a Surveyor, as applicable, as conforming to the specifications.

1.2.2.2 Steel-bar stock

Hot-rolled steel bars up to 305 mm (12 in.) in diameter may be used when approved for the items indicated in Part 5A-2-1 /Table 2.1.1.

1.2.2.3 Material for Engines of 375 kW (500 hp) Rated Power or Less

Material for engines having a rated power of 375 kW (500 hp) or less, including shafting, couplings, and coupling bolts will be accepted on the basis of the material manufacturer's certified test reports and a satisfactory surface inspection and hardness check witnessed by the Surveyor. Coupling bolts manufactured to a recognized bolt standard will not require material testing

1.2.2.4 Engines certified under quality assurance approval

For diesel engines certified under quality assurance assessment as indicated in [1.9.2(b)] of this section, material tests required by Sect [1.2.1] above need not be witnessed by the Surveyor; instead these are to be conducted by the engine manufacturer whose certified test reports may be accepted.

1.3 Design

1.3.1 Bedplate / Crankcase

The construction of bedplate or crankcase is to be rigid, oil tight, and it shall be provided with adequate number of bolts to secure the same to the vessel's structure. Also refer 1.6.3] of this section for seating of diesel engines.

1.3.2 Crankcase Doors

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

[1.4.1]. Crankcase doors are to be fastened and secured so that they will not be readily displaced by a crankcase explosion

1.3.3 Cylinders and covers, liners and pistons

Liners, cylinders, cylinder covers & pistons, which are subjected to high temperatures or pressures, are to be made of materials that are suitable for stresses and temperatures to which they are exposed.

1.3.4 Securing of nuts

All nuts of main bearings, connecting-rod bolts and all other moving parts are to be secured by split pins or other effective locking means.

1.3.5 Crankshafts

1.3.5.1 General

- (a) Scope: The Rules for the design of crankshafts are to be applied to diesel engines for propulsion and auxiliary purposes, where the design of engines is to be such that they 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 and fatigue testing is conducted, or when direct stress (strain) measurements are taken, the relevant documents with calculations/analysis and reliability data are to be submitted to validate the design.

- (b) Application: These Rules are applicable to only solid-forged and semi-built crankshafts of forged or cast steel, with one crank throw between main bearings.

- (c) Principles of calculation:

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

- Outlets of crankpin oil bores;
- Fillet transitions between the crankpin and web and between the journal and web.

The outlets of main journal oil bores are to be formed in the same way as the crankpin oil bores, otherwise separate documentation of fatigue safety may be required, when journal diameter is equal to or larger than the crankpin diameter.

Calculation of crankshaft strength determines the nominal alternating bending Refer Sect [1.3.5.2] and nominal alternating torsional stresses .Refer[1.3.5.3] which, multiplied by the appropriate stress concentration factors .Refer Sect [1.3.5.4] results in an equivalent alternating stress (uniaxial stress) .Refer Sect [1.3.5.6]. Then, the result is compared with the fatigue strength of the selected crankshaft material .Refer Sect[1.3.5.7]which will show whether or not the crankshaft concerned is suitably dimensioned .Refer Sect [1.3.5.8].

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

- a) Assumptions:

The calculations are based on a quasi-static model where the steady alternating loads are combined in a statically determined system. The

statically determined system is composed of a single crank throw supported in the center 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 , as per Figure 2.1.1 and Figure 2.1.2).

The bending moments M_{BR} and M_{BT} are calculated in the relevant section based on triangular bending moment diagrams due to the radial component F_R and tangential component F_T of the connecting-rod force, respectively (Refer: Figure 2.1.1).

For crank throws 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 (Refer Figure 2.1.2).

i) Bending moments and radial forces acting in web

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

The alternating compressive and bending stresses due to radial forces and bending moments are to be related to the cross-section of the crank web. This reference section comes from the web thickness W and the web width B (Refer Figure.2.1.3). The mean stresses are to be neglected.

ii) Bending acting in outlet of crankpin oil bore

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

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

Mean bending stresses are to be neglected.

b) Calculation of nominal alternating bending and compressive stresses in web:

The tangential and radial forces due to inertia loads and gas that acts upon the crankpin at each connecting-rod position will be calculated over 1 working cycle.

Taking into account the forces calculated over 1 working cycle, the distance from the main bearing midpoint, the time curve of the bending moments M_{BRF} , M_{BRO} , M_{BTO} and radial forces Q_{RF} , as defined in section [1.3.5.2]-(a)-(i) & (ii) will then be calculated.

In V-type engines, the bending moments that are gradually calculated from the inertia forces and gas of 2 cylinders that acts on one crank throw are superposed as per phase. Different designs (articulated-type connecting-rod or adjacent connecting rods and forked connecting-rod) are taken into account.

Where cranks of different geometrical configurations are there in 1 crankshaft, the calculation is required to cover all variants of the crank.

Then, the decisive alternating values will be calculated as per the following formulae:

$$X_N = \frac{1}{2} [X_{max} + X_{min}]$$

Where,

X_N = alternating force, moment or stress.

X_{max} = maximum value within 1 working cycle.

X_{min} = maximum value within 1 working cycle.

(i) *Nominal alternating bending and compressive stresses in web cross section.*

Using the following formulae, calculation of the nominal alternating bending and compressive stresses is done.

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

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

Where,

σ_{BFN} = nominal alternating bending stress related to the web, in N/mm².

M_{BRFN} = Alternating bending moment related to the center of the web, in N-m (Refer Figure 2.1.1 and Figure 2.1.2).

$$= \frac{1}{2} [M_{BFN \max} - M_{BFN \min}]$$

W_{eqw} = Section modulus related to cross-section of web, in mm³.

$$= \frac{B W^2}{6}$$

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

= 0.8 for 2-stroke engines

= 1.0 for 4-stroke engines

σ_{QFN} = Section nominal alternating compressive stress due to radial force related to the web, in N/mm².

Q_{RFN} = Alternating radial force related to the web, in N (Refer Figure 2.1.1 and Figure 2.1.2).

$$= \frac{1}{2} [Q_{RF \max} - Q_{RF \min}]$$

F_{wb} = Area related to cross-section of web, in mm².

$$= B \times W$$

(ii) *Nominal alternating bending stress in outlet of crankpin oil bore*

The calculation of nominal alternating bending stress is as follows:

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

Where

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

M_{BON} = Alternating bending moment calculated at the outlet of crankpin oil bore, in N-m.

$$= \frac{1}{2} [M_{BO \max} - M_{BO \min}]$$

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

ψ = Angular position, in degrees (Refer Figure 2.1.4)

W_e = Section modulus related to cross-section of axially bored crankpin, in mm^3 .

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

c) Calculation of alternating bending stresses in fillets:

The calculation of stresses is to be done for the crankpin fillet and the journal fillet.

(i) For the crankpin fillet :

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

Where,

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

α_B = stress concentration factor for bending in crankpin fillet (refer [1.3.5.4] of this section).

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

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

Where,

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

β_B = stress concentration factor for bending in journal fillet (refer [1.3.5.4] of this section).

β_Q = stress concentration factor for compression due to radial force in journal fillet (determined as per [1.3.5.4] of this section).

d) Calculation of alternating bending stresses in outlet of crankpin oil bore:

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

Where,

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

γ_B = stress concentration factor for bending in crankpin oil bore (determined as per Sect [1.3.5.4] of this section).

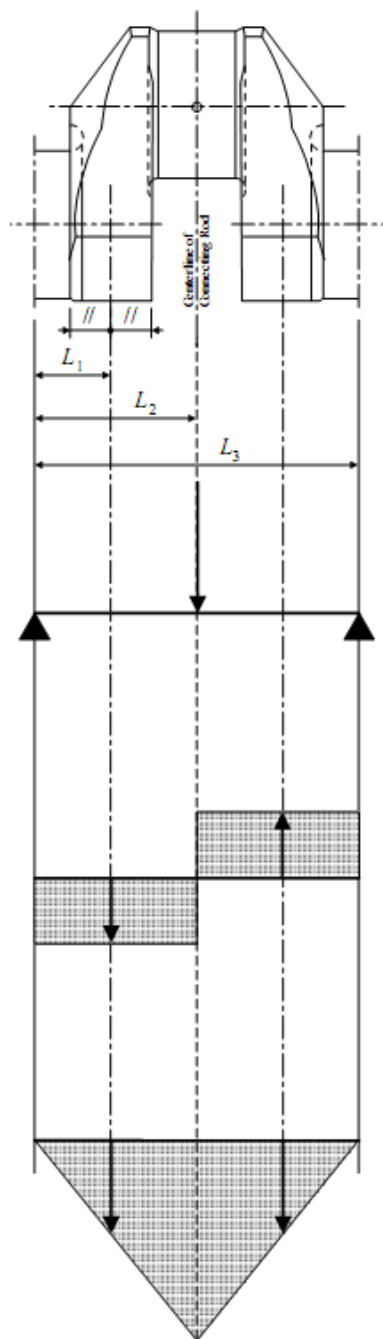


Figure 2.1.1: Crank Throw
for inline engine

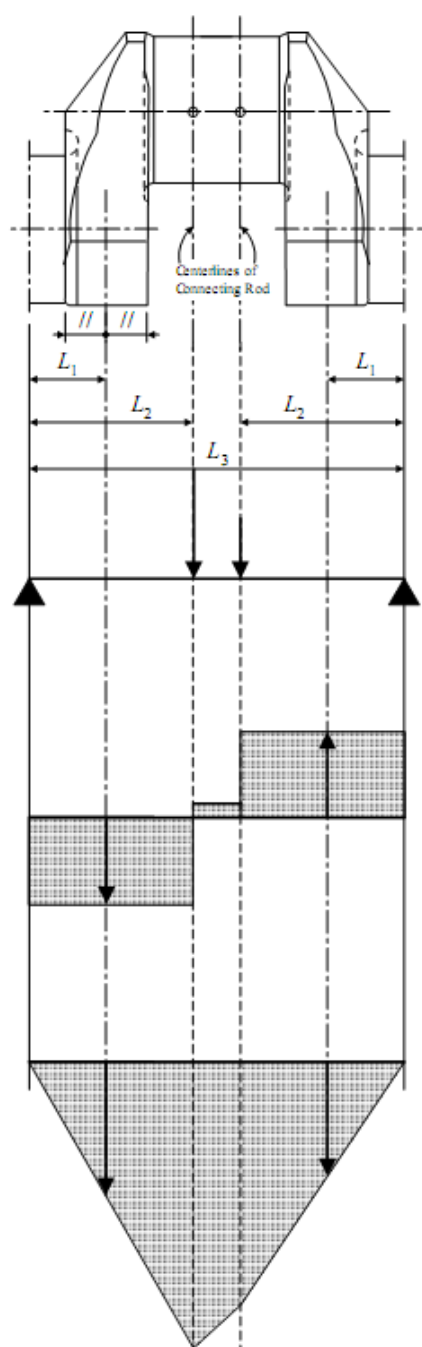


Figure 2.1.2: Crank Throw for Vee Engine with
2 adjacent connecting-rods

L_1 = Distance between main journal centerline and crank web center.

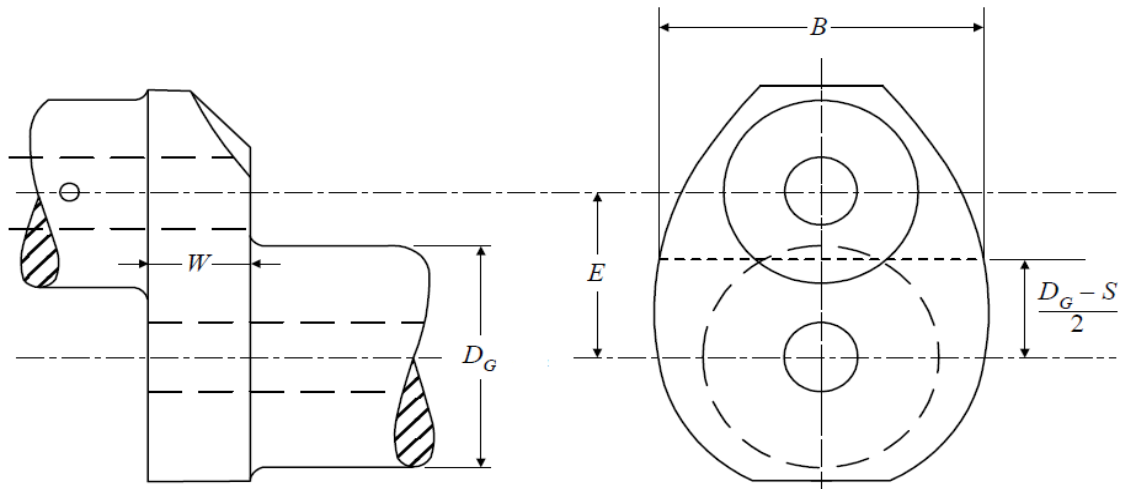
(also refer to Figure 2.1.3 for crankshaft without overlap)

L_2 = Distance between main journal centerline and connecting-rod center.

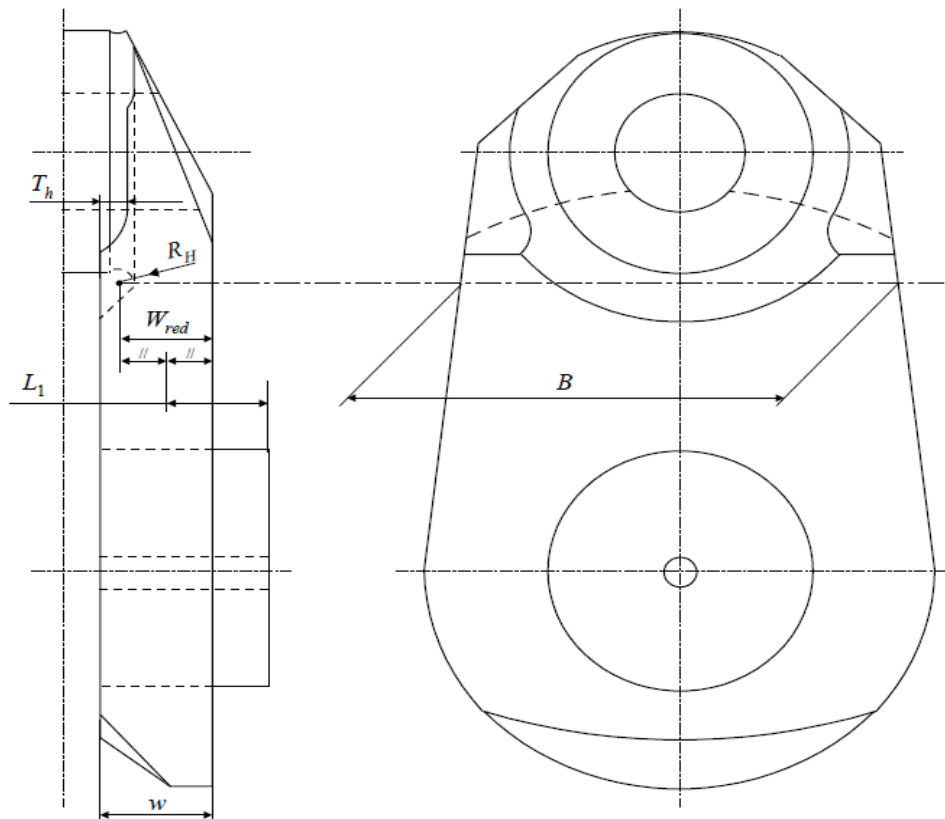
L_3 = Distance between two adjacent main journal centerlines

FIGURE: 2.1.3

REFERENCE AREA OF CRANK WEB SECTION

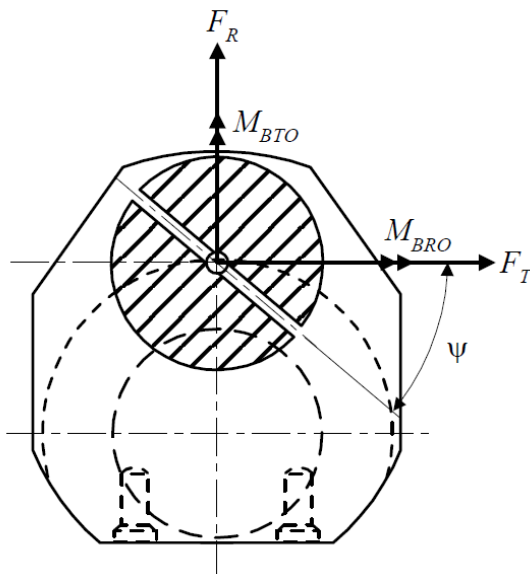


(a) Overlapped crankshaft



(b) Crankshaft without overlap

Figure:2.1.4, Crankpin Section Through the Oil bore



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

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

1.3.5.3 Calculation of alternating torsional stresses

a) General:

The details of the alternating torsional stresses that are used in determining the equivalent alternating stress in the crankshaft are to be furnished by the engine manufacturer, and verified with help of appropriate calculations, or crankshaft fatigue testing.

Where applicable, the manufacturer may apply the information contained in (b) below for the calculation for nominal alternating torsional stresses. The supporting documentation is to be submitted for review in all cases.

b) Calculation of nominal alternating torsional stresses:

The minimum and maximum torque is to be established for every mass point of the complete dynamic system. Similarly, it has to be established for the entire speed range using a harmonic synthesis of the forced vibrations from the 1st order up to and including the 15th order for 2-stroke cycle engines; and from the 0.5th order up to and including the 12th order for 4-stroke cycle engines.

Allowance must be made for the damping that is there in the system and for harsh conditions (misfiring [*] in one of the cylinders). The speed step calculation is to be so selected that resonance in the operational speed range of the engine gets detected.

***Note:** Misfiring is referred to as cylinder condition wherein no combustion but only a compression cycle occurs.

Where barred speed ranges are absolutely vital, they are to be so arranged that operability, despite their existence, is satisfactory. For normal firing

conditions, barred speed ranges above a speed ratio of $\lambda \geq 0.8$ are not to be there. The values so derived from such calculation are to be submitted for review.

The nominal alternating torsional stress in every mass point, which is vital for the assessment, results from the equation given below:

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

$$M_{TN} = \frac{1}{2} [M_{T \max} - M_{T \min}]$$

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

Where,

τ_N = Nominal alternating torsional stress referred to crankpin or journal, in N/mm².

M_{TN} = Maximum alternating torque, in N-m.

W_P = Polar section modulus related to cross-section of axially bored crankpin or bored journal, in mm³

$M_{T \max}$ = Minimum value of the torque, in N-m.

$M_{T \min}$ = Maximum value of the torque, in N-m.

For the crankshaft assessment, nominal alternating torsional stress i.e. under consideration in further calculations is the highest calculated value, as per the method given above, that occurs at the most torsionally loaded mass point of the crankshaft system.

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

Approval of the crankshaft will be based on the installation that has the largest nominal alternating torsional stress (but not more than the maximum figure specified by the engine manufacturer).

Thus, it is to be ensured by calculation that this approved nominal alternating torsional stress is not exceeded. For review, this calculation is to be submitted.

c) *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.

(i) For the crankpin fillet:

$$\tau_H = \alpha_T \tau_N$$

Where,

α_T = Stress concentration factor for torsion in crankpin fillet (determined as per Sect [1.3.5.4] below).

τ_N = Nominal alternating torsional stress related to crankpin diameter, in N/mm².

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

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

$$\tau_G = \beta_T \tau_N$$

Where

τ_G = alternating torsional stress in journal fillet, in N/mm²

β_T = stress concentration factor for torsion in journal fillet (determination as per Sect [1.3.5.4] below)

τ_N = nominal alternating torsional stress related to journal diameter, in N/mm²

- (iii) For the outlet of crankpin oil bore:

$$\tau_{TO} = \gamma_T \tau_N$$

Where,

τ_{TO} = Alternating stress in outlet of crankpin oil bore due to torsion, in N/mm².

γ_T = Stress concentration factor for torsion in outlet of crankpin oil bore (determined as per Sect [1.3.5.4] below).

τ_N = Nominal alternating torsional stress related to crankpin diameter, in N/mm².

1.3.5.4 Evaluation of stress concentration factors

- (a) General:

The stress concentration factors are evaluated using the equations in (b), (c) and (d) below which are applicable to the fillets and crankpin oil bore of solid forged web-type crankshafts and to the crankpin fillets of semi-built crankshafts only. The stress concentration factor equations concerning the oil bore are only applicable to a radially drilled oil hole. Where crankshaft geometry is outside the boundaries of the analytical Stress Concentration Factors (SCF) calculation method detailed in Sect [1.7] of this section may be undertaken. All crank dimensions essential for the calculation of stress concentration factors are shown in Figure 2.1.5.

The stress concentration factors for bending (α_B , β_B) are 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.

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

The stress concentration factors for torsion (α_T , β_T) are defined as the ratio of the maximum 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.

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

When reliable measurements and/or calculations are available, that allows direct assessment of stress concentration factors, relevant documents and their analysis method is to be submitted to establish their equivalence with the Rules.

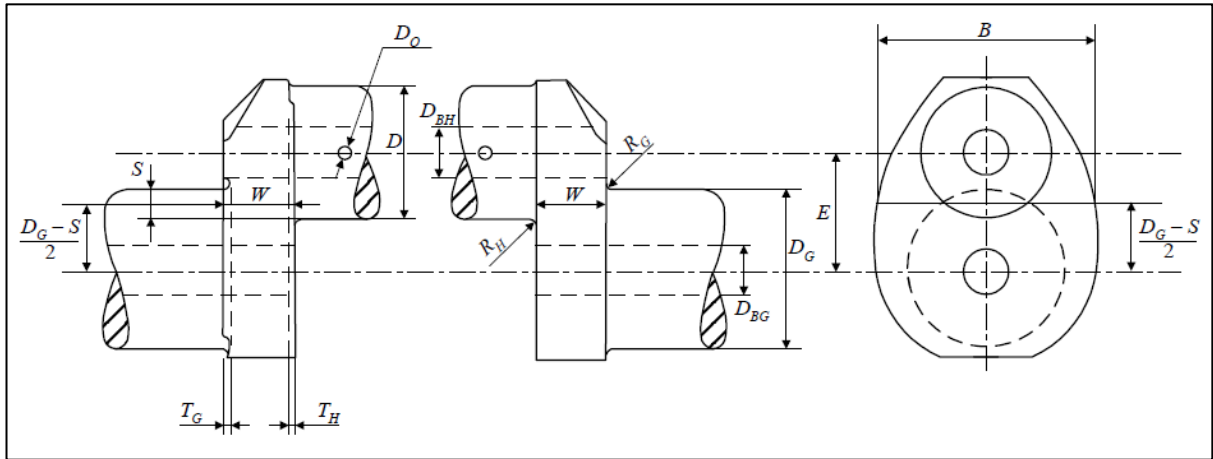


Figure 2.1.5: Crankpin dimensions

(i) Actual Dimensions

D = Crankpin diameter, in mm;

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

D_O = Diameter of oil bore in crankpin, in mm;

R_H = Fillet radius of crankpin, in mm;

T_H = Recess of crankpin fillet, in mm;

D_G = Journal diameter, in mm;

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

R_G = Fillet radius of journal, in mm;

T_G = Recess of journal fillet, in mm;

E = Pin eccentricity, in mm;

S = Pin overlap, in mm;

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

W^* = Web thickness, in mm

B^* = Width, in mm,

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

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

$$W_{red} = W - (T_H - R_H) \text{ (Refer Figure: 2.1.3).}$$

- Web width B must be taken in way of crankpin fillet radius center according to Figure 2.1.3.

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

Crankpin fillet
Journal fillet

$$r = \frac{R_H}{D}$$

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

$$s = \frac{S}{D}$$

$$w = \frac{W}{D} \text{ Crankshafts with overlap}$$

$$= \frac{W_{red}}{D} \text{ Crankshafts without overlap}$$

$$b = \frac{B}{D}$$

$$d_o = \frac{D_o}{D}$$

$$d_G = \frac{D_{BG}}{D}$$

$$d_H = \frac{D_{BH}}{D}$$

$$t_H = \frac{T_H}{D}$$

$$t_G = \frac{T_G}{D}$$

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 $f(\text{recess}) < 1$ then the factor $f(\text{recess})$ is not to be considered ($f(\text{recess}) = 1$).
- If $s < -0.5$ then $f(s, w)$ and $f(r, s)$ are to be evaluated replacing actual value of s by -0.5 .

(b) Crankpin fillet:

(i) **The stress concentration factor for bending (α_B) is:**

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

Where

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

$$f(w) = 2.179 w^{0.7171}$$

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

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

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

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

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

(ii) **The stress concentration factor for torsion (α_T) is :**

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

Where

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

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

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

(c) Journal fillet (not applicable to semi-built crankshaft).

(i) **The stress concentration factor for bending (β_B) is:**

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

Where

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

$$f_B(w) = 2.2422 w^{0.7548}$$

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

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

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

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

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

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

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

Where

$$f_Q(s) = 0.4368 + 2.163 (1-s) - 1.5212 (1-s)^2$$

$$f_Q(w) = \frac{w}{0.0637 + 0.9369 w}$$

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

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

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

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

(iii) **The stress concentration factor for torsion (β_T) is:**

$$\beta_T = \alpha_T \quad \text{if the diameters and fillet radii of crankpin and journal are the same.}$$

$$\beta_T = 0.8 \times f(r, s) \times f(b) \times f(w) \quad \text{if crankpin and journal diameters and/or radii are of different sizes.}$$

where $f(r, s)$, $f(b)$ and $f(w)$ are to be determined in accordance with Sect [1.3.5.4(b)] (Refer calculation of α_T), however, the radius of the journal fillet is to be related to the journal diameter:

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

- (d) Outlet of crankpin oil bore.
- (i) **The stress concentration factor for bending (γ_B) is:**

$$\gamma_B = 3 - 5.88 d_o + 34.6 d_o^2$$
- (ii) **The stress concentration factor for torsion (γ_T) is:**

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

1.3.5.5 Additional bending stresses

In addition to the alternating bending stresses in fillets .Refer Sect [1.3.5.2]

(c) above further bending stresses due to misalignment and bedplate deformation as well as due to axial and bending vibrations are to be taken into account by the application of σ_{add} which is given by the table below:

Type of Engine	σ_{add} [Nmm ²]
Crosshead Engines	$\pm 30(^*)$
Trunk Piston Engines	± 10
Notes: The additional alternating stress of ± 30 N/mm ² is composed of two components : 1. An additional alternating stress of ± 20 N/mm ² resulting from axial vibration. 2. An additional alternating stress of ± 10 N/mm ² resulting from misalignment / bed plate deformation.	

For assessment purposes, it is recommended that a value of ± 20 N/mm² shall be used for the axial vibration component 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.

1.3.5.6 Calculation of equivalent alternating stress

(a) 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 not time phased and the corresponding peak values occur at the same location.

As a result, calculation of the equivalent alternating stress is to be done 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 the principal stress resulting from combination of these two stress fields with the assumption that bending and torsion are time phased.

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.

(b) Equivalent alternating stress:

In accordance with the following equations, the equivalent alternating stress is to be calculated.

- For the crankpin fillet:

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

For the journal fillet: $\sigma_v = \pm \sqrt{(\sigma_{BG} + \sigma_{add})^2 + 3 \tau_G^2}$

- For the outlet of crankpin oil bore:

$$\sigma_v = \pm \frac{1}{3} \sigma_{BO} \left[1 + 2 \sqrt{1 + \frac{9}{4} \left(\frac{\tau_{TO}}{\sigma_{BO}} \right)^2} \right] \text{ Where } \sigma_v = \text{Equivalent Alternating Stress, in N/mm}^2, \text{ for other parameters referred to in Sect [1.3.5.2(c)], [1.3.5.3(c)] and [1.3.5.5] of this section.}$$

1.3.5.7 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. With the help of the following equation, the fatigue strength may be evaluated.

a) Related to the crankpin diameter:

$$\sigma_v = \pm K (0.42 \sigma_B + 39.3) \left[0.264 + 1.073 D^{-0.2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \sqrt{\frac{1}{R_X}} \right] \text{ Where}$$

$R_X = R_H$ in the fillet area

$= \frac{D_0}{2}$ in the oil bore area.

b) Related to the journal diameter:

$$\sigma_{DW} = \pm K (0.42 \sigma_B + 39.3) \left[0.264 + 1.073 D_G^{-0.2} + \frac{785 - \sigma_B}{4900} + \frac{196}{\sigma_B} \sqrt{\frac{1}{R_G}} \right], \text{ Where}$$

σ_{DW} = allowable fatigue strength of crankshaft, in N/mm²

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

= 1.00 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 cold rolling

process approved by INTLREG.

σ_B = minimum tensile strength of crankshaft material, in N/mm²

For other parameters refer to Sect [1.3.5.4(c)] of this section,

When a surface treatment process is applied, it must be specially approved by INTLREG.

These equations 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.

With the help of an experiment based either on full size crank throw (or crankshaft) or on specimens taken from a full size crank throw, as an alternative, the fatigue strength of the crankshaft can be determined.

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

1.3.5.8 Acceptability criteria

By comparing equivalent alternating stress and the fatigue strength, the sufficient dimensioning of a crank shaft is confirmed. On the basis of equation mentioned below, this comparison has to be carried out for the crank pin fillet, the journal fillet, the outlet of crankpin oil bore: $Q = \frac{\sigma_{DW}}{\sigma_v}$ Where, Q = acceptability factor

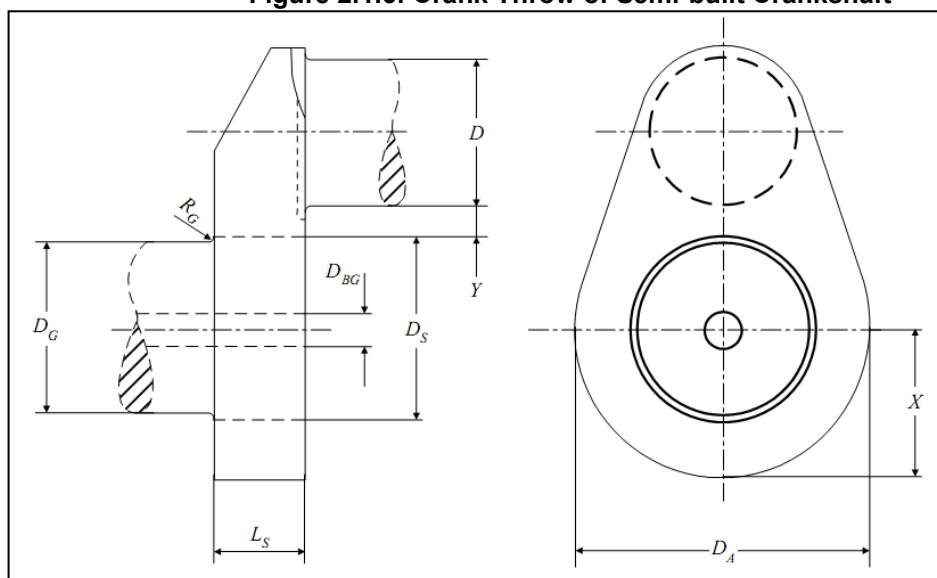
Adequate dimensioning of the crankshaft is ensured if the smallest of all acceptability factors satisfies the criteria: $Q \geq 1.15$

1.3.5.9 Calculation of shrink-fits of semi-built crankshaft

a) General

All crank dimensions necessary for the calculation of the shrink-fit is shown in Figure 2.1.6.

Figure 2.1.6: Crank Throw of Semi-built Crankshaft



Where

DA = Outside diameter of web, in mm, or twice the minimum distance x between center-line of journals and outer contour of web, whichever is less.

DS = Shrink diameter, in mm

DG = Journal diameter, in mm

DBG = Diameter of axial bore in journal, in mm

LS = Length of shrink-fit, in mm

RG = Fillet radius of journal, in mm.

Y = Distance between the adjacent generating lines of journal and pin, in mm, $Y \geq 0.05 \cdot DS$

Where, $Y < 0.1 \cdot DS$, 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.

With regard to the radius of the transition from the journal to the shrink diameter, the following is to be complied with:

$RG \geq 0.015 \cdot DG$ and

$RG \geq 0.5 \cdot (DS - DG)$, where the greater value is to be considered.

The actual oversize Z of the shrink-fit must be within the limits Zmin and Zmax calculated in accordance with Sections [1.3.5.9(c)] and [1.3.5.9(d)].

If the condition in (b) below cannot be fulfilled, the calculation methods of Zmin and Zmax in Sect [1.3.5.9(c)] and [1.3.5.9(d)] are not applicable due to multi-zone-plasticity problems.

In such case, Zmin and Zmax have to be established based on FEM calculations.

b) Maximum permissible hole in the journal pin

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

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

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 value of the maximum torque $MT_{\max}$, N-m, in accordance with section [1.3.5.3] (b).

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, in N/mm²

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

- c) Necessary minimum oversize of shrink-fit. The necessary minimum oversize is determined by the greater value calculated according to:

$$Z_{min} \geq \frac{\sigma_{sw} D_S}{E_m}$$

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

Where

Z_{min} = minimum oversize, in mm.

E_m = Young's modulus, in N/mm²

Σ_{sw} = minimum yield strength of material for crank web, in N/mm²

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

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

- d) Maximum permissible oversize of shrink-fit. In accordance with following equation, the maximum permissible oversize shall be calculated:

$$Z_{max} \leq D_S \left(\frac{\sigma_{sw}}{E_m} + \frac{1.8}{1000} \right)$$

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

1.3.6 Shaft couplings and clutches

The design and construction of fitted bolt and non-fitted bolt couplings, flexible couplings and clutches is to be as per the provisions of Ch-4, Sec-3, [3.10].

1.4 Engine Accessories

1.4.1. Explosion relief valves

1.4.1.1. Application

Approved type explosion relief valves are to be installed on enclosed crankcases of all engines with a cylinder bore of 200 mm (8 in.) or above or crankcase gross volume of 0.6 m³ (21 ft³) or above.

1.4.1.2. Valve construction and sizing:

The requirements applicable to these are as follows:

- The free area of each explosion relief valve is not to be less than 45 cm², and the total free area of all relief valves is to be not less than 115 cm² (7 in² for each cubic meter (1 in² for each 2 ft³) of crankcase gross volume. Within the crankcase, the total volume of the stationary parts may be discounted in estimating the crankcase gross volume (rotating and reciprocating components are to be included in the gross volume).
- Lightweight spring-loaded valve discs or other quick and self-closing devices are to be provided in crankcase explosion relief valves to relieve pressure in the event of an internal explosion and the inrush of air thereafter.
- Ductile materials, that are capable of bearing the shock of contact with stoppers in open position, shall be used to manufacture the valve discs in crankcase explosion relief valves.

- d) Designing and construction of crankcase explosion relief valves are to be done so that at a pressure not more than 0.2 bar (0.2 kgf /cm², 2.85 psi) they open quickly and remain fully open.
- e) Crankcase explosion relief valves are required to have a flame arrester that permits flow for relief of pressure and prevents passage of flame after an explosion.
- f) Crankcase explosion relief valves are to be type tested in that configuration which represents the installation arrangements to be used on an engine as specified in [1.8.9] of this section.
- g) Where crankcase relief valves have the suitable arrangements for shielding emissions after an explosion, it is to be type tested to establish that the shielding does not adversely affect its operational effectiveness.
- h) Crankcase explosion relief valves are to be provided with a copy of the manufacturer's installation and maintenance manual that is relevant to the size and type of valve being supplied for installation on a particular engine. Following information is to be contained in the manual:
 - Valve description with details of design and functional limits.
 - Copy of type test certification.
 - Installation instructions.
 - Maintenance in service instructions to include testing and renewal of any sealing arrangements.
 - Actions to be taken after a crankcase explosion.
- i) Copy of the installation and maintenance manual is to be made available on board.
- j) The detailed plan of arrangements of the crankcase explosion relief valves are to be submitted for approval as specified in , Ch-2 sec-1,[1.1.5].
- k) Valves are to be provided with appropriate markings that carries the information given below:
 - Manufacturer's name and address
 - Size and designation
 - Manufacturing month/year
 - Approved installation orientation

1.4.1.3. Location of valves

Engines having a bore of 200 mm (8 in.) and above, but not exceeding 250 mm (10 in.), are to have at least one valve near each end. However, for engines with more than 8 crank throws, near the middle of the engine an additional valve is required to be fitted.

Engines having a bore exceeding 250 mm (10 in.), but not exceeding 300 mm (11.8 in.), are to have at least one valve in way of each alternate crank throw, with a minimum of two valves

Engines having a bore exceeding 300 mm (11.8 in.) are to have at least one valve in way of each main crank throw.

1.4.1.4. Other compartments of crankcase

Additional relief valves are to be fitted on separate spaces of the crankcase such as gear or chain cases for camshaft or similar drives when the gross volume of such spaces is 0.6 m³(21 ft³) and above.

1.4.1.5. Scavenge spaces

Fitting of explosion relief valves are to be done in scavenge spaces which are in open connection to the cylinders.

1.4.2. Protection against crankcase explosions

1.4.2.1. General

As a protection against crankcase explosions all engines rated at 2250 kW (3000 hp) and above or having cylinders of more than 300 mm (11.8 in.) bore are to be provided with one of the following arrangements.

- Oil mist detection arrangements .Refer Sect [1.4.2.2], or
- Bearing temperature monitoring arrangements .Refer Sect [1.4.2.3] or
- Alternative arrangements .Refer Sect [1.4.2.4].

For low speed diesel engines, an alarm and an automatic slowdown of the engine are to be initiated by the above protection arrangements.

For medium and high speed diesel engines, they are to initiate an alarm and an automatic shutdown of the engine.

For automatic shutdown or automatic slowdown for vessels with the **UM** notation, Refer item B7 of Part 6, Table-8.2.2, item B4 of Part 6, Table-8.2.3, item G4 of Part 6, Table-8.2.7 and item A3 of Part 6, Table-8.2.10.

For emergency diesel engines automatic shutdown is not permitted; Refer Part 6 Ch-1, Section [2.9].

1.4.2.2. Oil mist detection arrangements

a) General

Where crankcase oil mist detection arrangements are fitted to engines, they are to be of an approved type and tested as specified in [1.9] of this section.

b) Installation

The oil mist detection system and arrangements are to be installed in accordance with the engine designer's and oil mist manufacturer's instructions / recommendations. The following particulars are to be included in the instructions

- (i) Schematic layout of engine oil mist detection and alarm system showing location of engine crankcase sample points and piping or cable arrangements together with pipe dimensions to detector.
- (ii) Evidence of study which justifies 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. All areas that have open communication with the crankcase are to be adequately monitored.
- (iii) The manufacturer's maintenance and test manual.

- (iv) Information relating to type or in-service testing of the engine with engine protection system test arrangements having approved types of oil mist detection equipment.

Copy of oil mist detection equipment maintenance & test manual required is to be provided onboard.

c) Arrangements

- (i) Oil mist detection and alarm information is to be capable of being read from a safe location away from the engine
- (ii) Each engine is to be provided with its own independent oil mist detection arrangement and a dedicated alarm.
- (iii) Oil mist detection and alarm systems are to be capable of being tested on the test bed and on board under engine at stand still and engine running at normal operating conditions in accordance with manufacturer's test procedure
- (iv) Alarms, automatic slowdowns and automatic shutdowns for the oil mist detection system are to be in accordance with Sect [1.4.2.1] above, Part 6 Chapter 8, Table 8.2.2, Table 8.2.3, Table 8.2.7 and Table 8.2.10, as applicable. The system arrangements are to comply with Part 6 Chapter 8 Sec-1/[1.3] & Sec 2.
- (v) The oil mist detection arrangements are to provide an alarm indication in the event of a foreseeable functional failure in the equipment and installation arrangements.
- (vi) The oil mist detection system is to provide an indication that any lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication.
- (vii) Where oil mist detection equipment includes the use of programmable electronic systems, the arrangements are to be in accordance with Part 6 Chapter 8 Section 2.
- (viii) Plans showing details and arrangements of oil mist detection and alarm arrangements are to be submitted for approval in accordance with Table 2.1.3.
- (ix) The equipment, together with detectors, is to be tested in the presence of the Surveyor when installed on the test bed and onboard to demonstrate that the detection and alarm system functionally operates.
- (x) Where sequential oil mist detection arrangements are provided the sampling frequency and time is to be as short as reasonably practicable

1.4.2.3. Bearing Temperature Monitoring Arrangements

Application of the following requirements is done where bearing temperature monitoring arrangements are provided:

(a) Monitoring of Bearings:

All bearings (main, crank, crosshead, thrust, etc.) are to be monitored for abnormal temperature, that have open communication with the crankcase.

(b) Slow Speed Diesel Engines.

For slow speed diesel engines, the lubricating oil temperature of each of the outlet of each main, crank, crosshead and thrust bearing may be monitored in lieu of directly monitoring the temperature of these bearings.

(c.) Alarms, automatic slowdowns and automatic shutdowns for bearing temperature monitoring arrangements are to be in accordance with Sect [1.4.2.1] above, Part-6, Chapter-8, Table-8.2.2, Table 8.2.3, Table 8.2.7 and Table 8.2.10, as applicable. The system arrangements are to comply with Part 6, Chapter 8, Sec-2.

1.4.2.4. Alternative arrangements

Where alternative arrangements are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase details are to be submitted for review, in order to determine the effectiveness of the arrangements for each specific engine design. It may be necessary to provide combinations of means, such as: oil splash temperature monitoring, crankcase pressure monitoring, recirculation arrangements so as to prevent the buildup of a potentially explosive condition. The details are to include, but not be limited to the following:

- Engine particulars – Type, Power, Speed, Stroke, Bore and Crankcase volume.
- Details of arrangements to prevent the build-up of potentially explosive conditions within the crankcase.
- Evidence to demonstrate that the arrangements are effective in preventing the build-up of potentially explosive conditions together with details of in-service experience
- Operating instructions and the maintenance and test instructions.

Where it is proposed to use the introduction of inert gas into the crankcase to minimize a potential crankcase explosion, details of the arrangements are to be submitted for consideration.

1.4.3. Governors and Over speed Protective Device

1.4.3.1. Governors

All diesel engines, except those driving electric generators (Refer: [1.4.4]), are to be fitted with governors which will prevent the engines from exceeding the rated speed by more than 15%.

1.4.3.2. Over speed Protective Devices

In addition to this speed governor each main engine having a rated power of 220 kW and above, and which can be declutched or which drives a controllable pitch propeller, is to be fitted with a separate over speed protective device so adjusted that the engine speed cannot exceed the rated speed by more than 20%. Equivalent arrangements may be accepted upon special consideration. The over speed protective device, including its driving mechanism, has to be independent from the required governor.

1.4.3.3. Electronic governors

Electronic speed governors fitted to main propulsion diesel engines, and which form part of a remote propulsion control system, are to comply with the following:

- i) An automatically available back up power supply is to be provided so as not to interrupt the power supply to these systems if lack of power to the governor control and actuator systems may cause major and sudden changes in the preset speed and/or direction of thrust of the propeller. At the main and remote (if provided) propulsion control stations, an alarm for the failure of the main power supply is required to be provided.
- ii) Local control of the engines is to be possible. At the local control position, means are to be provided for this purpose to disconnect the remote control signal. If this will also disconnect the speed governing functions required by Refer Sect [1.4.3.1] above, an additional separate speed governor is to be provided for such local mode of control.
- iii) In accordance with Part-6, Ch-8, Sec-7, [7.2.5.1], electronic speed governors and their electrical actuators are to be subjected to prototype environmental tests. Additionally in the presence of the Surveyor, the tests required by Part-6, Ch-8, Table-8.7.4 are to be carried out as prototype testing. However, no production unit certification in accordance with Part 6, Ch-8, Sec-7, [7.2.5.2] is required.

1.4.4. Speed Governors and over speed Protection for Generator Prime Movers

1.4.4.1 Speed Governing

Diesel engines driving propulsion, auxiliary or emergency electric generators are to be fitted with an operating governor which is capable of automatically maintaining the speed within the following limits:

- (a) The transient frequency variations in the electrical network when running at the indicated loads below are to be within $\pm 10\%$ of the rated frequency with a recovery time within $\pm 1\%$ of the final steady state condition in not more than 5 seconds when:
 - i) Running at full load (equal to rated output) of the generator and the maximum electrical step load is suddenly thrown off;

In the case when a step load equivalent to the rated output of a generator is thrown off, a transient frequency variation in excess of 10% of the rated frequency may be acceptable, provided the over speed protective device fitted in addition to the governor, as required by Sect [1.4.4.3] below, is not activated
 - ii) Running at no load and 50% of the full load of the generator is suddenly thrown on, followed by the remaining 50% after an interval sufficient to restore the frequency to steady state
- (b) Where the electrical power system is fitted with a power management system and sequential starting arrangements, the application of loads in multiple steps of less than 50% of rated load in (a) ii) above may be permitted, provided it is in accordance with Figure 2.1.7. The details of the power management system and sequential starting arrangements are to be submitted and its satisfactory operation is to be demonstrated to the Surveyor.
- c.) For diesel engines driving emergency generators, the requirements of (a)(i) and are to be met even when

- (i) Their total consumer load is applied suddenly, or
- (ii) 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 so that the declared maximum step loading is not exceeded
 - The compliance of time delays & loading sequence with the above is to be demonstrated at ship's trials.
- (d) The permanent frequency variation is to be within $\pm 5\%$ of the rated frequency at any load between no load and the full load.

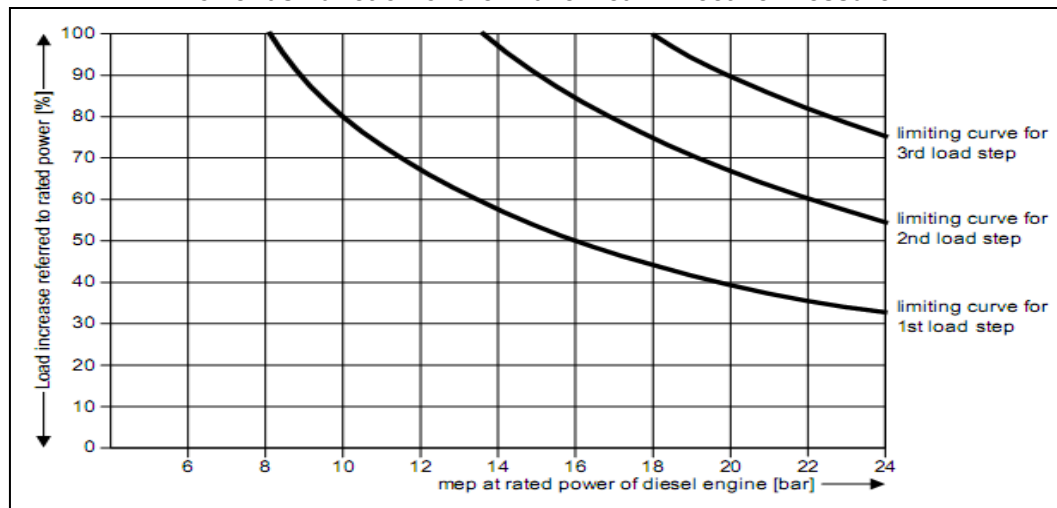
1.4.4.2 Generators in parallel

For diesel engines driving AC generators that operate in parallel, the governor's characteristics are to be such that in the range between 20% and 100% of the combined rated load of all generators, the load on any individual generator will not differ from its proportionate share of the total combined load by more than 15% of the rated power of the largest generator or 25% of the individual generator, whichever is less. In order to permit a load adjustment within the limits of 5% of the rated load at normal frequency, provisions are to be made to adjust the governors sufficiently fine.

1.4.4.3 Over speed protective device

Additionally to the governor, fitting of each engine driving an electric generator and having a rated power of 220 kW (295 hp) and over is to be done with a separate over speed device which is so adjusted that the speed cannot exceed the maximum rated speed by more than 15%. Provision is to be made for hand tripping.

FIGURE.2.1.7 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



1.4.5. Cylinder overpressure monitoring

For diesel engines having a bore exceeding 230 mm (9 in.), fitting of each cylinder is to be done with a means of indicating a predetermined overpressure. This may be a relief valve, a sentinel valve, audible and visual alarms, or equivalent. The device is to be set at a pressure to be determined by the engine manufacturer.

1.4.6. Scavenging Blowers

Electrically driven auxiliary scavenging blowers that are only used for starting and operation at lower speeds of an engine may be accepted based on the following:

- i) At least two (2) independently driven scavenger blowers are provided,
- ii) Each blower is capable of supplying the required volume and pressure of scavenging air for the satisfactory operation of the engine over the range required. The required range is determined by the capabilities of the installed turbochargers
- iii) Auxiliary blowers may be shutdown at an appropriate engine speed to allow for quick passing through a barred speed range
- iv) Capacity and vibration tests are carried out on each unit by the manufacturer, and
- v) Documentation verifying compliance with items *ii)* through *iv)* above is to be made available to the surveyor upon request.

Electric motors driving auxiliary scavenging blowers are to comply with Part 6-4-1 and are to be considered as a primary essential service in accordance with Part 6-1-2/[2.2] a

1.4.7. Fire extinguishing system for scavenge manifold

For crosshead type engines, scavenge spaces in open connection to the cylinder are to be permanently connected to an approved fire extinguishing system entirely separate from the fire extinguishing system of the engine room. A steam smothering system is acceptable for this purpose. Provisions for the design and installation of fixed fire-extinguishing system as per SOLAS ,Ch II-2/10.4

1.4.8. Warning notices

1.4.8.1 Crankcase

In order to caution against opening hot crankcase, preferably on crankcase door on each side of the engine or on the engine control stand, suitable warning notices are to be fitted. The notices are to specify a period of time for cooling after shutdown, based upon the size of the engine, but not less than 10 minutes in any case, before opening the door. Such notice is also to warn against restarting an overheated engine until the cause of overheating has been remedied.

1.4.8.2 Barred speed ranges

The engine speed indicator is to be so marked where a barred speed range is specified in accordance with torsional vibration analysis. To the engine a warning notice is to be fitted and at all local and remote propulsion control stations to the effect that operation in the barred range is to occur only while passing through the range and that operation within the barred range is to be avoided. Refer Chapter 4, Sec-4, [4.3] for torsional vibration criteria.

1.4.9. Jacket drain and over-pressure protection

At the lowest point of all cooling medium jackets, a drain cock is to be fitted. In order to prevent the cooling medium jacket from being over pressurized, means are required to be provided. This will not be required if the cooling pump is of the centrifugal type, such that the no-flow pressure is no greater than the design pressure of the jacket.

1.4.10. Monitoring

Required monitoring for engine's fuel oil, lubricating oil, cooling water, starting air and exhaust gas systems are provided in the system requirements, Refer [1.5] below. For propulsion machinery spaces intended for centralized or unattended operation, engine and engine system monitoring and safety system functions are provided in Refer e.g., Part 6, Chapter 8, Table 8.2.2 and Table 8.2.3.

1.4.11. Engine turning gear

Where an engine turning gear arrangement is provided, an interlock is to be furnished so that the starting air system cannot be actuated when the turning gear is engaged.

1.5 Piping Systems for Diesel Engines

The requirements of piping systems, essential for operation of diesel engines intended for propulsion, maneuvering, electric power generation and vessel safety, are provided in Ch 8/Sect 4. These systems include

Fuel oil:	Chapter 8, Sec-4,[4.2]
Lubricating oil:	Chapter 8, Sec-4, [4.3]
Cooling water:	Chapter 8, Sec-4, [4.4]
Starting air:	Chapter 8, Sec-4, [4.5]
Electric/ Battery starting:	Part 6 Ch-3 sec-4, [4.12]
Crankcase ventilation:	Chapter 8, Sec-4, [4.7]
Exhaust gas:	Chapter 8, Sec-4, [4.6]
Hydraulic and pneumatic systems:	Chapter 8, Sec-6, [6.2] & [6.3]

1.6 Installation of Diesel Engines

1.6.1 Metal Chocks - Metal chocks to be used are to be made of forged, rolled or cast steel

1.6.2 Cast Resin Chocks

An approved type of cast resin chocks (Refer Part 1 Ch-1, Sec-11 for Type Approval) may be used, provided that the arrangements and installation procedures are as per the manufacturer's recommendations. The proposed installation arrangements, with installation parameters viz. engine deadweight, holding-down bolt tightening torque, etc., and calculations that shows manufacturer's specified pressure is not exceeded. These are to be submitted for review in each case.

1.6.3 Seating Arrangements for Diesel Engines

Diesel engines are to be adequately supported and mounted to the structure of the vessel by bolted connections with consideration given to all the static and dynamic forces enforced by the engine.

1.6.4 Resilient Mountings

Resilient mountings may be used within the limits as suggested by manufacturer's instructions and specifications for elasticity and durability of such elements under shipboard ambient conditions.

1.6.5 Hot Surfaces

Hot surfaces which might possibly come in contact with the crew during operation are to be appropriately guarded or insulated. Where their temperature is likely to exceed 220°C (428°F), and where any leakage, under pressure or otherwise, of fuel oil, lubricating oil or

other flammable liquid might come into contact with such surfaces, are to be appropriately insulated with non-combustible impervious materials. Insulation material which is not impervious to oil is to be encased in sheet metal or an equivalent impervious sheath.

1.7 Calculation of Stress Concentration Factors in the Web Fillet Radii of Crankshafts by Utilizing Finite Element Method

1.7.1. General

The objective of the analysis is to apply the Finite Element Method (FEM) in order to develop Stress Concentration Factors (SCF) as a substitute to the analytically calculated SCF's at the crankshaft fillets in [1.3.5.4] of this section. The analytical methodology used here is based on empirical formulae that are developed using the strain gauge measurements of different crank geometries and thus, their application is also limited to those geometries.

In this Sub-section [1.7], the derived SCF's are basically the ratio of stresses calculated using FEM to nominal stresses in both pin fillets and journal. When used with respect to the analytical method stated in [1.3.5.4] of this section or the alternative method given above, von Mises stresses is to be calculated for bending and principal stresses for torsion.

The evaluation guidelines and the procedures followed herein are valid for both semi-built cranks and solid cranks (except for journal fillets). However, the calculation of SCF at the oil bores is not covered in this Sub-section [1.7]. The element accuracy of the used FE solver is to be tested (like with the help of modeling a simple geometry and the stresses obtained by FEM with the analytical solution for pure bending and torsion are to be compared).

The Boundary Element Method (BEM) may also be used in lieu of FEM.

1.7.2. Model Requirements

The preliminary recommendations and perceptions for building the FE-model are stated in [1.7.2.1] below and it is mandatory for the final FE-model to meet the requirement of [1.7.2.3] below.

1.7.2.1. Element Mesh Recommendations

To meet the mesh quality criteria for the evaluation of SCF's, it is recommended to construct the FE model as suggested below:

- i) The model shall at least have 1 complete crank, from the main bearing centerline to its opposite side.
- ii) Types of element used in the vicinity of the fillets:
 - 8 node hexahedral elements
 - 10 node tetrahedral elements
 - 20 node hexahedral elements
- iii) Mesh properties in fillet radii applies to ± 90 degrees in circumferential direction from the crank plane:
- iv) Maximum element size $a = r/4$ all through the entire fillet and also in the circumferential direction. However, when 20 node hexahedral elements are used, the element size may be extended up to $5a$ in the circumferential direction. 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.)

- v) Recommended element size in fillet depth direction
 - First layer thickness equal to element size of a
 - Second layer thickness equal to element size of $2a$
 - Third layer thickness equal to element size of $3a$
- vi) Minimum 6 elements are required across web thickness.
- vii) Generally, remaining crank should be apt for numeric stability of the solver.
- viii) Counterweights have to be modeled only when significant manipulation of the global stiffness of the crank is done.
- ix) As long as the influence on global stiffness is negligible and the proximity to the fillet is more than $2r$, refer to Figure 2.1.8, modeling of oil drillings is not required.
- x) Modeling of drillings and holes for weight reduction has to be included.
- xi) If software requirements are met, sub-modeling may be used.

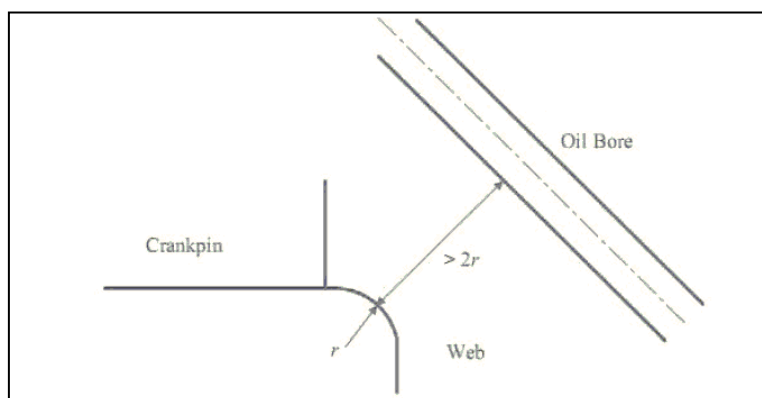


Figure 2.1.8: Oil Bore Proximity to Fillet

1.7.2.2. Materials

No consideration is given to 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 Young's Modulus and Poisson's ratio. Only reliable values for material parameters have to be used, either referring to literature or as measured on representative material samples. For steel, following values are advised for use:

$$E = 2.05 \times 10^5 \text{ MPa} \quad \text{and} \quad \nu = 0.3.$$

1.7.2.3. Element Mesh Quality Criteria

A second calculation with a refined mesh is to be executed if actual element mesh does not meet the following criteria at the examined area for SCF evaluation.

a) Principal Stresses Criterion

Ideally, the stress should be zero. To ascertain that, quality of the mesh should be checked by noting the stress component normal to the surface of the fillet radius. The following criterion is required with principal stresses σ_1 , σ_2 , and σ_3

$$(|\sigma_1|, |\sigma_2|, |\sigma_3|) < 0.03 \max(|\sigma_1|, |\sigma_2|, |\sigma_3|)$$

b) Averaged/Unaveraged Stresses Criterion

This criterion is based on the discontinuity of stress results over elements at the fillet for the SCF calculation:

At the examined location, unaveraged nodal stress results calculated from each element connected to node should differ by less than 5% from the 100% averaged nodal stress results at this node.

1.7.3. Load Cases

In lieu of the analytically determined SCF in [1.3.5.4] of this section, following load cases are to be calculated.

1.7.3.1. Torsion

Resembling the testing apparatus arrangements used for the investigations of SCF's of web fillet radii, the structure is loaded in pure torsion. In the model, surface warp located at the end faces is curbed. Refer to Figure 2.1.9.

When torque is applied to the central node located at the crankshaft axis, it acts as the master node. It enjoys 6 degrees of freedom and is rigidly connected to all the nodes of the end face.

Boundary and load conditions are valid for both in-line and V-type engines.

In both the crank pin fillet and journal, principal stresses are extracted and the equivalent torsional stress is calculated for all nodes:

$$\tau_{equiv} = \max \left(\frac{|\sigma_1 - \sigma_2|}{2}, \frac{|\sigma_2 - \sigma_3|}{2}, \frac{|\sigma_1 - \sigma_3|}{2} \right)$$

The maximum values used for the ensuing calculation of the SCF:

$$\alpha_T = \frac{\tau_{equiv,\alpha}}{\tau_N}$$

$$\beta_T = \frac{\tau_{equiv,\beta}}{\tau_N}$$

where

τ_N : nominal torsional stress for crankpin and journal as per [1.3.5.3] of this section
with the torsional torque T: $\tau_N = \frac{T}{W_P}$

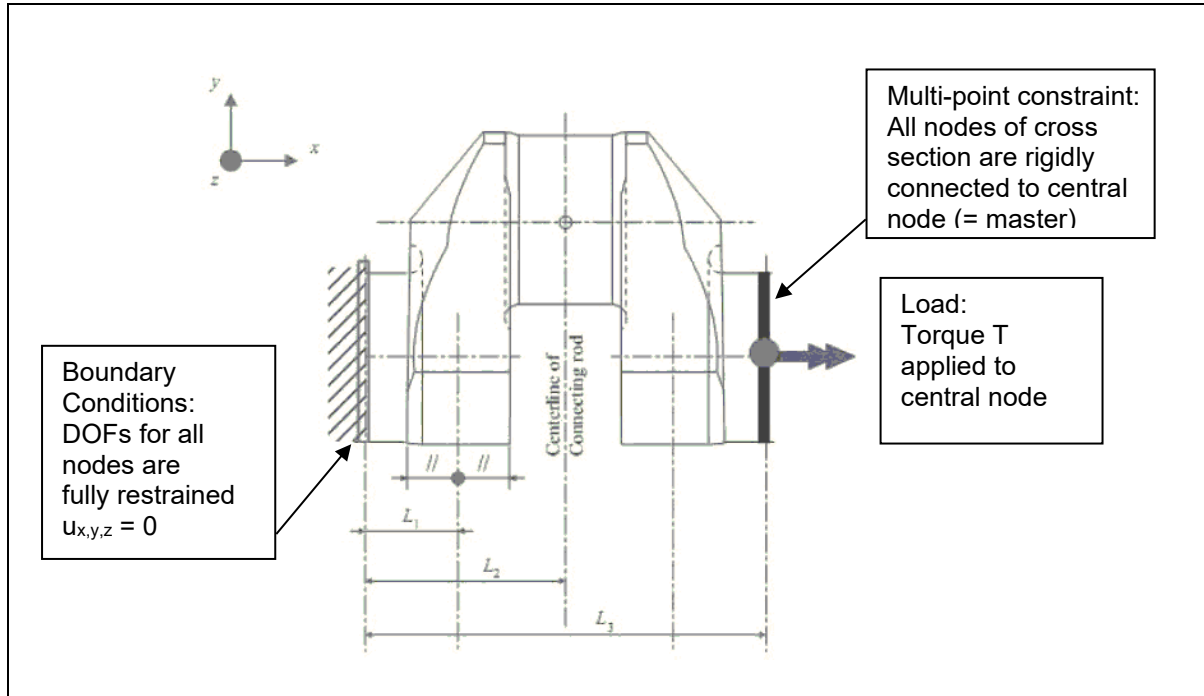


Figure 2.1.9: Boundary and Load Conditions for the Torsion Load Case

1.7.3.2. Pure Bending (4 Point Bending)

Resembling the testing apparatus arrangements used for the investigations of SCF's of web fillet radii, the structure is loaded in pure bending. In the model, surface warp at the end faces is curbed. Refer Figure 2.1.10.

When bending moment is applied to the central node located at the crankshaft axis, it acts as the master node. It enjoys 6 degrees of freedom and is rigidly connected to all the nodes of the end face.

Boundary and load conditions are valid for both in-line and V- type engines.

For all nodes in both the journal and pin fillet, von Mises equivalent stresses σ_{equiv} are extracted. The maximum value is used to calculate the SCF as per the following formulae:

$$\alpha_B = \frac{\sigma_{equiv,\alpha}}{\sigma_N}$$

$$\beta_B = \frac{\sigma_{equiv,\beta}}{\sigma_N}$$

Nominal stress σ_N is calculated as per [1.3.5.3] of this section with the bending moment M:

$$\sigma_N = \frac{M}{W_{eqw}}$$

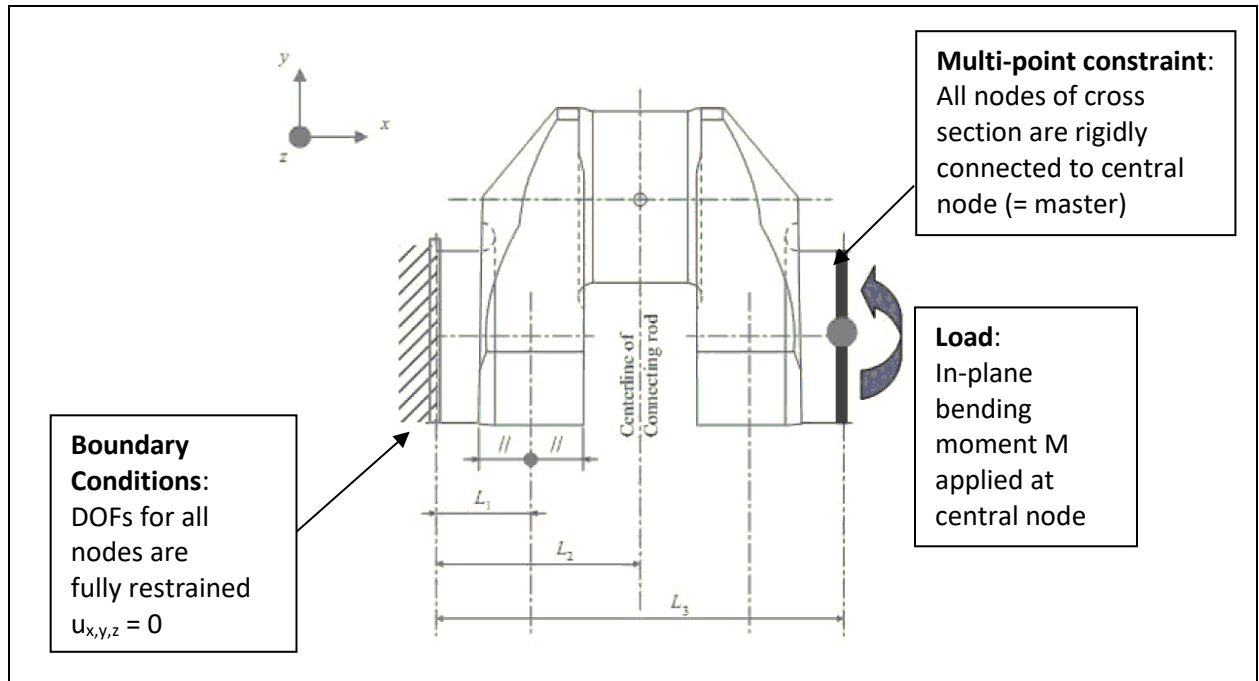


Figure 2.1.10: Boundary and Load Conditions for the Pure Bending Load Case

1.7.3.3. Bending With Shear Force (3 Point Bending)

This load case is calculated for SCF determination for pure transverse force (radial force, β_Q) for the journal fillet.

Resembling the testing apparatus arrangements used for the investigations of SCF's of web fillet radii, the structure is loaded in 3-point bending. In the model, surface warp at the both end faces is curbed. All nodes are rigidly connected to the centre node; and boundary conditions are applied. These nodes act as master nodes with 6 degrees of freedom. Refer to Figure 2.1.11.

The force is applied to the central node located at the pin centre line of the connecting rod and is connected to all nodes of the pin cross sectional area. Warping of the sectional area is not curbed.

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 as use of two connecting rod forces will bring about no significant change in the SCF.

The maximum equivalent von Mises stress σ_{3P} in the journal fillet is evaluated. Two ways are employed to determine SCF in the journal fillet, as shown below.

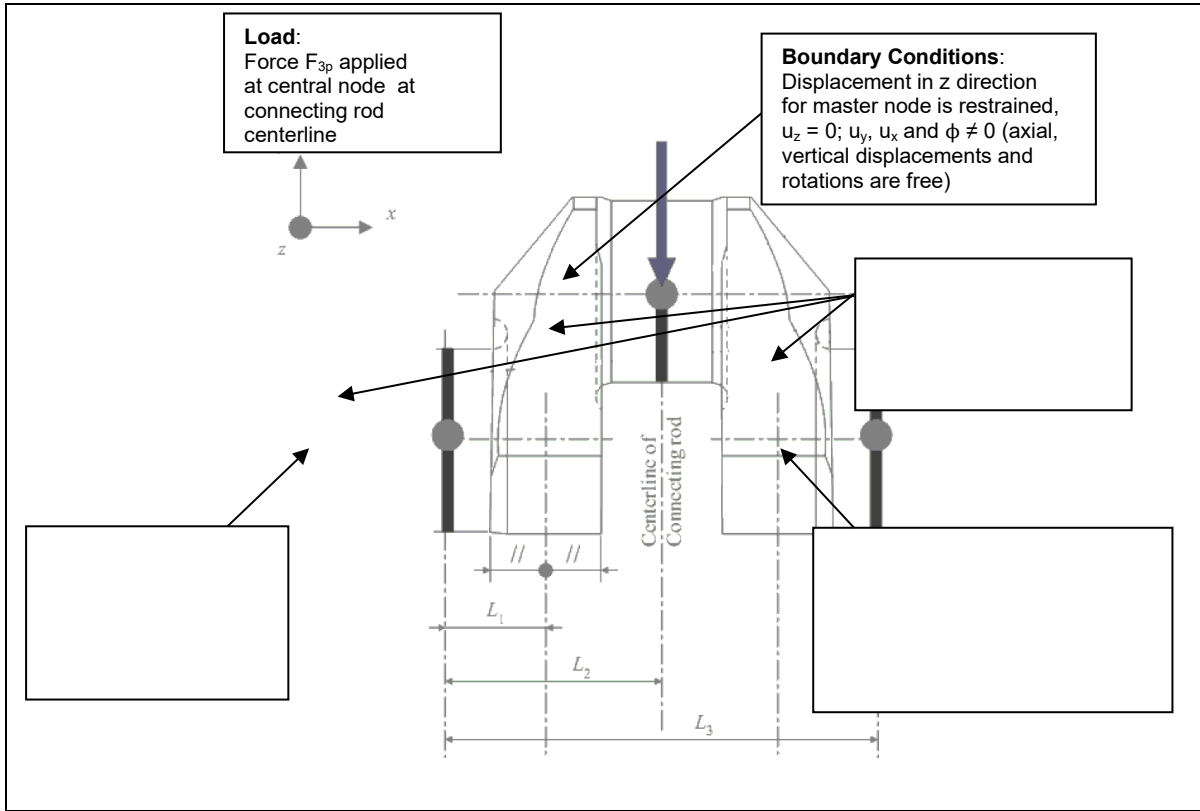


Figure 2.1.11: Boundary and Load Conditions for the 3-Point Bending Load Case of an Inline Engine

a) Method 1

Method 1 is based on the testing apparatus arrangements used for the investigations of SCF's of web fillet radii. The results from 3-point and 4-point bending are combined as given below:

$$\sigma_{3P} = \sigma_{N3P} \cdot \beta_B + \sigma_{Q3P} \cdot \beta_Q$$

Where

σ_{3P} = determined by the FE calculation.

Σ_{N3P} = nominal bending stress in the web center due to the force F_{3P} [N] applied to the centerline of the actual connecting rod, Refer Figure 2.1.12.

β_B = as determined in Section of [1.7.3.2] above.

$$\sigma_{Q3P} = \frac{Q_{3P}}{B \cdot W}$$

Q_{3P} = radial (shear) force in the web due to the force F_{3P} [N] applied to the centerline of the actual connecting rod, Refer Figure 2.1.3 and Figure 2.1.4.

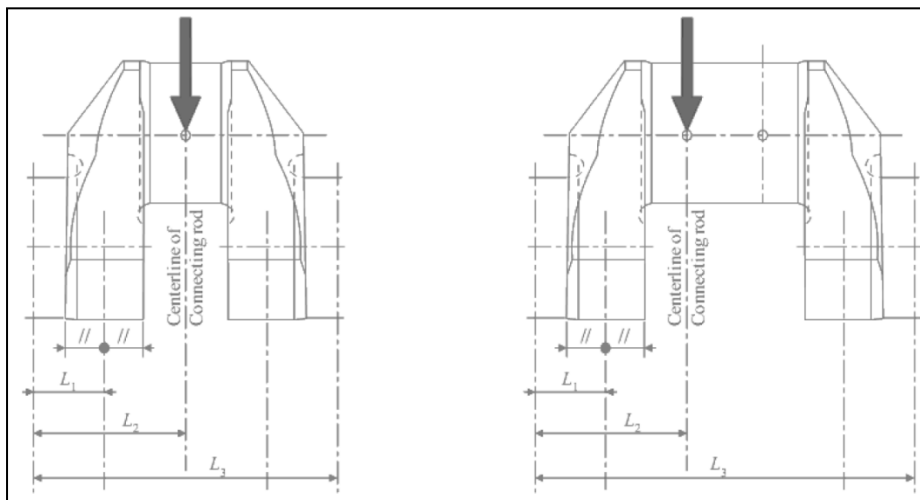


Figure 2.1.12: Load Applications for In-line and V-type Engines

b) Method 2

Method 2 is not based on the testing apparatus arrangements investigation. In a statically determined system with 1 crank throw supported by 2 bearings, bending moment and radial (shear) force are directly proportional. Thus, journal fillet SCF can be determined directly by 3-point bending FE calculation.

The SCF is calculated as given below:

$$\beta_{EQ} = \frac{\sigma_{3P}}{\sigma_{N3P}}$$

Refer, (a) above for symbols.

While this method is used, the radial force and stress determination (as per [1.3.5] of this section) become unnecessary. Then, the alternating bending stress in journal fillet as per [1.3.5.2(c)] is evaluated:

$$\sigma_{BG} = \pm |\beta_{BQ} \cdot \sigma_{BFN}|$$

This method is not applicable to the crankpin fillet and thus, this SCF, must not be used with respect to calculation methods other than those which assume a statically determined system as in [1.3.5] of this section.

1.8 Testing, Inspection and Certification of Diesel Engines

1.8.1 Material and Nondestructive Tests

For testing and nondestructive tests of materials intended for engine construction Refer [1.2.1] and [1.2.2] of this section.

Table 2.1.1: Material and Nondestructive Tests of Diesel Engine Parts

Engine Part (Refer note 1)	Material Tests (Refer note 5, 8)	Nondestructive Tests (Refer note 2)	
		Magnetic Particle, Liquid Penetrant, or Similar Tests (Refer note 3)	Ultrasonic Tests (Refer note 6)
Crankshafts, forged, cast, fully built, or semi-built	all	all	all
Crankshaft coupling flange (non integral) for main propulsion engines	above 400 mm (15.7 in.) bore	–	–
Coupling bolts for crankshaft	above 400 mm (15.7 in.) bore	–	–
Connecting rods and connecting rod bearing caps (7)	all	all	above 400 mm (15.7 in.) bore
Piston rods	above 400 mm (15.7 in.) bore	above 400 mm (15.7 in.) bore	above 400 mm (15.7 in.) bore
Crosshead	above 400 mm (15.7 in.) bore	–	–
Cylinder liner – steel/gray and nodular iron parts	above 300 mm (11.8 in.) bore	–	–
Steel/gray and nodular iron cylinder covers	above 300 mm (11.8 in.) bore	above 400 mm (15.7 in.) bore	all
Tie rods	all	above 400 mm (15.7 in.) bore	–
Steel piston crowns	above 400 mm (15.7 in.) bore	above 400 mm (15.7 in.) bore	all
Bolts and studs for cylinder covers, crossheads, main bearings, connecting rod bearings	above 300 mm (11.8 in.) bore	above 400 mm (15.7 in.) bore	–
Steel gear wheels for camshaft drives	above 400 mm (15.7 in.) bore	above 400 mm (15.7 in.) bore	–
Steel castings for welded bedplates (including main bearing housing)	all	all	all
Steel forgings for welded bedplates (including main bearing housing)	all	–	–
Plates for welded bedplates (including main bearing housing); frames, crankcases and entablatures of welded construction	all	–	–
Weld seams of important structural parts as determined by engine designer	–	As specified by engine designer	As specified by engine designer
Notes:- 1. The turbochargers, superchargers and piping systems, such as fuel oil injection, starting air, etc. are not covered here. For turbochargers and superchargers, refer Sec-2, [2.2]. For material tests of piping components, refer Chapter-8, Table 8.1.1 and Table 8.1.2. 2. Where evidence to doubt the reliability of any engine component is not there, a nondestructive test by approved detecting methods may be required. 3. Tests are to be done at positions agreed to by the Surveyor and manufacturer both, where it is inferred from their experience, that defects are likely. 4. For tie rods, magnetic particle test is to be done at each threaded portion, which is two times the length of the thread. 5. Surveyor shall witness the tests for these items or for engines certified under quality assurance assessment, tests by the manufacturer will be sufficient; refer [1.2.2.1] of this section. 6. Ultrasonic test report to be verified by the manufacturer of the engine, refer [1.8.4.3](d) of this section. 7. NDT is not applicable to the connecting rod bearing caps. 8. For engines < 375 kW, refer [1.2.2.3] of this section.			

1.8.2 Hydrostatic Tests of Diesel Engine Components

Hydrostatic tests of diesel engine parts and components are to be as specified in Table 2.1.2. These tests are to be executed by the manufacturer who produces acceptable certificate of tests. However, Surveyor certifies the independently driven pumps for fuel oil, lubricating oil, and cooling water services of diesel engines of bores exceeding 300 mm (11.8 in.); refer Chapter 8, Sec-1,

Table 2.1.2: Test Pressures for Parts of Internal-combustion Engines

Engine Part	Test Pressure (P = max. working pressure of engine part)
Cylinder cover, cooling space. For forged cylinder covers, test methods other than pressure testing may be accepted, e.g., nondestructive examination and dimensional checks.	7 bar (7 kgf/cm ² , 100 psi)
Cylinder liner, over the whole length of cooling space	7 bar (7 kgf/cm ² , 100 psi)
Cylinder jacket, cooling space	4 bar (4 kgf/cm ² , 58 psi) but not less than 1.5P
Exhaust valve, cooling space	4 bar (4 kgf/cm ² , 58 psi) but not less than 1.5P
Piston crown, cooling space, where the cooling space is sealed by piston rod or by piston rod and skirt (test after assembly). For forged piston crowns test methods other than pressure testing may be used, e.g., nondestructive examination and dimensional checks.	7 bar (7 kgf/cm ² , 100 psi)
Fuel-injection system (pump body pressure side, valve and pipe)	1.5P or P + 300 bar (P + 306 kgf/cm ² , P + 4350 psi) which ever is less
Hydraulic System, high pressure piping for hydraulic drive of exhaust gas valve	1.5P
Scavenge-pump cylinder	4 bar (4 kgf/cm ² , 58 psi)
Turbocharger, cooling space (Refer Sec-2, [2.6.1.3])	4 bar (4 kgf/cm ² , 58 psi) but not less than 1.5P
Exhaust pipe, cooling space	4 bar (4 kgf/cm ² , 58 psi) but not less than 1.5P
Engine-driven air compressor, (cylinders, covers, intercoolers and aftercoolers) air side	1.5P
Engine-driven air compressor, (cylinders, covers, intercoolers and aftercoolers) water side	4 bar (4 kgf/cm ² , 58 psi) but not less than 1.5P
Coolers, each side (charge air coolers need only be tested on the water side)	4 bar (4 kgf/cm ² , 58 psi) but not less than 1.5P
Engine driven pumps (oil, water, fuel, bilge)	4 bar (4 kgf/cm ² , 58 psi) but not less than 1.5P
Independently driven pumps (oil, water, fuel) for engines with bores >300 mm (11.8 in.)	1.5P, for certification of pumps; Refer Chapter 8, Sec-1, [1.4]

1.8.3 Safety Valves & Relief Valves

1.8.3.1 Crankcase Explosion Relief Valves

All crankcase explosion relief valves are to be type tested as specified in [1.9] of this section. INTLREG Surveyor's presence during type testing is a prerequisite. In case the crankcase explosion relief valve is covered under a type approval, this type testing can be waived, subject to agreement between attending Surveyor and presentation of a document of compliance by the manufacturer to the Surveyor. The document of compliance is required to confirm that the relief valves have been manufactured as per the product design certificate associated with the type approval.

1.8.3.2 Safety Valves

Safety valves are to be tested and set in the presence of Surveyor, where provided

1.8.4 Manufacturer's Quality Control

1.8.4.1 Quality Plan

Prior to commencement of construction, the manufacturer is to submit to the Surveyor a quality plan setting out the quality control that it plans to perform on, but not limited to the following:

- issuance of material specifications for purchasing	- NDT written procedures and qualification documentation
- Receiving inspection of materials	- NDT plan
- receiving inspection of finished components and parts	- casting and weld defect resolutions
- dimensional and functional checks on finished components and parts	- subassembly inspection: alignment and dimension checks, functional tests
- edge preparation and fit-up tolerances	- assembly and fit specifications
- welding procedure qualification	- testing of safety devices
- welder qualification	- hydrostatic testing plan
- Weld inspection plan	- engine test plan
- welding defect tracking	

The Surveyor reviews the quality plan. It is his discretion to identify inspection hold points on the quality plan, in addition to those required in Sect [1.8.1] through [1.8.3]. For all cases, the manufacturer is to maintain traceability and documentation of materials and parts; welders, welds and NDT records; dimension and alignment measurements bolted joint pretension values; hydrostatic test records; and other quality control measurements; which are presented to the Surveyor during the inspection. After the construction is completed, the quality control documents are to be compiled in a folio and a copy of which is to be presented to the Surveyor

- i) The engine manufacturer is to have a quality control system that is suitable for the actual engine types to be certified by the INTLREG. The quality control system is also to apply to any sub-suppliers. The INTLREG 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. The INTLREG requires that certain parts are verified and documented by means of Society Certificate (SC), Work Certificate (W) or Test Report (TR).
- ii) Society Certificate (SC). This is a document issued by the INTLREG stating that:
 - Conformity with Rule requirements.
 - That the tests and inspections have been carried out on the certified product itself, or on samples taken from the certified product itself.
 - That the inspection and tests were performed in the presence of the Surveyor or in accordance with special agreements (i.e., ACS).

iii.) *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 certified product itself, on samples taken from the raw material, used for the product to be certified.
- 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 the INTLREG Certificate and endorsed by the INTLREG under the following cases:

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

iv) *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.

v) The documents above are used for product documentation as well as for documentation of single inspections such as crack detection, dimensional check, etc. If agreed to by the INTLREG, 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.

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

vii) The manufacturer is not exempted from responsibility for any relevant tests and inspections of those parts for which documentation is not explicitly requested by the INTLREG

Manufacturing works is to be equipped 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.

1.8.4.2 Welding on Engine Entablatures, Frames, Bedplates and Power Transmitting Component

a. *Welding Procedure*. Before commencing the welding, manufacturer is to prove it to the Surveyor that the intended welding process, welding filler metal, preheat, post weld heat treatment, etc., as applicable, and have been qualified for joining the base metal. The intended welding procedure is to be supported by welding procedure qualification record (PQR) acceptable to the Surveyor or done in his presence. The extent to which a PQR may be used to back multiple welding procedures is to be determined considering a recognized welding standard and is subject to acceptance being given by the Surveyor.

- b. *Welders and welding operators.* Before commencing the welding, manufacturer is to prove it to the Surveyor that the welder or the welding operator is enough qualified for the intended job. In general, welders and welding operators are to be qualified as specified in Part 2, Ch-3, Sec-4, [4.6] in the presence of the Surveyor or if supporting documents, welder performance qualification records (WPQ) acceptable to the Surveyor are presented. The extent to which a WPQ may be used to back multiple welding procedures is to be determined considering a recognized welding standard and is subject to Surveyor's acceptance.
- c. *Facility-specific PQR and WPQ.* To establish the capability of a particular facility, PQR and WPQ are to be conducted at and also certified those facilities only where the fabrication or weld repair is to be conducted. Normally, if PQR and WPQ are conducted at other facilities, it is not acceptable without attaining acceptance of the Surveyor specifically.
- d. *Welding filler metals.* All welding filler metals are to be certified by their manufacturers as complying with appropriate recognized national or international standards. Welding filler metals tested, certified and listed by INTLREG, for meeting such a standard may be used in all cases. Refer Part-2, Ch-3, Sec-5 for approval of filler metals. Welding filler metals not so listed may also be accepted provided that
 - i) They are of the same type as that proven in qualifying the welding procedure; and
 - ii) They are of a make acceptable to the Surveyor; and
 - iii) For welding of Group I engineering structures, representative production test pieces are to be taken to prove the mechanical properties of the weld metal.
- (e) *Tack welds.* Tack welds, where used, are to be made with filler metal suitable for the base metal. Tack welds intended to be left in place and form part of the finished weld are to be made by qualified welders using process and filler metal the same as or equivalent to the welding procedure to be used for the first pass. When preheating is required, the same preheating should be applied prior to tack welding.
- (f) *Repair of defective welds.* Any weld joint imperfection disclosed by examination in Sect [1.8.4.3(c)] below and deemed unacceptable is to be removed by mechanical means or thermal gouging processes, after which the joint is to be welded using the appropriate qualified welding procedure by a qualified welder. Preheat and post-weld heat treatment is to be performed, as applicable. Upon completion of repair, the repaired weld is to be re-examined by the appropriate technique that disclosed the defect in the original weld.
- (g) *Repair of castings by welding.* Casting surface defects and defects revealed by nondestructive tests specified in Table 2.1.1 and deemed unacceptable may be repaired by welding. All welding repairs are to be conducted using qualified welding procedure and by qualified welders as per (a), (b) and (c) above. The welding procedure, preheat and post weld heat treatment, as applicable, are to be in accordance with engine designer's specifications and supported by appropriate PQR. The Surveyor is to be notified prior to proceeding with the repair. Where welding repair is to be conducted at the foundry, the same procedure is to be adhered to. Defects detected by nondestructive tests required by Table 2.1.1 are to be re-examined by at least the same technique after completion of repair.

1.8.4.3 Inspection and Nondestructive Tests

- (a) *Qualification of procedures and operators.* Before proceeding to conduct nondestructive tests required by Table 2.1.1, the manufacturer is to have a written procedure for conducting each of these tests and for qualifying the operators intended for conducting these tests. Subcontractors, if employed for this purpose, are to be similarly qualified. In general, the processes of qualifying the procedures and the operators and the necessary technical supervision and training are to be in accordance with a recognized standard.
- (b) *Nondestructive test procedures of engine parts.* Parts requiring ultrasonic tests by Table 2.1.1 are each to be provided with a test plan. Typically, for ultrasonic testing, the plan is to specify:

• Part to be tested	• Scanning coverage and rate
• Ultrasonic equipment	• Calibration procedure
• Couplant	• Acceptance standards
• Reference block(s)	

As a minimum, dye penetrant test plans are to specify the part to be tested, penetrant type and developer, procedure for retest, allowable ambient and test piece temperatures, and acceptance standards; and magnetic particle test plans are to specify parts to be tested, magnetization technique and equipment, surface preparation, type of ferromagnetic particles, and acceptance standards.

- (c) *Nondestructive tests of welds.* The manufacturer's quality plan for weld inspection should include visual inspection, measurement of weld sizes, as well as nondestructive tests (dye penetrant, magnetic particle, radiography or ultrasonic), as may be specified by the engine designer for important structural parts.
- (d) *Documentation.* The manufacturer is to document and certify the results of the required nondestructive tests. The number and locations of unacceptable indications found are to be reported, together with corrective action taken, preferably on a sketch, along with questionable areas and any required areas not examined, where applicable.
- (e) *Witness by Surveyor.* All documents required in Sect [1.8.4.3] are to be made available to the Surveyor. Where in doubt, or for purposes of verification, the Surveyor may request for a demonstration of any nondestructive tests required by Table 2.1.1 to be conducted in his presence.

1.8.4.4 Assembly and Fit

The quality plan of the manufacturer require checks on important fit, alignment, tolerances, pre-tensioning, etc. that are specified by the engine designers. Recorded data i.e. measured in as assembled is to be made available to the Surveyor, who may request for its verification.

1.8.5 Type Tests of Diesel Engines

1.8.5.1 Application

All the new types of diesel engine, as defined in Sect [1.8.5.2] below, are type tested under the conditions specified in [1.8.5], except that mass-produced engines intended to be certified by quality assurance may be type tested as specified in [1.8.7] of this section. The testing of the engine for the purpose of determining the rated power and 110% power is to be conducted at the ambient

reference conditions given in [1.1.4] of this section, or power corrections are to be made. A type test executed for a type of engine at any place of manufacture will be accepted for all engines of the same type built by licensee's and licensee's. A type test executed on one engine with a given number of cylinders will be accepted for all engines of the same type with different number of cylinders. However, a type test of an in-line engine may not always cover the V-version. Subject to the INTLREG discretion, separate type tests may be required for the V-version (a type test of a V-engine covers the in-line engines, unless the bmep is higher). Items such as axial crankshaft vibration, torsional vibration in camshaft drives, and crankshafts, etc. may vary considerably with the number of cylinders and may influence the choice of engine to be selected for type testing.

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

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

Where a previously approved conventional type of engine (i.e., non-electronically controlled) is modified to an electronically controlled engine, the requirement to conduct those tests specified in [1.8.5] of this section which were already done as a part of the conventional engine approval and for which the results have shown that it would not be impacted due to the addition of the electronic controls, may be subject to special consideration.

1.8.5.2 Engine Type Definition

For purposes of type tests, a diesel engine "type", as specified by the manufacturer's type designation, is to be defined by:

- The working cycle (2-stroke, 4-stroke)
- The cylinder arrangement (in-line, v-Type)
- The rated power per cylinder at rated speed and mean effective pressure
- The kind of fuel (liquid, dual fuel, gaseous)
- The method of fuel injection (direct or indirect)
- The valve and injection operation (by cams or electronically controlled)
- The cylinder bore
- The stroke
- The scavenging system (naturally aspirated or supercharged)
- The supercharging system (constant or pulsating pressure)
- The charged air cooling system (provided with intercooler or not, number of cooling stages)

Engines may be considered the same type, provided they do not differ from any of the above items.

1.8.5.3 Increase in Rated Power

The engine is type approved up to the tested ratings and pressures (100% corresponding to MCR). Provided documentary evidence of successful service experience with the classified rating of 100% is submitted, an increase (if approved based on crankshaft calculation and crankshaft drawings) may be permitted without a new type test if the increase from the type tested engine is within:

- i)* 5% of the maximum combustion pressure, or
- ii)* 5% of the mean effective pressure, or
- iii)* 5% of the rpm.

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

- i)* 10% of the maximum combustion pressure, or
- ii)* 10% of the mean effective pressure, or
- iii)* 10% of the rpm.

1.8.5.4 Stages of Type Tests

Each type test is divided in three stages:

- Stage A: Manufacturer's tests; This includes some of the testing made during the engine development, function testing, and collection of measured parameters and records of testing hours. The results of testing required by INTLREG or stipulated by the designer are to be presented to the INTLREG before starting stage B.
- Stage B: Type assessment tests to be conducted in a Surveyor's presence;
- Stage C: component inspection after testing by Surveyor.

The complete type testing program is subject to approval by the INTLREG. The extent the Surveyor's attendance is to be agreed in each case, but at least during stage B and C. Testing prior to the witnessed type testing (stage B and C), is also considered as a part of the complete type testing program. Upon completion of the type testing (stage A through C), a type test report is to be submitted to INTLREG for review. The type test report is to contain:

- i)* Overall description of tests performed during stage A. Records are to be kept by the builders QA management for presentation to INTLREG
- ii)* Detailed description of the load and functional tests conducted during stage B;
- iii)* Inspection results from stage C.

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

High speed engines for marine use are normally to be subjected to an endurance test of 100 hours at full load. Omission or simplification of the type test may be considered for the type approval of engines with long service experience from non-marine fields or for the extension of type approval of engines of a well-known type, in excess of the limits given in this section

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

These stages are described in details as given below:

- (a) Stage A: manufacturer's tests. The manufacturer is to carry out functional tests in order to collect and record the engine's operating data. During these tests, the engine is to be operated at the load points specified by the engine manufacturer and the pertinent operating values are to be recorded. The load points may be selected according to the range of applications.

The tests are to include the normal and the emergency operating modes as specified below:

i) *Normal operating mode.*

The load points 25%, 50%, 75%, 100% and 110% of the rated power for continuous operation:

- Along the nominal (theoretical) propeller curve and at constant rated speed for propulsion engines if applicable mode of operation (i.e., driving controllable pitch propellers);
- At constant rated speed for engines intended to drive electric generators including a test at no load and rated speed;

The limit points of the permissible operating range, as defined by the engine manufacturer.

For high speed engines, the 100 hour full load test and the low cycle fatigue test apply as required in connection with the design assessment.

Specific tests of parts of the engine stipulated by the designer.

ii) *Emergency operating mode.*

The manufacturer's test for turbocharged engines is to include the determination of the maximum attainable continuous power output in the following cases of simulated turbocharger damage:

- Engines with one turbocharger: with the rotor blocked or removed;
- Engines with more than two or two turbochargers: with one of it shut off.

- (b) Stage B: type tests to be witnessed by the Surveyor. The engine is to be operated at the load points shown in Figure 2.1.13. The data measured and recorded at each load point is to cover all required parameters for the engine operation.

The operating time per load point depends on the engine size (achievement

of steady-state condition) and on the time for collection of the operating values. For (i) below, an operating time of two hours is required and two sets of readings are to be taken at a minimum interval of one hour. For (ii) through (vi) below, the operating time per load point is not to be less than 30 minutes.

- c) Rated power, i.e., 100% output at 100% torque and 100% speed corresponding to load point 1
 - d) 100% power at maximum permissible speed corresponding to load point 2.
 - e) Maximum permissible torque (at least and normally 110%) at 100% speed corresponding to load point 3; or maximum permissible power (at least and normally 110%) and 103.2% speed according to nominal propeller curve corresponding to load point 3a. Load point 3a applies to engines only driving fixed pitch propellers or water jets. Load point 3 applies to all other purposes. Load point 3 (or 3a as applicable) is to be replaced with a load that corresponds to the specified overload and duration approved for intermittent use. This applies where such overload rating exceeds 110% of MCR. Where the approved intermittent overload rating is less than 110% of MCR, subject overload rating has to replace the load point at 100% of MCR. In such case the load point at 110% of MCR remains.
 - f) Minimum permissible speed at 100% torque corresponding to load point 4.
 - g) Minimum permissible speed at 90% torque corresponding to load point 5.
 - h) Part load operation, e.g., 75%, 50%, 25% of maximum continuous rated power and speed according to the nominal propeller curve (i.e., 90.8%, 79.3% and 62.9% speed) corresponding to point 6, 7 and 8, or at constant rated speed setting corresponding to points 9, 10 and 11, depending on the intended application of the engine.
 - i) Crosshead engines not restricted for use with C.P. propellers are to be tested with no load at the associated maximum permissible engine speed.
- iii)* For turbocharged engines, maximum achievable power when operating along the nominal propeller curve and when operating with constant governor setting for rated speed under the following conditions:
- Engines equipped with one turbocharger: with the rotor blocked or removed,
 - Engines equipped with two or more turbochargers: with one turbocharger shut off.

Engines intended for single propulsion with a fixed pitch propeller are to be able to run continuously at a speed (rpm) of 40% of full speed along the theoretical propeller curve when one turbocharger is out of operation.

iv) Functional tests are to be performed for the following:

- The lowest engine speed according to the nominal propeller curve
- The engine starting and reversing appliances, where applicable for the purpose of determining the minimum air pressure and the consumption for a start.

- The speed governor
 - The safety system, for over speed and low lubricating oil pressure specifically
 - Integration Test -For electronically controlled diesel engines, integration tests are to substantiate 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 determined on the basis of FMEA as required in [1.9.2] of this section
- v) Verification of compliance with requirements for jacketing of high-pressure fuel oil lines, screening of pipe connections in piping containing flammable liquids and insulation of hot surfaces:
- a) The engine is to be inspected for jacketing of high-pressure fuel oil lines, including the system for the detection of leakage, and proper screening of pipe connections in piping containing flammable liquids.
 - b) Proper insulation of hot surfaces is to be verified while running the engine at 100% load, alternatively at the overload approved for intermittent use. Readings of surface temperatures are to be done by use of Infrared Thermo scanning Equipment. Equivalent measurement equipment may be used when so approved by INTLREG . Readings obtained are to be randomly verified by use of contact thermometers.
- (c) *Stage C: component inspection by the Surveyor.* The crankshaft deflections are to be measured in the specified (by designer) condition (except for engines where no specification exists). High speed engines for marine use are normally to be stripped down for a complete inspection after the type test. For all the other engines, after the test run, the following components of one cylinder for in-line and of two cylinders for V-engines are to be presented for the Surveyor's inspection (engines with long service experience from non-marine fields can have a reduced extent of opening):
- Piston removed and dismantled
 - Crosshead bearing, dismantled
 - Guide planes
 - Connecting rod bearings (big and small end, special attention to serrations and fretting on contact surfaces with the bearing backsides) and main bearing, dismantled.
 - Cylinder liner in the installed condition
 - Cylinder head, valves disassembled
 - Control gear or chain, camshaft and crankcase with opened covers (the engine must be tunable by turning gear for this inspection)
- For V-engines, the cylinder units are to be selected from both cylinder banks and different crank throws.
- Further dismantling of the engine may be required by and at the discretion of the Surveyor.
- (d) *De-rated Engine.* If an engine has been design approved, and internal testing per Stage A is documented to a rating higher than the one type tested, the Type Approval may be extended to the increased power / mep / rpm upon submission of an Extended Delivery Test Report at:

- i) Test at over speed (only if nominal speed has increased)
 - ii) Rated power, (i.e. 100% output at 100% torque and 100% speed corresponding to load point 1., 2 measurements with one running hour in between
 - iii) Maximum permissible torque (normally 110%) at 100% speed corresponding to load point 3 or maximum permissible power (normally 110%) and speed according to nominal propeller curve corresponding to load point 3a., 1/2 hour
 - iv) 100% power at maximum permissible speed corresponding to load point 2 1/2 hour
- (e) *Integration Test.* An integration test demonstrating that the response of the complete mechanical, hydraulic and electronic system is as predicted maybe carried out for acceptance of subsystems (Turbocharger, Engine Control System, Dual Fuel, Exhaust Gas treatment...) separately approved. The scope of these tests is to be proposed by the designer/licensor taking into account of impact on engine.
- (f) *Measurements and Recordings.* During all testing, the ambient conditions (air temperature, air pressure and humidity) are to be recorded. As a minimum, the following engine data are to be measured and recorded:
- i) Engine rpm
 - ii) Torque
 - iii) Maximum combustion pressure for each cylinder*
 - iv) Mean indicated pressure for each cylinder*
 - v) Charging air pressure and temperature
 - vi) Exhaust gas temperature
 - vii) Fuel rack position or similar parameter related to engine load
 - viii) Turbocharger speed
 - ix) All engine parameters that are required for control and monitoring for the intended use (propulsion, auxiliary, emergency).

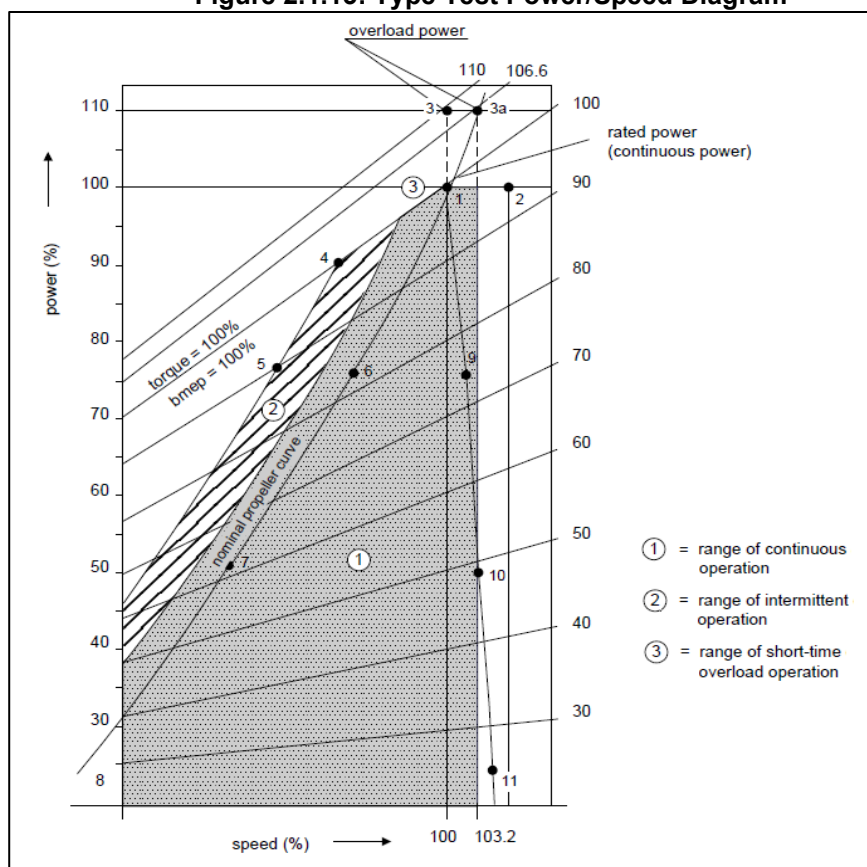
* *Note:* For engines where the standard production cylinder heads are not designed for such measurements, a special cylinder head made for this purpose may be used. In such a case, the measurements may be carried out as part of Stage A and are to be properly documented. Where deemed necessary (e.g., for dual fuel engines), the measurement of maximum combustion pressure and mean indicated pressure may be carried out by indirect means, provided the reliability of the method is documented. Calibration records for the instrumentation used to collect data as listed above are to be presented to and reviewed by the attending Surveyor. Additional measurements may be required in connection with the design assessment.

- (g) Safety Precautions. Before any test run is carried out, all relevant equipment for the safety of attending personnel is to be made available by the manufacturer/shipyard and is to be operational, and its correct functioning is to be verified. This applies especially to crankcase explosive conditions protection, but also over-speed protection and any other shut down function. The inspection for jacketing of high-pressure fuel oil lines and proper screening of pipe connections is also to be carried out before the test runs. Interlock test of turning gear is to be performed when installed.

1.8.5.5 Additional Tests

For engines intended to be used for emergency services, supplementary tests according to the regulations of the Administration whose flag the vessel flies may be required.

Figure 2.1.13: Type Test Power/Speed Diagram



1.8.6 Shop Tests of Internal Combustion, I.C. Engines

Prior to carrying out any test run, all required safety devices are to be installed by the manufacturer / shipyard and are to be operational. This applies especially to crankcase explosive conditions protection, but also to over-speed protection and any other shut down function. The over speed protective device is to be set to a value, which is not higher than the over speed value that was demonstrated during the type test for that engine. This set point is to be verified by the surveyor

Each diesel engine where required to be certified by [1.1.1] of this section except those manufactured on the basis of the Type Approval Program referred to in [1.9.1] of this section, is to be tested in Surveyor's presence, as per the provisions of [1.8.6]. The scope of tests may be expanded as required by specific engine application

1.8.6.1 General

The operational data corresponding to each of the specified test load conditions are to be determined and recorded and 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. Calibration records for the instrumentation are to be presented to the attending Surveyor. In each case, all measurements conducted at the various load points shall be carried out at steady operating conditions. The readings for 100% power (rated power at rated speed) are to be taken twice at an interval of at least 30 minutes.

(a) Environmental Test Condition

The following environmental test conditions are to be recorded

- Ambient air temperature
- Ambient air pressure
- Atmospheric humidity

(b) *Load Points.*

For each required load point, the following parameters are 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

Before any official testing, the engines shall be run-in as prescribed by the engine manufacturer. Adequate test bed facilities for loads as required in this section are to be provided. All fluids used for testing purposes such as fuel, lubrication oil and cooling water are to be suitable for the purpose intended (e.g., they are to be clean, preheated if necessary and cause no harm to engine parts). This applies to all fluids used temporarily or repeatedly for testing purposes only.

(c) *Inspections.*

Engines are to be inspected for:

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

These inspections are normally to be made during the Shop trials by the manufacturer and the attending surveyor, but at the discretion of the

INTLREG parts of these inspections may be postponed to the shipboard testing.

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

1.8.6.2 Engines Driving Propellers or Impellers

Main propulsion engines driving propellers are to be tested under the conditions given below:

- i)* 100% of rated power (MCR) at rated engine speed (n_O), for at least 60 minute
- ii)* 110% of rated power at an engine speed of $n = 1.032n_O$. Records to be taken after 15 minutes or after having reached steady conditions, whichever is shorter.

Note: Only required once for each different engine/turbocharger configuration

- iii)* Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.
- iv)* 90%, 75%, 50% and 25% of rated power, in accordance with the nominal propeller curve (the sequence to be selected by the engine manufacturer).
- v)* Starting and reversing maneuvers.
- vi)* After running on the test bed, the fuel delivery system of the engine is to be adjusted so that the engine output is limited to the rated power and so that the engine cannot be overloaded under service condition, unless intermittent overload power is approved by the INTLREG. In that case, the fuel delivery system is to be blocked to that power.
- vii)* Testing of governor and independent over speed protective device.
- viii)* Testing of shutdown device.

1.8.6.3 Engines Driving Generators Dedicated for Propulsion Motors

For engines intended for driving electric propulsion generators, the tests are to be done at the rated speed with a constant governor setting under the conditions given below:

- i)* 100% rated power for minimum 60 min., after attaining steady conditions.
- ii)* 110% of rated power for 15 min., after having reached steady conditions.
- iii)* After running on the test bed, the fuel delivery system of the engine is to be adjusted so that an overload power of 110% of the rated power can be supplied. Due regard is to be given to service conditions after installation on board and to the governor characteristics, including the activation of generator protective devices. Refer also [1.4.4.1(b)] of this section for governor characteristics allied with power management systems
- iv)* 75%, 50% and 25% of rated power and idle run. (The sequence to be selected by the engine manufacturer).

- v) Start-up tests.
- vi) Testing of governor and independent over speed protective device.
- vii) Testing of shutdown device.

1.8.6.4 Engines Driving Other Generators for Auxiliary Purposes

Engines intended for driving vessel service generators and emergency generators, are to be tested as specified in Sect (1.8.6.3). After running on the test bed, the fuel delivery system of the engine is to be adjusted so that an overload power of 110% of the rated power can be supplied. Due regard is to be given to service conditions after installation on board and to the governor characteristics including the activation of generator protective devices. Refer also Sect [1.4.4.1](b) for governor characteristics associated with power management systems.

1.8.6.5 Electronically Controlled Engines

For electronically controlled engines, integration tests are to be conducted. They are to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes. The scope of these tests is to be determined based on those tests that have been established for the type testing. If such tests are technically unfeasible at the works, these tests may be conducted during sea trial. The scope of these tests is to be agreed with the INTLREG for selected cases based on the FMEA required in this Section

1.8.6.6 Inspection after Tests

After shop tests, engine components that are randomly selected at the Surveyor's discretion, are to be presented for inspection. Where engine manufacturers also require crankshaft deflection to be periodically checked during service, it is to be measured at this time after the shop test and its results are recorded for future reference.

1.8.7 Type Tests of Mass-produced Diesel Engines

1.8.7.1 Application

- (a) *General*. Each type of diesel engine mass produced (Refer [1.8.7.2] below) under the accepted quality assurance program is to be type tested in accordance with the provisions of [1.8.7]. A type test carried out for a type of engine at a place of manufacture will be accepted for all engines of the same type built by licensees and licensors. A type test carried out on one engine having a given number of cylinders will qualify all engines of the same type having a different number of cylinders. The type test is to be conducted in the presence of the Surveyor.

Consideration will be given to modification of the type test requirements for existing engine designs which have proven reliability in service.

- (b) *Alternative Certification Scheme (ACS)*. Mass produced diesel engines may be eligible for certification under ACS program

1.8.7.2 Definition of Mass Production of Diesel Engines

A diesel engine intended for propulsion or auxiliary service is considered mass-produced, provided it meets the criteria specified below:

- The engines are manufactured in quantity.
- The materials and components used for the engine construction are manufactured with approved quality control procedures specified by the engine builder.

- The machinery used for manufacturing of the engine components is specially calibrated and subject to regular inspection in order to meet the engine builder's specifications and quality requirements and to allow for assembly or interchangeability of components without any re-machining.
- Each assembled engine undergoes a bench test as per specified procedures.
- Final testing, in accordance with specified procedures, is carried out on engines selected at random after bench testing.

1.8.7.3 Tests to be witnessed by the Surveyor

(a) Load points:

- i) 80 hours at rated power
- ii) 8 hours at 110% overload and alternately 100% rpm and 103% rpm;
- iii) 10 hours at partial loads (in steps of 90%, 75%, 50% and 25% of rated power)
- iv) 2 hours at intermittent loads.

The tests are to be executed in cycles, with each cycle comprising of all the above load points and it repeated until the specified test durations are attained.

(b) Functional tests:

- i) The engine starting and reversing appliances,
- ii) The speed governor,
- iii) The over speed device,
- iv) The lubricating oil failure indication device,
- v) The condition of turbocharger i.e. out of action (where applicable),
- vi) Operating at minimum speed for main propulsion engines and at idle speed for auxiliary engines.

(c.) Component inspection. After completion of the type test, main parts of the engine are to be dismantled for examination by the Surveyor.

1.8.7.4 Measurements and Recordings

Measurements and recordings of the following parameters is to be done:

Ambient test conditions:

- Air temperature
- Relative humidity
- Barometric pressure
- Characteristics of fuel and lubricating oil
- External cooling water temperature

Engine measurements:

- Engine power
- Engine rpm
- Maximum combustion pressure (indicator diagram, where feasible)
- Torque or brake load
- Turbocharger rpm
- Exhaust smoke
- Lubricating oil temperature and pressure
- Cooling water temperature and pressure

- Exhaust gas temperature in exhaust manifold and, if possible, at each cylinder outlet and for Supercharged engines
- Exhaust gas pressure & temperature at inlet and outlet of exhaust gas turbine and charge air cooler
- Air pressure and temperature at turbocharger's and cooler's inlet and outlet
- Cooling water temperature at charge air cooler inlet

Examination results after type tests: This covers disassembling and examination of the main parts and the parts subjected to wear.

1.8.7.5 Additional Tests

For engines intended for different purposes and having different performances for each purpose, type test program is to be extended to cover each performance under consideration of the harsh condition.

1.8.8 Type Testing procedure for crankcase explosion relief valves

1.8.8.1. Scope

In this Topic [1.8.8], some important type tests and standard test conditions that use methane gas and air mixture are specified. These demonstrate that crankcase explosion relief valves intended to be fitted to engines and gear cases are in satisfactory operating conditions. It is to be noted that this test procedure is applicable to explosion relief valves fitted with flame arrestors only.

Note: Where internal oil wetting of a flame arrester is a design feature of an explosion relief valve, some alternative testing arrangements may be proposed by the manufacturer as these demonstrate compliance with this Sub-section [1.7]. INTLREG should agree upon some of the alternative testing arrangements.

1.8.8.2. Recognized Standards

- i) EN 12874:2001: Flame arresters – Performance requisites, test methods and restrictions on use.
- ii) ISO/IEC EN 17025:2005: General requisites for the competence of testing and calibration laboratories.
- iii) EN 1070:1998: Safety of Machinery – Terminology.
- iv) VDI 3673: Part 1: Pressure Venting of Dust Explosions.
- v) IMO MSC/Circular 677 – Revised Standards for the Design, Testing and Locating of Devices to Prevent the Passage of Flame into Cargo Tanks in Tankers

1.8.8.3. Purpose of type testing

The purpose of type testing crankcase explosion relief valves is to verify the following:

- i) The effectiveness of the flame arrester.
- ii) Whether or not the valve closes after an explosion.
- iii) Whether or not the valve is gas/air tight after an explosion.
- iv) Establish the level of overpressure protection provided by the valve.

1.8.8.4. Test Facility requirements

So that these are acceptable to INTLREG, test facilities performing type testing of crankcase explosion relief valves are required to meet the following requirements:

- i) The test facilities are to be attributed to a National or International Standard, e.g., ISO/IEC 17025 and those are to be acceptable to INTLREG.
- ii) The test facilities are to be so equipped that they can adequately perform and record explosion testing as per the required procedure.
- iii) There are to be such equipment in the test facilities that can ably control and measure methane gas in air concentration within a test vessel to accuracy level of $\pm 0.1\%$.
- iv) The test facilities are to be capable of effective point located ignition of methane gas in air mixture.
- v) The pressure measuring equipment shall be capable of measuring the pressure in the test vessel in at least 2 positions: one at the valve and the other at the test vessel center. The measuring arrangements shall adequately measure and record the pressure changes throughout an explosion test at a frequency identifying the speed of events during an explosion. Each test result is to be documented by video recording and using a heat sensitive camera.
- vi) The dimensions of test vessel that is used for explosion testing is to be properly documented and are to be such that the vessel is not "pipe like" with the distance between dished ends not more than 2.5 times its diameter. The test vessel's internal volume is to include standpipe arrangements.
- vii) A flange is to be provided in the test vessel used for explosion testing and is to be located centrally at one end perpendicular to the vessel longitudinal axis, for mounting the explosion relief valve. The orientation of the test vessel is to be consistent with how the valve will be installed in service, i.e., in the horizontal plane or the vertical plane.
- viii) A circular plate for fitting between the pressure vessel flange and valve tested with the dimensions given below, is to be provided:
 - Outside diameter - 2 times the outer diameter of the valve top cover.
 - Internal bore with same internal diameter as the valve to be tested.
- ix) The test vessel should have connections for measurement of methane in an air mixture at the top and bottom.
- x) The test vessel is to be have means of fitting an ignition source at a position specified in Sect [1.8.8.5] below.
- xi) As far as possible, the test vessel volume is to be related to the size and capability of the relief valve to be tested. In general, the volume is to correspond to the requirement in [1.4.1.2] of this section for the free area of explosion relief valve to be not less than $115 \text{ cm}^2/\text{m}^3$ (0.505 in $2/\text{ft}^3$) of crankcase gross volume.

Notes:

- a) Means that the valve testing of a valve that possess 1150 cm^2 (178.25 in^2) of free area, would require a test vessel of a volume of 10 m^3 (353.15 ft^3).
- b) Where relief valve's free area is greater than $115 \text{ cm}^2/\text{m}^3$ (0.505 in $2/\text{ft}^3$) of the crankcase gross volume, the consistency of volume of the test vessel with the design ratio is to be maintained.
- c) The volume of the test vessel is not to vary by more than $\pm 15\%$ from the design cm^2/m^3 volume ratio, in any case.

1.8.8.5. Process for Explosion Test

Explosion tests to substantiate the functionality of crankcase explosion relief valves are to be executed using an air and methane mixture with a volumetric methane concentration of $9.5\% \pm 0.5\%$. The pressure in the test vessel is not to be less than atmospheric pressure and not exceed the opening pressure of the relief valve.

The concentration of methane in the test vessel is to be measured at the top and bottom and these concentrations are not to differ by more than 0.5%.

The ignition of the methane and air mixture is to be done at the centerline of the test vessel at a position approximately $1/3^{\text{rd}}$ of the height or length of the test vessel opposite to where the valve is mounted.

The maximum of 100 Joule (0.0947 BTU) explosive charge is to be used for ignition.

1.8.8.6. Valves to be Tested

1. The valves to be type tested [including testing specified in (iii) below] are to be chosen from the manufacturer's normal production line.
2. For approval of a specific valve size, 3 valves are to be tested as specified in (iii) below and [1.8.8.7] below. For a series of valves, refer [1.8.8.9] below.
3. The valves chosen for type testing should have been previously tested at the manufacturer's plant so that it is demonstrated that the opening pressure is as per the specification within a tolerance of $\pm 20\%$ and that the valve is airtight at a pressure below the opening pressure for at least 30 seconds.

Notes: This test is to validate that the valve is airtight after its assembly at the manufacturer's plant and that opens at the required pressure demonstrating that the correct spring is fitted.

4. The type testing of valves is to identify the orientation in which they are intended to be installed on the engine or gear case. 3 valves of each size are to be tested for each installation orientation, i.e., in the vertical and/or horizontal positions.

1.8.8.7. Method of testing

a) *General Requirements*

During explosion testing, following requirements are to be satisfied:

- i) Surveyor is to witness the explosion testing.
- ii) Where valves are installed on an engine or gear case with shielding arrangements to deflect the emission of explosion combustion products, testing of the valves is to be done with the shielding arrangements fitted.
- iii) When favorable weather conditions are found, successive explosion testing to establish a valve's functionality is to be executed as quickly as possible.
- iv) During explosion testing, the pressure rise and decay is to be recorded.
- v) During each test, the external condition of the valves is to be monitored for indication of any flame release by video and heat sensitive camera.

b) *Stages of Testing*

There are three stages of explosion testing for each valve and they all are required to be approved for being type tested.

i) Stage 1

In this Stage, 2 explosion tests are to be done in test vessel with a circular plate described in [1.8.8.4-(viii)] above fitted and the opening in the plate covered by a 0.05 mm (0.002 inch) thick polythene film.

Note: These tests establish a reference pressure level that help in the determination of the capability of a relief valve in terms of pressure rise in the test vessel (Refer Sect [1.8.8.8-(vi)] below).

ii) Stage 2

- Two explosion tests are to be done on 3 different valves of the same size and each valve is to be mounted in the orientation for which approval is sought, i.e., in the vertical or horizontal position with the circular plate described in Sect [1.8.8.4-(viii)] above located between the valve and pressure vessel mounting flange.
- The first of the two tests on each valve is to be done with a 0.05 mm (0.002 inch) thick polythene bag with a minimum diameter of thrice the diameter of the circular plate and volume not less than 30% of the test vessel and enclosing the valve and circular plate. Prior to carrying out the explosion test, the polythene bag is to be empty of air and is required to provide visible means of assessing whether there is flame transmission through the relief valve following an explosion consistent with the requirements of the standards identified in Sect [1.8.8.2] above.

Note: During the test, the explosion pressure opens up the valve and some unburned methane/ air mixture will be collected in the polythene bag. When the flame reaches the flame arrester and if gets transmitted through the flame arrester, the methane/air mixture in the bag will be ignited and will be visible.

- If the first explosion test successfully demonstrates that there was no combustion outside the flame arrester or any signs of it and there are no visible signs of damage to the flame arrester or valve, a second explosion test without the polythene bag arrangement is to be quickly done after the first test. During the second explosion test, the valve is to be visually monitored for indication of combustion outside the flame arrester and video records are to be kept for further analysis. The second test demonstrate that valve can still function in the event of a secondary crankcase explosion.
- After each explosion, the test vessel should be maintained in the closed condition for at least 10 seconds so that the tightness of the valve is ascertained. The tightness of the valve can be substantiated during the test from the pressure/time records or by separate test after the second explosion test is complete.

iii) Stage 3

In Stage 3, it is required to carry out two more explosion tests as described in Stage 1, (Refer (i) above) These provide an average base line value for assessment of pressure rise identifying that the test vessel ambient conditions may have altered during Stage 2 testing of explosion relief valves (Refer (ii)

above).

1.8.8.8. Records and Assessment

For verifying compliance with the requisites of this Topic Sect [1.8.8], assessment and records of the valves used for explosion testing is to cover the following items:

- i) The valves to be tested are to have been design approved.
- ii) The designation, characteristics and dimensions of the valves are to be tested and recorded. This is to include the free area of the valve and of the flame arrester and the amount of valve lift at 0.2 bar (0.2 kgf/cm² 2.85lbf/in²).
- iii) The volume of the test vessel is to be determined and recorded.
- iv) During explosion test, for acceptance of the functioning of the flame arrester, there must not be any indication of flame or combustion outside the valve. A lab test can help in confirming that by taking into account measurements from the heat sensitive camera.
- v) The decay and rise of pressure during an explosion is to be recorded with indication of the pressure variation that shows the maximum overpressure and steady under pressure in the test vessel during testing. In pressure vessel, the pressure variation is to be recorded at two points.
- vi) During the three stages, effect of an explosion relief valve following an explosion and in terms of pressure rise is established from maximum pressures recorded at center of the test vessel. The rise in pressure within the test vessel due to the installation of a relief valve is the difference between average pressure of the 4 explosions from Stages 1 and 3 .Refer Sect [1.8.8.7(b)]-(i) & (iii) above) and the average of the first tests on the 3 valves in Stage 2, (Refer Sect [1.8.8.7(b)]-(ii) above). The rise in pressure is not to go beyond the specified limit by the manufacturer.
- vii) After the explosion, the valve tightness is to be ascertained by verifying from records at testing time that an under pressure of at least 0.3 bar (3.06 kgf/cm², 43.5 psi) is held by the test vessel for minimum 10 seconds. The test verifies that valve has closed properly and is reasonably gas-tight after dynamic operation during an explosion.
- viii) After each explosion test in Stage 2, Refer Sect [1.8.8.7(b)]-(ii) above, the external condition of the flame arrester is to be examined for indications of serious damage and/or deformation that may affect the valve operation.
- ix) The valves should be dismantled and the condition of all components ascertained and documented, after the explosion tests are accomplished. Any indication of valve sticking or uneven opening that may affect valve operation is to be noted, in particular. Report shall have the photographic records of the valve condition.

1.8.8.9. Design Series Qualification

a) General

The quenching devices used to prevent the passage of flame can be qualified for the purpose they serve and that evaluation applies to other similar devices of identical type, where one device has been tested and found fit for the purpose.

b) Flame Arrester

The quenching ability of a flame arrester depends on the total mass of quenching lamellas/mesh. If the materials, their thickness, depth of lamellas/thickness of mesh layer and the quenching gaps are same, then

the same quenching ability can be qualified for diversely sized flame arresters, if (i) and (ii) below are satisfied.

$$(i) \frac{n_1}{n_2} = \sqrt{\frac{S_1}{S_2}}$$

$$(ii) \frac{A_1}{A_2} = \frac{S_1}{S_2}$$

Where

n_1 =total depth of flame arrester corresponding to the number of lamellas of size 1 quenching device for a valve with a relief area equal to S_1

n_2 =total depth of flame arrester corresponding to the number of lamellas of size 2 quenching device for a valve with a relief area equal to S_2 .

A_1 =free area of quenching device for a valve with a relief area equal to S_1 .

A_2 =free area of quenching device for a valve with a relief area equal to S_2

c) Valves of Larger Sizes than Have Been Satisfactorily Tested.

The qualification of large sized explosion relief valves that are larger than the earlier ones and which have been previously satisfactorily tested as specified in Sections [1.8.8.7] and [1.8.8.8] above can be evaluated again where valves are of identical type and features of construction are subjected to the following:

- i) The free area of a larger valve does not exceed three times +5% that of the valve that has been satisfactorily tested.
- ii) One valve of the largest size, subject to (i) above, requiring qualification is subject to satisfactory testing required by Sections [1.8.8.6(3)] and [1.8.8.7(b)]-(ii) above except that a single valve will be accepted in Sect [1.8.8.7(b)]-(ii) 1st point) and the volume of the test vessel is not to be less than one third of the volume required by Sect [1.8.8.4](xi).
- iii) The assessment and records are to be in accordance with Sect [1.8.8.8] above noting that Sect [1.8.8.8](vi) above will only be applicable to Stage 2 for a single valve.

d) Valves of Smaller Sizes than Have Been Satisfactorily Tested

The qualification of explosion relief valves of larger sizes than that which has been previously satisfactorily tested as per Sections [1.8.8.7] and [1.8.8.8] can be evaluated where valves are of identical type and features of construction are subjected to the following:

- i) The free area of a smaller valve is not less than 1/3rd of the valve that has been satisfactorily tested.
- ii) One valve of the smallest size, subject to (i) above, requiring qualification is subject to satisfactory testing required by Sect [1.8.8.6(3)] and [1.8.8.7(b)]-(ii) above except that a single valve will be accepted in Sect ([1.8.8.7(b)]-(ii) 1st point) and the volume of the test vessel is not to be more than the volume required by Sect [1.8.8.4](xi).
- iii) The assessment and records are to be as per Sect [1.8.8.8] above noting that Sect [1.8.8.8](vi) will only be applicable to Stage 2 for a single valve.

1.8.8.10. Reporting and acceptance

- a) Full report provided by the test facility covers the following information

and documents:

- i) Test specification.
 - ii) Test pressure vessel and valves testing details.
 - iii) The orientation in which the valve was tested, (vertical or horizontal position).
 - iv) Methane in air concentration for each test.
 - v) Ignition source
 - vi) Pressure curves for each test.
 - vii) Video recordings of each valve test.
 - viii) The assessment and records mentioned in Sect [1.8.8.8] above.
- b) An explosion relief valve is accepted on the basis of design approved plans and particulars and test facility's report of the type testing results.

1.8.9 Type Testing Procedure for Crankcase Oil Mist Detection and Alarm Equipment

1.8.9.1. Scope

The scope of this topic [1.8.9] covers the tests required for Crankcase Oil Mist Detection and Alarm Equipment. These tests will demonstrate that the equipments are to be fitted to diesel engines in conformation to a defined standard for type testing.

Note: This same test procedure will apply to oil mist detection and alarm equipment intended for gear cases.

1.8.9.2. Recognized Environmental Test Standards

Equipment tests as required by [1.5] of this section are to in line with Part-6, Ch-8, Table 8.7.3.

1.8.9.3. Purpose of type testing

The type testing of crankcase oil mist detection and alarm equipment is required to verify the following:

- i) The system functionality.
- ii) The effectiveness and the accuracy of the oil mist detectors.
- iii) The alarm set points.
- iv) Time delays between leaving of the oil mist from the source and the alarm activation.
- v) Functional failure detection.
- vi) The influence of optical obscuration on the detection.

1.8.9.4. Test Facility requirements

Following criteria needs to be fulfilled by the used test facilities that perform type testing of crankcase oil mist detection and alarm equipment:

- i) A full range of provisions for carrying out the environmental and functionality tests required by this procedure are to be available and acceptable to INTLREG.
- ii) The test facility that verifies the functionality of the equipment is to be equipped so that it can control, measure and record oil mist concentration levels in terms

of mg/l to an accuracy of $\pm 10\%$ accordance with this procedure.

1.8.9.5. Equipment Testing

The range of tests is to include . Refer Part-6-8-7/[7.2.5.1] Prototype Environmental Testing also):

- a) For the Alarm/Monitoring Panel
 - i) Functional tests stated in Sect [1.8.9.6] below.
 - ii) Dry heat test.
 - iii) Electrical power supply failure test.
 - iv) Power supply variation test.
 - v) Damp heat test.
 - vi) EMC test.
 - vii) Insulation resistance test.
 - viii) Vibration test.
 - ix) High voltage test.
 - x) Static and dynamic inclinations, if moving parts are enclosed.
- b) For the Detectors
 - i) Functional tests stated in Sect [1.8.9.6] below.
 - ii) Dry heat test.
 - iii) Electrical power supply failure test.
 - iv) Power supply variation test.
 - v) Damp heat test.
 - vi) EMC test where susceptible.
 - vii) Vibration test.
 - viii) Insulation resistance test.
 - ix) High voltage test.
 - x) Static and dynamic inclinations.

1.8.9.6. Functional Tests

- a) To verify the functionality of crankcase oil mist detection and alarm equipment, tests are to be done in line with (b) through (d) below with known oil mist concentration in air, in mg/l to $\pm 10\%$ accuracy.
- b) The oil mist concentration in the test chamber is to be measured in the top and bottom and these are not to differ by more than 10%. Refer Sect [1.8.9.8-(a)-(i)] below.
- c) The oil mist monitoring arrangements shall detect oil mist in air concentrations between 0 and 10% of the lower explosive limit (LEL) or between 0 and percentage corresponding to a level not less than two times the maximum oil mist concentration alarm set point.

Note: The LEL corresponds to an oil mist concentration of approximately 50 mg/l

(~4.1% weight of oil-in air mixture).

- d) The alarm set point for oil mist concentration in air is to provide an alarm at a maximum level corresponding to not more than 5% of the LEL or approx. 2.5 mg/l.
- e) When alarm set points are altered, the means of their adjustment and indication of set points are to be substantiated against the equipment manufacturer's instructions.
- f) Where using piping arrangements, oil mist is drawn into a detector/monitor, the time delay between the leaving of the sample from the crankcase and the alarm activation is to be determined for the longest and shortest lengths of pipes recommended by the manufacturer. The pipe arrangements are to be as per manufacturer's instructions/recommendations.
- g) It is to be demonstrated that detector equipment openings that comes in contact of crankcase atmosphere and may be exposed to oil splash and spray from engine lubricating oil, do not occlude or become obstructed if such conditions persist for long time. Testing is to be as per the proposed arrangements on which manufacturer and INTLREG have mutually agreed.
- h) It is to be demonstrated that if exposed to water vapor from the crankcase atmosphere, affecting the detector equipment's sensitivity, it will still not affect the functionality and operability of the detector equipment. Where exposure to water vapor and/or water condensation has been identified as a source of equipment malfunctioning, testing shall demonstrate that any mitigating arrangements, such as heating, are effective. Testing is to be in line with arrangements proposed by the manufacturer and agreed by INTLREG.

Note: In addition to that required by [1.8.9.5-(b)-(v)] above, the testing is concerned with the condensation effects that result from the fact that detection equipment are at a lower temperature than the crankcase atmosphere.

1.8.9.7. Detectors and Alarm Equipment to be Tested

For type testing, detectors and alarm equipment are to be selected by the Surveyor from the usual production line of the manufacturer.

Two detectors, in two different conditions are to be tested. While one is to be tested in the clean condition, other in a condition that represents the maximum level of lens obscuration stated by the manufacturer.

1.8.9.8. Method of testing

During type testing, following requirements are to be met:

- a) Oil mist generation is required to satisfactorily meet the requisites of (i) to (v) given below.
 - i) Using a suitable equipment, oil mist is to be generated. This oil mist uses SAE 80 monograde mineral oil or equivalent and is supplied to a test chamber with volume of not less than 1 m³. 5 µm is the maximum droplet size of the oil mist i.e. produced.

Note: Sedimentation method is to be employed to check the oil droplet size.
 - ii) Gravimetric deterministic method or equivalent are employed to ascertain the oil mist concentrations used.

Note: For the test, this method is a process where the weight difference of a 0.8 µm pore size membrane filter is ensured from weighing the filter prior to and after drawing 1 L of oil mist through the filter from the oil mist test chamber. For the same purpose, a recalculating fan is to be fitted in the oil mist chamber.

- iii) Oil mist samples are to be taken out at regular intervals and the results so derived are to be plotted against the oil mist detector output. The detector is to be located just in line from where oil mist samples are withdrawn.
 - iv) The gravimetric analysis results are considered invalid and are therefore rejected, if the resultant calibration curve has an increasing gradient with respect to the oil mist detection reading. This occurs when inadequate time is given for the homogenization of oil mist. In the same way, single results which are more than 10% below the calibration curve are to be rejected. This occurs when the integrity of the filter unit has been compromised and all the oil is not collected on the filter paper.
 - v) The filters are to be weighed to a precision of 0.1 mg and the volume of air/oil mist sampling is to be 10 ml.
- b) Surveyor is required to witness the testing.
 - c) All the oil mist detection equipment is to be tested in that orientation (vertical, horizontal or inclined) in which will be installed on an gear case or engine. This is specified by the manufacturer of the equipment.
 - d) Type testing for each type of oil mist detection and alarm equipment for which a manufacturer seeks approval, is to be executed. Where adjustment of sensitivity levels is possible, testing is executed at the extreme and mid-point level settings.

1.8.9.9. Assessment

Following parameters are to be assessed with respect to of oil mist detection equipment after testing:

- i) For approval of its design, the equipment to be tested is assessed.
- ii) The details of the detection equipment to be tested are to be recorded, like the name of manufacturer, type designation, alarm settings and oil mist concentration assessment capability.
- iii) After tests are accomplished, the detection equipment is to be examined and the condition of all components ascertained and documented. Reports are to also include photographic records of the monitoring devices condition.

1.8.9.10. Design Series Qualification

Once one type of detection equipment is approved, the same may be used to qualify other devices with similar construction details. Thus, proposals may be submitted for consideration.

1.8.9.11. Reporting and acceptance

- a) The full report which includes the following information and documents is presented by the test facility:
 - i) Test specification.
 - ii) Details of equipment tested.
 - iii) Test results.

b) Acceptance

The crankcase oil mist detection equipment is accepted on the basis of the design approved plans and particulars and report of type testing furnished by test facility. For the acceptance purpose, the following information is to be submitted:

- i) Detailed description of oil mist detection equipment and system including alarms.
- ii) A copy of the test facility's report identified in Sect [1.8.9.11] above.
- iii) A schematic layout of engine oil mist detection arrangements wherein location of detectors/ sensors and piping arrangements and dimensions is properly shown.
- iv) Test and Maintenance manual is to include the following:
 - Limit setting and instructions for risk free limit levels.
 - Maintenance routines and spare parts recommendations.
 - Intended use of equipment and its operation.
 - Functionality tests to demonstrate that equipment is operational and that any faults can be identified and corrective actions notified.
 - Where required, details of configurations where the equipment is intended to be used and where not.

1.9 Certification, Approval Plans and Data for Diesel Engines

1.9.1. Certification of Diesel Engine

1.9.1.1. General

Each diesel engine required to be approved and certified as per the provisions of [1.1.1] of this section in the following manner:

- i) To have necessary design approval of the engines(s) and for which, plans and data as per [1.1.5] of this section are to be submitted to INTLREG; and the engine's performance is to be verified with help of a type test that is to be conducted in the presence of a Surveyor as specified in [1.8.5] or [1.8.7] of this section, as appropriate;
- ii) It is to be surveyed during its construction covering but not restricting it to the survey of material and nondestructive tests as per [1.8.1] of this section, hydrostatic tests of components as indicated in [1.8.2] of this section, and tests and setting of relief valves, as applicable; and
- iii) A performance test is to be conducted as specified in [1.8.6] of this section and to the satisfaction of a Surveyor on the finished unit.

1.9.1.2. Certification under Type Approval Program

- a) Product design assessment. Product design assessment. Upon manufacturer's application, each model of a type of diesel engine may be design assessed as mentioned in Part-1, Ch-1, Sec-11. Each design of an engine type is to be approved as per [1.9.1.1(i)] above. Engines so approved may be applied to INTLREG for listing on the INTLREG website in the Design Approved Products Index [refer Part-1, Ch-1, Sec 11 (DA)]. Once listed, and subject to renewal and updating of certificate as specified in Part-1, Ch-1, Sect 11 it is not required to submit engine particulars to INTLREG each time the engine is proposed for use on board a vessel.
- b) Mass produced engines. Manufacturer of mass-produced engines, who runs a quality assurance system in the manufacturing plant, may apply

to INTLREG for a quality assurance assessment, as mentioned in Part-1, Ch-1, Sec-11 (PQA).

After satisfactory assessment under Part-1, Ch-1, Sec-11(PQA), engines produced in those plants will not require a Surveyor's attendance at the tests and inspections as given in [1.9.1.1]-(ii) & (iii) above. Such tests and inspections are to be executed by the manufacturer whose quality control documents will be accepted. Certification of each engine will be based on verification of approval of the design and on continued effectiveness of the quality assurance system. Refer Part-1, Ch-1, Sec-11.

- c) Non-mass Produced Engines. The manufacturers of non-mass produced engines, who runs a quality assurance system in the manufacturing plants, may apply to INTLREG for a quality assurance assessment, as described in Part-1, Ch-1, Sec-11 (AQS) or Part-1, Ch-1, Sec-11 (RQS). Certification to Part-1, Ch-1, Sec-11(PQA) may also be considered as specified in Chapter 1, Table 1.2.1.
- d) Type Approval Program. Engine types which have their designs approved as specified in (a) above and the quality assurance system of their manufacturing facilities approved as mentioned in (b) or (c) above will be deemed Type Approved and will be qualified for listing on the INTLREG website as Type Approved Products.

1.9.2. Plans and Data for Diesel Engines

For each type of engine that seeks approval, its manufacturer needs to submit the plans and data listed in the Table-2.1.3 and Table 2.1.4 below and as applicable to the type of engine for approval (A), approval of materials and weld procedure specifications (A*), or for information (R). After INTLREG gives the approval of an engine type for the first time, only those documents listed in the table which have undergone applicable changes will have to be submitted again for their consideration. In cases, where both (A*) and (R) are shown, the first refers to welded components and the second to cast components.

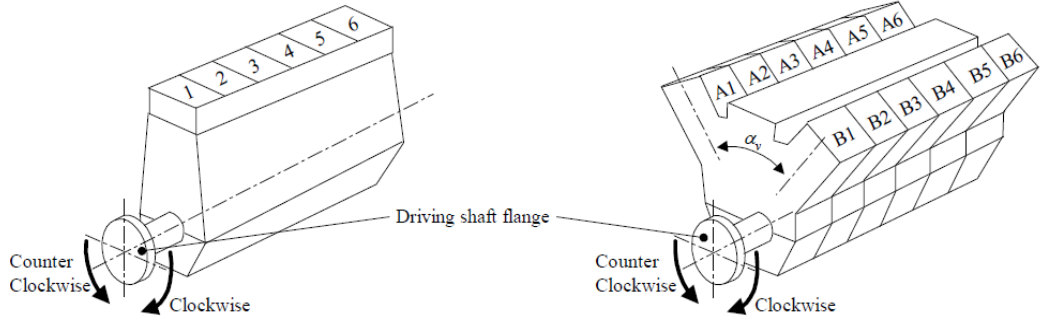
Table 2.1.3: Plans and Data for Diesel Engines

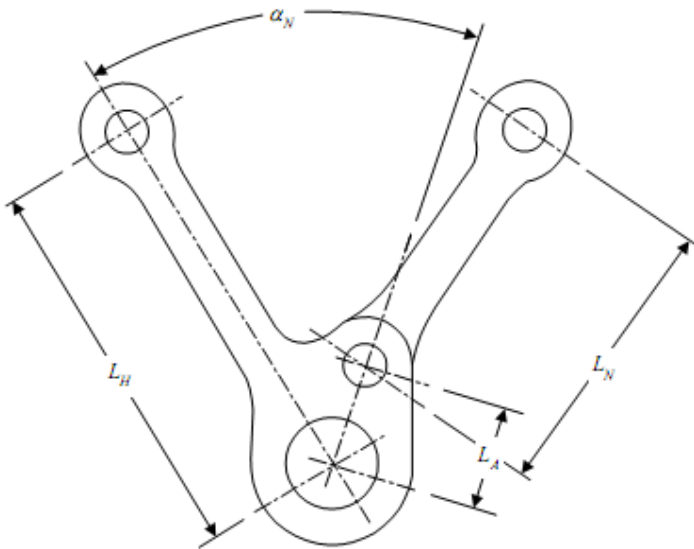
No.	A/R	Item
1	R	Engine particulars as per attached sheet
2	R	Engine transverse cross-section
3	R	Engine longitudinal section
4	R/A*	Bedplate and crankcase, cast or welded with welding details and instructions (Refer note 9)
5	R	Thrust bearing assembly (Refer note 3)
6	R/A*	Thrust bearing bedplate, cast or welded with welding details and instructions (Refer note 9)
7	R/A*	Frame/frame box, cast or welded with welding details and instructions (Refer note 1,9)
8	R	Tie rod
9	R	Cylinder head, assembly
10	R	Cylinder liner
11	A	Crankshaft, details each cylinder No.
12	A	Crankshaft, assembly, each cylinder No.

No.	A/R	Item
13	A	Thrust shaft or intermediate shaft (if integral with engine)
14	A	Shaft coupling bolts
15	A	Counterweights (if not integral with crankshaft) including fastening
16	R	Connecting rod
17	R	Connecting rod, assembly
18	R	Crosshead, assembly (Refer note 2)
19	R	Piston rod, assembly (Refer note 2)
20	R	Piston, assembly
21	R	Camshaft drive, assembly
22	A	Material specifications of main parts with information on nondestructive testing and pressure tests (Refer note 8)
23	R	Arrangement of foundation (for main engines only)
24	A	Schematic layout or other equivalent documents of starting air system on the engine (Refer note 6)
25	A	Schematic layout or other equivalent documents of fuel oil system on the engine (Refer note 6)
26	A	Schematic layout or other equivalent documents of lubricating oil system on the engine (Refer note 6)
27	A	Schematic layout or other equivalent documents of cooling water system on the engine (Refer note 6)
28	A	Schematic diagram of engine control and safety system on the engine (Refer note 6)
29	R	Shielding and insulation of exhaust pipes, assembly
30	A	Shielding of high pressure fuel pipes, assembly (Refer note 4)
31	A	Arrangement of crankcase explosion relief valve (Refer note 5)
32	R	Operation and service manuals (Refer note 7)
33	A	Schematic layout or other equivalent documents of hydraulic systems (for valve lift) on the engine
34	A	Type test program and type test report
35	A	High pressure parts for fuel oil injection system (Refer note 10)
Notes: - For only one cylinder - Required only if adequate details are not shown on the transverse cross section and longitudinal section - If integral to the engine and not integrated in the bedplate - For all engines - For engines with a cylinder diameter of 200 mm or more or a crankcase volume of 0.6 m³ or more - For the system, if supplied by the engine manufacturer. Where engines is equipped with electronic control systems, a failure mode and effects analysis (FMEA) is to be submitted to demonstrate that their failure will not result in the loss of vital services for the engine's operability and that operation of the engine will not be lost or degraded beyond an acceptable performance criteria. - Operation manuals and service manuals are to comprise of maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fittings/settings together with test requirements when maintenance is done.		

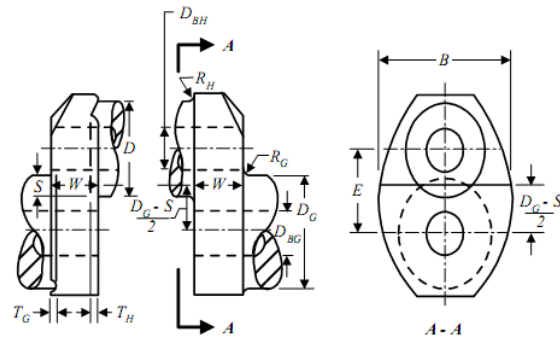
No.	A/R	Item
8.		For comparison with requirements for material, NDT and pressure testing, as applicable.
9.		The weld procedure specification is to cover details of pre and post weld heat treatment, weld consumables and fit-up conditions.
10.		The documentation is to comprise of pressures, pipe dimensions and materials specifications.

Table 2.1.4: Data Sheet for Calculation of Crankshafts for Diesel Engines

1.	Engine Builder		
2.	Engine Type Designation		
3.	Stroke-Cycle	☐ 2 SCSA	☐ 4 SCSA
4.	Kind of engine ☐ In-line engine ☐ V-type engine with adjacent connecting rods ☐ V-type engine with articulated-type connecting rods ☐ rods V-type engine with forked/inner connecting rods ☐ Crosshead engine ☐ Trunk piston engine		
5.	Combustion Method ☐ Direct injection ☐ Pre-combustion chamber ☐ Others:		
6.	 Figure 2.1.14: Designation of the cylinders		
7.	Sense of Rotation (corresponding to Sl. No. 6) ☐ Clockwise ☐ Counter clockwise		
8.	Firing Order (corresponding to Sl. No. 6 and 7)		
9.	Firing Intervals [deg] (corresponding to Sl. No. 8)		
10.	Rated Power		kW

11.	Rated Engine Speed		1/min
12.	Mean Effective Pressure		bar
13.	Mean Indicated Pressure		bar
14.	Maximum Cylinder Pressure (Gauge)		bar
15	Charge Air Pressure (Gauge) (before inlet valves or scavenge ports)		bar
16	Nominal Compression Ratio		–
17	Number of Cylinders		–
18	Diameter of Cylinders		mm
19	Length of Piston Stroke		mm
20	Length of Connecting Rod (between bearing centers)		mm
21	Oscillating Mass of One Cylinder (mass of piston, rings, pin, piston rod, crosshead, oscillating part of connecting rod)		kg
22	Digitalized Gas Pressure Curve (Gauge) – presented at equidistant intervals [bar versus crank angle] – (intervals not more than 5° CA) ☐ given in the attachment		
Additional Data of V-Type Engines			
23	V-Angle α_v (corresponding to Figure in Item 6)		deg
For the Cylinder Bank with Articulated-type Connecting Rod (Dimensions corresponding to Figure in Item 27)			
24	Maximum Cylinder Pressure (Gauge)		bar
25	Charge Air Pressure (Gauge) (before inlet valves or scavenge ports)		bar
26	Nominal Compression Ratio		
27	 Articulated-type connecting rod		
28	Distance to Link Point L_A		mm

29	Link Angle α_N		deg
30	Length of Connecting Rod L_N		mm
31	Oscillating Mass of One Cylinder (mass of piston, rings, pin, piston rod, crosshead, oscillating part of connecting rod)		kg
32	Digitalized Gas Pressure Curve (Gauge) – presented at equidistant intervals [bar versus crank angle] – (intervals not more than 5° CA) ☐ given in the attachment		
For the Cylinder Bank with Inner Connecting Rod			
33	Oscillating Mass of One Cylinder (mass of piston, rings, pin, piston rod, crosshead, oscillating part of connecting rod)		kg
Data of Crankshaft (Dimensions corresponding to Figure in Item 39)			
Note: For asymmetric cranks the dimensions are to be entered both for the left and right part of the crank throw.			
34	Drawing No.		
35	Kind of crankshaft (e.g., solid-forged crankshaft, semi-built crankshaft, etc.)		
36	Method of Manufacture (e.g., free form forged, cast steel, etc.): ☐ Description of the forging process – if c.g.f forged or drop-forged – given in the attachment		
37	Heat treatment (e.g., tempered)		
38	Surface Treatment of Fillets, Journals and Pins (e.g., induction hardened, nitrided, rolled, etc.): ☐ Full details given in the attachment		
39	Crank throw for in-line engine Crank throw for engine with 2 adjacent connecting rods		



Crank dimensions necessary for the calculation of stress concentration factors

40	Crankpin Diameter D		mm
41	Diameter of Bore in Crankpin D_{BH}		mm
42	Fillet Radius of Crankpin R_H		mm
43	Recess of Crankpin T_H		mm
44	Journal Diameter D_G		mm
45	Diameter of Bore in Journal D_{BG}		mm
46	Fillet Radius of Journal R_G		mm
47	Recess of Journal T_G		mm
48	Web Thickness W		mm
49	Web Width B		mm
50	Bending Length L_1		mm
51	Bending Length L_2		mm
52	Bending Length L_3		mm
53	Oil Bore Design ☐ Safety margin against fatigue at the oil bores is not less than acceptable in the fillets		
54	Diameter of Oil Bore		mm
55	Smallest Edge Radius of Oil Bore		mm
56	Surface Roughness of Oil Bore Fillet		μm
57	Inclination of Oil Bore Axis related to Shaft Axis		deg
Additional Data for Shrink-Fits of Semi-Built Crankshafts (dimensions corresponding to Figure in Item 58)			

58	Crank throw of semi-built crankshaft		
59	Shrink Diameter D_S		mm
60	Length of Shrink-Fit L_S		mm
61	Outside Diameter of Web D_A or Twice the Minimum Distance x (the smaller value is to be entered)		mm
62	Amount of Shrink-Fit (upper and lower tolerances)		mm
			%
63	Maximum Torque (ascertained according to Sect [1.3.5.3] of this section with consideration of the mean torque)		N-m
Data of Crankshaft Material <u>Note:</u> Minimum values of mechanical properties of material obtained from longitudinal test specimens			
64	Material Designation (according to DIN, AISI, etc.)		
65	Method of Material Melting Process (e.g., open-hearth furnace, electric furnace, etc.)		
66	Tensile Strength		N/mm ²
67	Yield Strength		N/mm ²
68	Reduction in Area at Break		%
69	Elongation A5		%
70	Impact Energy – KV		J
71	Young's Modulus		N/mm ²
Additional Data for Journals of Semi-Built Crankshafts			
72	Material Designation (according to DIN, AISI, etc.)		
73	Tensile Strength		N/mm ²
74	Yield Strength		N/mm ²
Data according to calculation of torsional stresses			
75	Max. nominal alternating torsional stress (ascertained by means of a harmonic synthesis according to Sect [1.3.5.3] of this section and		N/mm ²

	related to cross- sectional area of bored crank pin)		
76	Engine speed (at which the max. nominal alternating torsional stress occurs)		N/mm ²
77	Minimum engine speed (for which the harmonic synthesis was carried out)		N/mm ²
Data of stress concentration factors (S.C.F.) and/or fatigue strength furnished by reliable measurements <u>Note:</u> To be filled in only when data for stress concentration factors and/or fatigue are furnished by the engine manufacturer on the basis of measurements. Full supporting details are to be enclosed.			
78	S.C.F. for Bending in Crankpin Fillet α_B		–
79	S.C.F. for Torsion in Crankpin Fillet α_T		–
80	S.C.F. for Bending in Journal Fillet β_B		–
81	S.C.F. for Shearing in Journal Fillet β_Q		–
82	S.C.F. for Torsion in Journal Fillet β_T		–
83	Allowable Fatigue Strength of Crankshaft σ_{DW}		N/mm ²
Remarks			
Manufacturer's Representative.....		Date	

1.10 Shipboard Trials of Diesel Engines

After the conclusion of the running-in program, diesel engines are to undergo shipboard trials in the presence of a Surveyor, in accordance with the following procedure. Tests other than those listed below may be required by statutory instruments (e.g., EEDI verification).

1.10.1 Engines Driving Fixed Pitch Propellers or Impellers

For main propulsion engines directly driving fixed pitch propellers or impellers, the following running tests are to be carried out:

- i) For at least 4 hours at rated engine speed (n_0)
- ii) For at least 2 hours, at engine speed corresponding to the continuous cruising power
- iii) Where permitted by engine adjustment, at engine speed $n = 1.032 n_0$ for 30 minutes
- iv) Starting and reversing maneuvers.
- v) At minimum on load speed.
- vi) In direction opposite to propeller rotation, at a minimum engine speed of $n = 0.7n_0$ for 10 minutes.
- vii) Testing of safety and monitoring systems

At approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer During stopping tests according to Resolution MSC.137 (76)

1.10.2 Engines Driving Controllable Pitch Propellers

For main propulsion engines driven by reversing gears or controllable pitch propellers, tests as per Sect [1.10.1] above apply or as appropriate. Additionally controllable pitch propellers are to be tested with various propeller pitches. With reverse pitch suitable for maneuvering, Refer Sect [1.10.1] for additional requirements in the case of a barred speed range.

1.10.3 Engines Driving Propulsion Generators,

Main Power Supply Generators and / or Emergency Generators

The running tests are to be carried out at the rated speed under the following conditions:

- i) At 100% power (rated electrical power of generator) for at least 60 min.
- ii) At 110% power (rated electrical power of generator) for at least 10 min.

Each engine is to be tested at 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 generator 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.

- iii) Demonstration of the generator prime movers' and governors' ability to handle load steps

1.10.4 Engines Driving Auxiliaries

Engines driving auxiliaries are to be subjected to an operational test at 100% power (MCR) at corresponding speed n_O for at least 30 min, and at approved intermittent overload (testing for duration as approved).

1.10.5 Engines Burning Residual Fuel Oil or Other Special Fuel Oils

The suitability of propulsion and auxiliary diesel engines to burn residual fuel oils or other special fuel oils, where they are intended to burn such fuel oils in service, is to be demonstrated.

1.10.6 Torsional Vibration Barred Speed Range

Where torsional vibration analyses indicate that a torsional vibration critical is within the engine operating speed range, the conduct of torsi graph tests and marking of the barred speed range, as appropriate

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.

Notes:

- 1) Applies both for manual and automatic passing-through systems;
- 2) 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
- 3) The engine is to be checked for stable running (steady fuel index) at both upper and lower borders of the bsr. Steady fuel index means an oscillation range less than 5% of the effective stroke (idle to full index).

1.10.7 ***Propulsion Engines also Driving Power Take Off (PTO) Generator***

The running tests are to be carried out at the rated speed, under the following conditions:

- i.) 100% engine power (MCR) at corresponding speed n_O for at least 4 hours
- ii) 100% propeller branch power at engine speed n_O (unless already covered in the above test) for 2 hours.
- iii) 100% PTO branch power at engine speed n_O for at least 1 hour

1.11 Spare Parts

1.11.1. General

For classification purposes, spare parts are not required. Yet, the spare parts list given in Table 2.1.5 and Table 2.1.6 below is provided as guidance for vessels intended for unrestricted service. Depending on the engine design, some other spare parts other than those listed below, like electronic control cards, should also be considered as recommended by Manufacturer.

Table 2.1.5: Spare Parts for Main Propulsion Diesel Engines

Spare Parts	Description	Number Recommended
Main bearings	Main bearings or shells for one bearing of each size and type fitted, complete with shims, bolts and nuts	1 set
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 set
	Inner and outer race with rollers, where roller-thrust bearings are fitted	1
Cylinder liner	Cylinder liner, complete with joint ring and gaskets for one cylinder	1
Cylinder cover	Cylinder cover, complete with all valves, joint rings and gaskets.	1
	Cylinder-cover bolts and nuts, for one cylinder	1/2 set
Cylinder valves	Exhaust valves, complete with castings, 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
	Relief valve, complete	1
	Engines with one or two fuel valves per cylinder: fuel valves complete with springs and fittings for half the number of cylinders on one engine	As applicable
	Engines with three or more fuel valves per cylinder: two fuel valves complete per cylinder for half the number of cylinders on one engine and a sufficient number of valve parts, excluding the body, to form with those fitted on each cylinder for a complete engine set	As applicable
Cylinder cooling	Cooling pipes, fittings, and seals or their equivalent for one cylinder unit	1 set
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
Cross-head bearing lubrication	Engines fitted with a separate attached pump for lubrication of cross-head bearing, a complete pump with fittings for one cylinder unit	1
Pistons	Cross-head 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
Piston rings	Piston rings of each type for one cylinder	1 set
Piston cooling	Telescopic cooling pipes, fittings and seals or their equivalent, for one cylinder unit	1 set
Gear and chain for camshaft drivers	Gear wheel drive: Wheels for the camshaft drive of one engine	1 set
	Chain Drive: Separate links with pins and rollers of each size and type fitted.	6

Spare Parts	Description	Number Recommended
	Bearings bushes of each type fitted	1 set
Cylinder lubricators	Lubricator, complete, of the largest size, with its chain drive or gear wheels, or equivalent spare part kit	1
Fuel-injection pumps	Fuel pump complete or when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valve springs, etc.), or equivalent high pressure fuel pump	1
Fuel pump cams	Engines fitted with separate cams for ahead and astern drive for the fuel pump: One piece of cam nose with fittings for each ahead and astern drive for one cylinder unit	1 set
Fuel injection piping	High pressure double wall fuel pipe of each size and shape fitted, complete with couplings	1 set
Scavenge blowers (including turbochargers)	Bearings, nozzle rings, gear wheels and complete attached lubricating pump or equivalent working parts of other types. [Note: Where an engine with one blower out of action can be maneuvered satisfactorily, spare parts, except for the necessary blanking arrangements, may be omitted.]	1 set
Scavenging system	Suction and delivery valves for one pump of each type fitted	1/2 set
Overspeed governors	A complete set of working parts for one governor	1 set
Gaskets and packings	Special gaskets and packings of each size and type fitted for cylinder covers and cylinder liners for one cylinder	1 set
Tools	Necessary special tools	1 set

Table 2.1.6: Spare Parts for Auxiliary Diesel Engines

Spare Parts	Description	Number Recommended
Main bearings	Main bearings or shells for one bearing of each size and type fitted, complete with shims, bolts and nuts	1
Cylinder valves	Exhaust valves, complete with casings, seats, springs and other fittings in 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
	Relief valve, complete	1
	Fuel valves of each size and type fitted, complete with all fittings for one engine	1/2 set
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
Piston rings	Piston rings, for one cylinder	1 set
Piston cooling	Telescopic cooling pipes and fittings or their equivalent for one cylinder unit	1 set
Fuel-injection pumps	Fuel pump complete or, when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valve springs, etc.), or equivalent high pressure fuel pump	1
Fuel-injection piping	High-pressure double wall fuel pipe of each size and shape fitted, complete with couplings	1
Gaskets and packings	Special gaskets and packings of each size and type fitted, for cylinder covers and cylinder liners for one cylinder	1 set

SECTION 2 TURBOCHARGERS

Contents

2.1 General Requirements.....110

2.2 Materials requirements 112

2.3 Design Requirements and Corresponding Type Testing 113

2.4 Piping systems, Alarms & Monitoring 114

2.5 Turbocharger Installation 115

2.7 Spare Parts 118

2.1 General Requirements

2.1.1 Application

Turbochargers for diesel engines rated 100 kW (135 hp) and over, intended for propulsion and auxiliary services essential for propulsion, maneuvering and safety of the vessel Refer Chapter1,Section1,[1.1] (Propulsion and maneuvering capability) are to be designed, constructed, tested, certified and installed .

Turbochargers for diesel engines rated less than 100 kW (135 hp) are to be designed, constructed and equipped in accordance with good commercial and marine practice Acceptance of such turbochargers will be based on manufacturer's affidavit, verification of turbocharger nameplate data-and subjected to a satisfactory performance test after installation conducted in the presence of the Surveyor.

2.1.2 General Definitions

2.1.2.1 Turbocharger

The term 'Turbocharger' in this section refers to superchargers, turbo blowers; scavenge blowers and other similar equipment designed to modify the diesel engine cylinders with air at a higher pressure and hence higher density than air at atmospheric pressure.

Turbochargers are to be type approved, either separately or as a part of an engine.

Turbochargers are categorized 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

2.1.2.2 Maximum operating speed

The maximum operating speed is the maximum permissible speed for which the turbocharger is designed to run continuously at the maximum permissible operating temperature. This speed is used for making strength calculations.

2.1.3 Documents to be submitted

2.1.3.1 Turbocharger construction

- a) Turbochargers of category A
 - Containment test report
 - Cross sectional drawing with principal dimension and names of components
 - Test program
- b) Turbochargers of categories B and C
 - Cross sectional drawing with principal dimensions and materials of housing components for
 - containment evaluation
 - Documentation of containment in the event of disc fracture
 - Maximum permissible operating speed (rpm)
 - Alarm level for over-speed

- Maximum permissible exhaust gas temperature before turbine
 - Alarm level for exhaust gas temperature before turbine
 - Minimum lubrication oil inlet pressure
 - Lubrication oil inlet pressure low alarm set point
 - Maximum lubrication oil outlet temperature
 - Lubrication oil outlet temperature high alarm set point
 - Maximum permissible vibration levels (i.e., self- and externally generated vibration). (Alarm levels may be equal to permissible limits but shall not be reached when operating the engine at 110% power or at any approved intermittent overload beyond the 110%).
 - Arrangement of lubrication system, all variants within a range
 - Type test reports
 - Test program
- c) Turbochargers of category C
- Drawings of the housing and rotating parts including details of blade fixing
 - Material specifications (chemical composition & mechanical properties) of all parts mentioned above
 - Welding details and welding procedure of above mentioned parts, if applicable
 - Documentation of safe torque transmission when the disc is connected to the shaft by an interference fit (applicable to two sizes in a generic range of turbochargers)
 - Information on expected lifespan, considering creep, low cycle fatigue and high cycle fatigue
 - Operation and maintenance manuals (applicable to two sizes in a generic range of turbochargers)

2.1.3.2 Turbocharger system and appurtenances

- Lubrication system
- Cooling system

2.1.3.3 Data

- a) Turbochargers for engines with cylinder bores ≤ 300 mm (11.8 in.):
- Operating speed and temperatures
 - Speed and temperature limitations
 - Balancing data
 - Type test data
- b) Turbochargers for engines with cylinder bores > 300 mm (11.8 in.):
- Operating speed and temperatures
 - Speed and temperature limitations
 - Mass and velocity of rotating elements
 - Balancing data

- Type test data

2.1.3.4 Materials

- a) Turbochargers for engines with cylinder bores ≤ 300 mm (11.8 in.):
 - Material specifications with details of welding and surface treatments
- b) Turbochargers for engines with cylinder bores > 300 mm (11.8 in.):
 - Material specifications with details of welding and surface treatments, including density, Poisson's ratio, range of chemical composition, room-temperature physical properties and, where material is subject to temperatures more than 427°C (800°F), the high-temperature strength characteristics as well as creep rate and rupture strength for the design service life.

2.1.3.5 Calculation and analyses

- a) Turbochargers for engines with cylinder bores > 300 mm (11.8 in.):
 - Design basis and design analyses for turbine and compressor rotors and blading including calculations and test results to validate the suitability and strength of components for the intended service.

2.2 Materials requirements

2.2.1 Material specifications and purchase orders

Materials that are used in the construction of turbochargers are to conform to approved specifications in connection with the design in each case. For the purpose of information and verification, the copies of the same material specifications and purchase orders are to be submitted to the Surveyor.

2.2.2 Engines with cylinder bore ≤ 300 mm (11.8 in.)

Surveyor need not verify the materials for turbochargers intended for engines with cylinder bore ≤ 300 mm. However, the turbocharger manufacturer is to be assured of the quality of the material

2.2.3 Engines with cylinder bore > 300 mm (11.8 in.)

Materials are to meet specifications mentioned in Part: 2, Chapter: 2 (Materials for machinery) or that approved in connection with the design. Except as mentioned in section [2.2.4], materials for turbocharger intended for engines with cylinder bore > 300 mm (11.8 in) are to be tested in presence of Surveyor

2.2.3.1 Forgings: compressor and turbine rotors and shafts.

2.2.3.2 Blade Material

2.2.4 Alternative material test requirements

2.2.4.1 Alternative specifications

Materials manufactured as per the specifications other than those stated under Part 2, Chapter 2 may be accepted, provided that those are approved in connection with the design and also verified or tested by a Surveyor complying with the he specifications.

2.2.4.2 Steel-bar stock

Hot-rolled steel bars of diameter up to 305 mm (12 in.) may be used when approved to be used in place of any of the forgings as mentioned in [2.2.3.1] above

2.2.4.3 Certification under quality assurance assessment

Turbochargers certified under quality assurance assessment as mentioned in section [2.6.2.2] (b), material tests and inspections mentioned in Sect [1.2.1] need not be witnessed by the Surveyor. Such tests are to be conducted by the turbocharger manufacturer whose certified material test reports will be accepted instead.

2.3 Design Requirements and Corresponding Type Testing

2.3.1 General

The turbochargers are to be designed to operate under conditions given in Table 8.2.9 and Table 8.2.10

The component lifetime and the alarm level for speed are to be based on 45°C air inlet temperature.

The air inlet of turbochargers is to be fitted with a filter.

2.3.2 Turbochargers are to fulfill 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.

2.3.2.1 For turbochargers of categories B and C, containment is to be documented by testing. Fulfillment of this requirement can be awarded to a generic range of turbochargers based on testing of one specific unit. Testing of a large unit is preferred as this is considered conservative for all smaller units in the generic range. In any case, it is to be documented (e.g., by calculation) that the selected test unit really is representative for the whole generic range.

The minimum test speeds, relative to the maximum permissible operating speed, are:

- For the compressor: 120%
- For the turbine: 140% or the natural burst speed, whichever is lower

Containment tests are to be performed at working temperature.

A numerical analysis (simulation) of sufficient containment integrity of the casing based on calculations by means of a simulation model may be accepted in lieu of the practical containment test, provided that:

- i) 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 is to be performed at least once by the manufacturer for acceptance of the numerical simulation method in lieu of tests.
- ii) The corresponding numerical simulation for the containment is performed for the same speeds as specified for the containment test.
- iii) 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.
- iv) The design of the turbocharger regarding geometry and kinematics is similar to the turbocharger that was used for the reference containment test. In general, totally new designs will call for a new reference containment test.

2.3.2.2 Disc-shaft Shrinkage Fit (applicable to turbochargers of category C)

In cases where the disc is connected to the shaft with interference fit, calculations are to substantiate safe torque transmission during all relevant operating conditions such as maximum speed, maximum torque and maximum temperature gradient combined with minimum shrinkage amount.

2.3.2.3 Type Testing (applicable to turbochargers > 1000 kW)

The type test for a generic range of turbochargers may be carried out either on an engine (for which the turbocharger is foreseen) or in a test rig.

Turbochargers are to be subjected to at least 500 load cycles at the limits of operation. This test may be waived if the turbocharger together with the engine is subjected to this kind of low cycle testing.

The suitability of the turbocharger for such kind of operation is to be preliminarily stated by the manufacturer. The rotor vibration characteristics are to be measured and recorded in order to identify possible sub-synchronous vibrations and resonances.

The type test is to be completed by a hot running test at maximum permissible speed combined with maximum permissible temperature for at least one hour. After this test, the turbocharger is to be opened for examination, with focus on possible rubbing and the bearing conditions.

2.4 Piping systems, Alarms & Monitoring

The lubricating oil and cooling water piping systems of turbochargers are to be in line with the provisions of Chapter 8, Sec-4, [4.3]&[4.4], respectively

For all turbochargers over 1000 kW, indications and alarms as listed below are required. Indications may be provided at either local or remote locations

Monitored Parameters	Turbochargers category B		Turbochargers category C		Notes
	Alarm (High) (4)	Indication (4)	Alarm (High) (4)	Indication (4)	
Speed					
Exhaust gas at each turbocharger inlet, temperature	Alarm (High) (1)	Indication (1)	Alarm (High)	Indication	High temp. alarms for each cylinder at engine is acceptable (2)
Lube. oil at turbocharger outlet, temperature			Alarm (High)	Indication	If not forced system, oil temperature near earings
Lube. oil at turbocharger inlet, pressure	Alarm (Low)	Indication	Alarm (Low)	Indication	Only for forced lubrication systems (3)

Notes:

- 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.

2.5 Turbocharger Installation

2.5.1 Air inlet

A filter is to be fitted in the air inlet of the turbocharger to minimize the possibility of the entrance of harmful foreign materials or water.

2.5.2 Hot surfaces

Hot surfaces which are likely to come into contact with the crew are to be water-jacketed or effectively insulated. Where the temperature of hot surfaces is to exceed 220°C (428°F) and where any leakage, under pressure or otherwise, of fuel oil, lubricating oil or other flammable liquid is to occur and where these substances may come into contact with such surfaces, suitable insulation with non-combustible materials that are impervious to such liquids is required. Insulation material that is not impervious to oil is required to be encased in sheet metal or an equivalent impervious sheath.

2.5.3 Pipe and duct connections

Pipe or duct connections to the turbocharger casing are to be so made that the transmission of excessive loads or moments to the turbochargers is prevented.

2.6 Testing, Inspection and Certification of Turbochargers

2.6.1 Shop inspection and tests

The following shop inspection and tests for turbochargers of engines having cylinder bores greater than 300 mm (11.8 in.) are to be performed and these are to be witnessed by a Surveyor.

2.6.1.1 Material tests

Materials used in the construction of turbines are to be tested in presence of a Surveyor in line with the provisions of [2.2] of this section. This does not apply to independently driven auxiliary blowers that are not required during continuous operation of the engine.

2.6.1.2 Welded fabrication

All welded fabrication is to be performed using qualified welding procedures, by qualified welders, and with welding consumables acceptable to the Surveyors. Refer Part 2, Ch-3, Sec-3.

2.6.1.3 Hydrostatic tests

The cooling spaces of each outlet casing and gas inlet are to be hydrostatically tested to 1.5 times the working pressure but i.e. not to be less than 4 bars.

2.6.1.4 Dynamic balancing

Dynamic balancing of rotors is to be carried out at a speed equal to the natural period of the balancing machine and rotor combined.

2.6.1.5 Shop trial

Once fabrication and assembly are completed, each turbocharger is to be subjected to a shop trial, either on a test engine or test bed, in line with the manufacturer's test schedule, which is to be submitted for review prior to the trial. During the trial, the tests given below are to be conducted:

- (i) Inducer wheels and impeller are to be over speed tested for 3 minutes either:
 - ☐ On a test engine at 10% above the maximum operating speed at operating temperature, or
 - ☐ On a test bed at 20% above the maximum operating speed at ambient temperature
- (ii) A mechanical running test for at least 20 minutes at maximum operating speed and operating temperature, or a test run on the engine for which the turbocharger is intended for 20 minutes at 110% of the engine's rated output.

2.6.2 Certification of Turbochargers

2.6.2.1 General

Each turbocharger required to be certified by [2.1.1] of this section is:

- (i) To have its design approved by INTLREG; for which plans and data as required by [2.1.3] of this section are to be submitted for the approval of the society, and a unit of the same type is to be satisfactorily type tested Refer [2.3.2.3] of this section)
- (ii) To be surveyed during its construction for ensuring compliance with the design approved, along with, but not restricted to, material tests, hydrostatic tests, dynamic balancing, performance tests, etc., as stated in[2.6.1] above, all to be executed to the Surveyor's satisfaction.

Alternatively, the manufacturer is to 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.

For turbochargers of category C, this is to be verified by means of periodic product audits of an Alternative Certification Scheme (ACS). These audits are to focus on:

- Chemical composition of material for the rotating parts
- Mechanical properties of the material of a representative specimen for the rotating parts and the casing
- UT and crack detection of rotating parts
- Dimensional inspection of rotating parts
- Rotor balancing
- Hydraulic testing of cooling spaces to 4 bars or 1.5 times maximum working pressure, whichever is higher
- Over speed test of all compressor wheels for 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 over speed test may be waived for forged wheels that are individually controlled by an approved nondestructive method.

Turbochargers are to be delivered with

- For turbochargers of category C, a class certificate, which at a minimum cites the applicable type approval and the ACS, when ACS applies
- For turbochargers of category B, a work's certificate, which at a minimum cites the applicable type approval, which includes production assessment

2.6.2.2 Approval under the Type Approval Program

a) Product design assessment:

Upon application by the manufacturer, design assessment of each model of a type of turbocharger is to be done as stated in Part-1, Ch-1, sect 11. For this purpose, each design of a turbocharger type is to be approved in line with [2.6.2.1(i)] above. However, the type tests specified in [2.3.2.3] of this section are to be done in line with an approved test schedule and a Surveyor is to witness them. Turbochargers so approved may be applied to INTLREG for listing on the INTLREG website as Products Design Assessed. Once listed, these are subject to renewal and updating of the certificate as required by Part-1, Ch-1, Sec;11 each time the turbocharger is proposed for use on board a vessel then turbocharger particulars will not be required to be submitted to INTLREG.

b) Mass produced turbochargers:

A manufacturer of mass-produced turbochargers, who operates a quality assurance system in the manufacturing facilities, may apply to INTLREG for quality assurance approval given in Part-1, Ch-1, Sec-11 (PQA).

Upon satisfactory assessment under Part-1, Ch-1, Sec-11 (PQA), turbochargers produced in those facilities will not require a Surveyor's attendance at the tests and inspections indicated in [2.6.2.1(ii)] above. The manufacturer, whose quality control documents will be accepted, is required to execute such tests and inspections. Depending on the verification and approval of the design and on continued effectiveness of the quality assurance system, will the certification of each turbocharger be based. Refer Part-1, Ch-1, Sec-11

For every turbo-charger unit liable to be installed on an engine intended for a ship classed by INTLREG, the manufacturer is to supply a statement certifying that the turbo-charger is identical with one that underwent the tests specified and that prescribed tests were carried out. Results of these tests are to be also stated. This statement is to be made on a form agreed with INTLREG and a copy is to be sent to INTLREG. Each statement must have a number which is to appear on the turbo-charger

c) Non-mass produced Turbochargers:

A manufacturer of non-mass produced turbochargers, who operates a quality assurance system in the manufacturing facilities, may apply to INTLREG for quality assurance assessment described in Part-1, Ch-1, Sec-111(AQS) or Part-1, Ch-1, Sec-11 (RQS). Certification to Part-1, Ch-1, Sec 11(PQA) may also be considered in line with Chapter 1, Table 1.2.1.

d) Type Approval Program:

Approval of the design of turbocharger types which are done in accordance with (a) above and the quality assurance system of their manufacturing facilities approved in accordance with (b) or (c) above will be deemed Type Approved

and will be eligible for listing on the INTLREG website as Type Approved Product.

2.6.3 Engine and Shipboard Trials

In the presence of the Surveyor, the operation of each turbocharger, after installation on the engine, is to be demonstrated and that also establishes its ability to function satisfactorily under operating conditions and its freedom from harmful vibrations at speeds within the operating range is also ascertained. The test schedules are to be as stated in Sec-1, [1.8.6] and Sec-1, [1.10] for engine shop test and shipboard trial, respectively.

2.7 Spare Parts

While spare parts are not required for classification purposes, the spare parts listed in Sec-1, [1.11] serves as guidance for vessels intended for unrestricted service. The owner bears the responsibility of the maintenance of spare parts aboard each vessel.

SECTION 3 GAS TURBINES

Contents

3.1 General..... 120

3.2 Materials 122

3.3 Design 123

3.4 Gas turbine accessories..... 124

3.5 Piping and electrical systems for gas turbines 127

3.6 Gas Turbine Installation 127

3.7 Testing, inspection and certification of gas turbines 127

3.8 Spare parts 129

3.9 Plans and Data for Gas Turbines 129

3.10 Turning Gear: 131

3.11 Acoustic enclosures 131

3.1 General

3.1.1 Application

According to the requirements of this section, gas turbines with a rated power of 100 kW (135 hp) and over, intended for propulsion and auxiliary services vital to propulsion, maneuvering and safety (Refer Chapter-1, Sec-1, [1.1]) of the vessel, are to be designed, constructed, tested, certified and installed.

Gas turbines with a rated power of less than 100 kW (135 hp) are not required to conform to the provisions of this section but shall be designed, constructed and equipped in line with good commercial and marine practice. Such gas turbines are accepted only after the attainment of manufacturer's affidavit, verification of gas turbines, nameplate data and subject to a satisfactory performance test after installation i.e. conducted in the presence of the Surveyor.

Gas turbines with a rated power of 100 kW (135 hp) and over, intended for services considered not vital to propulsion, maneuvering and safety, are not required to be designed, constructed and certified by INTLREG in line with the provisions of this section. They are to conform to safety features, such as over speed protection, etc., stated in [3.4] of this section hereunder, or as applicable, and are subject to a satisfactory performance test after installation, conducted in the presence of the Surveyor.

Provisions for piping systems of gas turbines specifically fuel oil, lubricating oil, cooling water and exhaust gas systems, are addressed in Chapter-8, Section 4.

3.1.2 Definitions OF Rated Power

Rated power is the maximum power output at which the turbine is designed to run continuously at its rated speed. Gas turbine power is to be that developed at the lowest expected inlet air temperature and this design inlet air temperature not to exceed 15°C (59°F).

3.1.3 Documents to be submitted

3.1.3.1 Gas turbine construction

- Sectional assembly
- Casings
- Foundation and fastening
- Combustion chambers
- Gasifiers
- Regenerators or recuperators
- Turbine rotors
- Compressor rotors
- Compressor and turbine discs
- Blading
- Shafts
- Bearing arrangements
- Thrust bearing

3.1.3.2 Gas turbine systems and accessories

- Couplings
- Clutches
- Starting arrangements
- Fuel oil system
- Shielding of fuel oil service piping
- Lubricating oil system
- Air-intake system
- Exhaust system
- Shielding and insulation of exhaust pipes, assembly
- Governor arrangements
- Safety systems and devices and associated failure modes and effects analysis
- Control oil system
- Bleed/cooling/seal air system
- Cooling system
- Electrical and instrumentation schematics
- Accessory drives
- Water wash
- Enclosure arrangement
- Fire protection (gas turbine manufacturer supplied)

3.1.3.3 Data

- Rated power, maximum intermittent power for 1 hour operating time, maximum power (peak)
- Rated engine speed, including gas generator and power turbine speeds and limits (rpm)
- Rated compressor discharge temperature and limit
- Rated power turbine inlet temperature and limit
- Other engine limiting parameters
- Compressor maps
- Allowable combustor outlet temperature spread
- Combustion fuel equivalence ratio
- Sense of rotation (clockwise/counterclockwise)
- Maximum temperature at which rated power can be achieved
- Compressor configuration
- Combustor configuration
- Turbine configuration
- Mass and moment of inertia of rotating elements
- Balancing data
- Type test schedule, measurements and data
- Manufacturer's shop test schedule
- Manufacturer's recommended overhaul schedule

3.1.3.4 Materials

3.1.3.

Material specifications (including density, Poisson's ratio, range of chemical composition, room- temperature physical properties and, where material is subject to temperatures exceeding 427°C (800°F), the elevated temperature mechanical properties, as well as creep rate and rupture strength for the design service life).

3.1.3.5 Calculations and analyses

Design basis for turbine and compressor rotors and blading including calculations or test results to validate the suitability and strength of components for the intended service.

Blade containment strength, refer [3.3.5] of this section.

Design service life data

Vibration analysis of the entire propulsion shafting system; refer [3.3.1.2] below and Chapter-4, Sec-4.

3.2 Materials

3.2.1 Material specifications and tests

Materials used in the construction of gas turbines are to conform to approved design specifications. For information and verification, copies of material specifications and purchase orders are to be submitted to the Surveyor.

Except as noted in [3.2.2] below, the following materials are to be tested, inspected and certified by the Surveyor or in his presence. The materials are to meet the specifications of Part 2, Chapter 2, or to the requirements of the approved design specifications:

- (i) **Forgings:** Compressor & turbine rotors, shafts, couplings, coupling bolts, integral gears & pinions.
- (ii) **Castings:** Compressor and turbine casings where the temperature goes beyond 232°C (450°F) or where approved for use in place of any of the above forgings.
- (iii) **Plates:** Plates for casings of fabricated construction where the casing pressure goes beyond 41.4 bar (42.9 Kg/cm², 600 psi) or the casing temperature goes beyond 371°C (700°F).
- (iv) **Blade material:** Material for all turbine blades.
- (v) **Pipes, pipe fittings and valves:** Refer Chapter-8, Table 8.1.1 and Table 8.1.2.

3.2.2 Alternative materials and tests

3.2.2.1 Alternative specifications

Material manufactured to specifications other than those stated in Part 2, Chapter 2 may be accepted, provided that their design are approved and verified or tested by a Surveyor, as applicable, as conforming to the specifications.

3.2.2.2 Steel-bar stock

Hot-rolled steel bars up to 305 mm (12 in.) in diameter may be used in place of any of the forgings as per [3.2.1(i)] above and as per the conditions outlined in Part-2, Ch-2, Sec-3 after they are approved.

3.2.2.3 Materials for Turbines of 375 kW (500 hp) rated power or less

On the basis of the material manufacturer's certified test reports and a satisfactory surface inspection and hardness check that witnessed by the Surveyor will the

materials for the turbines of 375 kW (500 hp) rated power or less, including shafting, pinions, integral gears, couplings and coupling bolts be accepted. Material testing of coupling bolts manufactured to a recognized bolt standard and used as coupling bolts do not require material testing.

3.2.2.4 Certification under quality assurance assessment

For gas turbines certified under quality assurance assessment as stated in [3.7.2.2](b) of this section, material tests required by [3.2.1] above need not be witnessed by the Surveyor; rather such tests may be conducted by the turbine manufacturer whose certified material test reports will be accepted.

3.3 Design

3.3.1 Rotors and blades

3.3.1.1 Criteria

Rotors, bearings, discs, drums and blades are to be designed in accordance line with sound engineering principles, considering criteria's such as fatigue, high temperature creep, etc. These design criteria along with engineering analyses validating the suitability of the design for the rated power and speed are to be submitted for review.

Design criteria are to include the design service life, which is the maximum number of hours of operation at rated power and speed. In between major overhauls, the service life is generally not to be less than 5000 hours or the equivalent of 1 year of the vessel's service.

The rated power is to be taken as that developed at the lowest expected inlet air temperature. This temperature is not to exceed 15°C (59°F), in any case.

3.3.1.2 Vibration

Evaluation of the shafting system for different modes of vibrations (axial, lateral, torsional) and their coupled effect, as appropriate, is to be done by the designer. The design and manufacture of compressor and turbine rotors, rotor discs and rotor blades are to ensure freedom from undue vibration within the full operating speed range. Where critical speeds are found by calculation to occur within the operating speed range, vibration tests may be required in order to verify the calculations.

Vibration monitoring is to form an integral part of the gas turbine safety and control system. The vibration monitoring system is to be capable of detecting the out-of-balance of major parts with means being provided to shut down the gas turbine, before an over-critical situation occurs, i.e. multiple rotor blade or disc release.

3.3.2 Operation above the rated speed and power

For the purpose of reviewing, the design criteria along with the operating envelope, engineering analyses and type test data for this operation are to be submitted where operation above the rated speed and power for short duration is required in service, the design criteria along with operating envelope.

3.3.3 Overhaul interval

The manufacturer recommends overhaul schedule and the same is to be submitted for information and record purposes

3.3.4 Type test data

The manufacturer has to submit type test data in support of the design and the test is to be witnessed and certified by a Surveyor or by an independent agency. This data is to contain at

least the test schedule, measurements taken during the tests and test results. In lieu of type tests data, properly documented actual operational experience may be considered too.

3.3.5 Casing

The casing of the gas turbine is to be so designed that, at over speed up to 15% above the rated speed, failure of blades or blade attachment devices will be controllable.

Containment strength calculations or other method such as computer simulation or impingement test, verifying the above requirement are to be submitted for review

3.4 Gas turbine accessories

3.4.1 Over speed protective devices

Over speed protective devices are to be provided to all propulsion and generator turbines so that the rated speed does not exceed by more than 15%.

Where two or more turbines are coupled to the same output gear without clutches, for all the turbines, just one over speed protective device may be considered. This is not to prevent operation with one or more turbines uncoupled.

3.4.2 Operating governors for propulsion gas turbines

With the help of a separate independent speed governor system in addition to the over speed protective device mentioned in [3.4.1] above, the fitting of the propulsion turbines coupled to reverse gear, electric transmission, controllable-pitch propeller or similar are to be done. This system is to be capable of controlling the speed of the unloaded turbine without bringing the over speed protective device into action.

3.4.3 Operating governors for turbines driving electric generators

3.4.3.1 Speed governing

An operating governor is to be fitted to each gas turbine driving propulsion, vessel service or emergency electric generator. The governor is to be capable of automatically maintaining the turbine speed within the following limits.

- a) The momentary speed variation in the electrical network when running at the indicated load is to be within 10% of the rated frequency- when:
 - (i) Running at full load (equal to rated output) of the generator and the maximum electrical step load is suddenly thrown off;
 - (ii) Running at no load and 50% of the full load of the generator is suddenly thrown on, followed by the remaining 50% after an interval sufficient to restore the frequency to steady state.

In all instances, the frequency is to return to within $\pm 1\%$ of the final steady state condition in not more than five (5) seconds

- b) For gas turbines driving emergency generators, the requirements of [3.4.3.1(a)-(ii)] above are to be met. However, if the sum of all emergency loads that can be automatically connected is more than 50% of the full load of the emergency generator, the sum of the emergency loads is to be used as the first applied load.
- c) The permanent frequency variation is to be within $\pm 5\%$ of the rated frequency at any load between no load and the full load.

3.4.3.2 Load sharing

Gas turbines driving AC generators that operate in parallel are required to have the following governor characteristics. In case of the range that ranges between 20% and 100% of the combined rated load of all generators, the load on any individual

generator will not differ from proportionate share of the total combined load by more than the lesser of the following:

- 15% of the rated power of the largest generator or
- 25% of the individual generator.

3.4.3.3 Fine adjustments

Provisions are to be made to adjust the governors sufficiently fine in order to permit load adjustment within the limits of 5% of the rated load at normal frequency.

3.4.3.4 Turbines driving electric propulsion generators

Gas turbines that drive electric propulsion generators, where required by the control system, are to be provided with means for local hand control, as well as remote adjustment from the control station

3.4.4 Safety systems and devices

3.4.4.1 General

Gas turbines are to be fitted with automatic safety systems and devices to safeguard against hazardous conditions arising from the malfunctioning in their operations. Their design is to be evaluated with failure mode and effect analysis, which is to be submitted for review.

3.4.4.2 Automatic shutdown

Gas turbines are to be fitted with a quick acting device that automatically shut off fuel supply during times of:

- i) Over speed;
- ii) Excessive high vacuum at compressor inlet;
- iii) Loss of flame during operation;
- iv) Low lubricating oil pressure in reduction gear;
- v) Low lubricating oil pressure;
- vi) Excessive vibration;
- vii) Excessive axial displacement of each rotor (except for gas turbines fitted with roller bearings); or
- viii) Excessively high exhaust gas temperature.

3.4.4.3 Automatic temperature controls

Gas turbines are to be fitted with automatic control systems so as to maintain steady state temperatures throughout the turbines' normal operating ranges in the following systems

- i) Over speed;
- ii) Fuel Oil
- iii) Exhaust gas.

3.4.4.4 Starting system safety

- a) Automatic purging-

Prior to initiating commencing the ignition process, automatic purging is required for starts and restarts. The purge phase is to be of adequate duration to clear all the turbine parts of accumulated liquid or gaseous fuel.

b) Preset time

Fitting of the starting control system is to be done with the help of ignition detection devices. The control system is to automatically abort the ignition, shut off the main fuel valve and begin with a purge phase in case if light does not shut off within a preset time.

3.4.4.5 Alarms and shutdowns

Table: 2.3.1, List of alarms and shutdowns

Table 2.3.1 summarizes the required alarms and, where applicable, the corresponding requirements for their shutdown

Monitored parameter	Alarm	Shutdown
Speed	High	Required (Refer note 2)
Lubricating oil pressure	Low (Refer note 1)	Required (Refer note 2)
Lubricating oil pressure of reduction gear	Low (Refer note 1)	Required (Refer note 2)
Differential pressure across lubricating oil filter	High	
Lubricating oil temperature	High	
Fuel oil supply pressure	Low	
Fuel oil temperature	High	
Cooling medium temperature	High	
Bearing temperature	High	
Flame and ignition	Failure	Required (Refer 2)
Automatic starting	Failure	
Vibration	Excessive (Refer note 1)	Required (Refer note 2)
Axial displacement of rotor	High	Required (Refer note 2, 3)
Exhaust gas temperature	High (Refer note 1)	Required (Refer note 2)
Vacuum at compressor inlet	High (Refer note 1)	Required (Refer note 2)
Control system power	Loss	
Notes: 1. Alarm is to be set at a point prior to set for shutdown. 2. Each shutdown is to be accompanied by its own alarm. 3. Except where fitted with roller bearings		

3.4.5 Hand trip gear

Hand trip gear is to be provided locally at the turbine control platform and, where applicable, at the centralized control station for shutting off the fuel in an emergency situation.

3.4.6 Air-intake filters and anti-icing

In order to minimize entry of water and harmful foreign matter, demisters and filters are to be provided to air-intake. These are to be so designed that the accumulation of salt deposits on the compressor and turbine blades is prevented. In order to prevent icing in the air intake, means are required to be provided.

3.4.7 Silencers

Inlet and exhaust silencers are to be fitted to restrict the sound power level at 1 m from the gas turbine system to 90 dB and 110 dB for manned and unmanned machinery spaces, respectively.

3.5 Piping and electrical systems for gas turbines

The **requirements** of piping and electrical systems associated with operation of gas turbines for propulsion, electric power generation and vessel's safety are stated in Chapter 8, Sec-4 & Sec-6 and Part 6, Ch-3, Sec-4. These systems include:

Fuel oil:	Chapter 8, Sec-4, [4.2](Refer Ch-8, [4.2.4] in particular)
Lubricating oil:	Chapter 8, Sec-4, [4.3] (Refer Ch-8, [4.3.2] & [4.3.3] in particular)
Cooling water:	Chapter 8, Sec-4, [4.4]
Starting air:	Chapter 8, Sec-4, [4.5]
Electric starting:	Part 6, Ch-3 sec-4, [4.12]
Exhaust gas:	Chapter 8, Sec-4, [4.6.6]
Hydraulic systems:	Chapter 8, Sec-6, [6.2]

3.6 Gas Turbine Installation**3.6.1 Pipe and duct connections**

Pipe or duct connections to the gas turbine casing are to be so made that the transmission of excessive loads or moments to the turbine is prevented.

3.6.2 Intake and exhaust

Air inlets are to be located at high elevations, as much as possible to minimize water intake, and are to be fitted with demisters, anti-icing arrangements, baffle and silencers as specified in [3.4.6] & [3.4.7] of this section. Air-intake ducting is to be arranged as per the turbine manufacturer's recommendations for providing the gas turbine with a uniform pressure and velocity flow field at the compressor inlet. The exhaust outlets are to be designed to expel turbine exhaust gas at a velocity, and are to be so located as to prevent reinjection of exhaust gas into the intake.

3.6.3 Hot surfaces & Thermal Insulation

It is required to suitably guard and also insulate the hot surfaces that are likely to come into contact with the crew during operation. Hot surfaces which may attain temperature exceeding 220°C (428°F), and likely to come into contact with any leakage, under pressure or otherwise, of fuel oil, lubricating oil or other flammable liquid, are to be suitably insulated with non-combustible materials that are impervious to such liquids. The insulation material which is not impervious to oil is to be encased in sheet metal or an equivalent impervious sheath.

3.7 Testing, inspection and certification of gas turbines**3.7.1 Shop Inspection and Tests**

Following shop tests and inspection for all gas turbines are required to be certified by INTLREG as per [3.1.1] of this section and also witnessed by a Surveyor.

3.7.1.1 Material tests

Materials used in the construction of turbines are to be tested in the presence of a Surveyor in line with the provisions of [3.2] of this section.

3.7.1.2 Welded fabrication

All welded fabrication is to be performed using qualified welding procedures, by qualified welders, and with welding consumables acceptable to the Surveyors. Refer Part 2, Ch-3, Sec-3.

3.7.1.3 Pressure tests

During normal operation, turbine casings are to be subjected to a pressure test of 1.5 times the highest pressure in the casing. Temporary diaphragms may be used to divide turbine casings to allow for an even distribution of the test pressures. Where hydrostatic tests are not feasible, in each case, alternative tests to determine soundness and workmanship are to be submitted for consideration and approval. Heat exchangers and intercoolers are to be hydrostatically tested on both sides to 1.5 times the design pressure.

3.7.1.4 Dynamic Balancing of Rotor

All finished turbine rotors and compressor are to be dynamically balanced at a speed equal to the natural period of the balancing machine and rotor, combined.

3.7.1.5 Shop trial

After completion of fabrication and assembly, each gas turbine is to be subjected to a shop trial in line with the manufacturer's test schedule, During the trial, turbine is to attain its over speed limit to enable the testing of the operation of the over speed protective device

3.7.2 Certification of gas turbines

3.7.2.1 General

Each gas turbine required to be certified as per the provisions of [3.1.1] of this section.

- 1) To have its design approved by INTLREG, plans and data as require are to be submitted to INTLREG for approval, and a gas turbine of the same type is to have been satisfactorily type tested or to have a documented record of satisfactory service experience
- 2) To be surveyed during its construction for compliance with the approved design, along with, but not limited to, material and nondestructive tests, pressure tests, dynamic balancing, performance tests, etc., as indicated in Sect [3.7.1], all to be carried out to the satisfaction of the Surveyor.

3.7.2.2 Approval under type approval program

a) Product design assessment:

Upon manufacturer's application, each model of a type of turbine may be design assessed as specified in Part-1, Ch-1, Sec-11. . For this purpose, each design of a turbine type is to be approved . However, the type test is to be conducted in line with an approved test schedule and is to be witnessed by a Surveyor.

b) Mass produced turbines:

Manufacturer of mass-produced turbines, who operates a quality assurance system in the manufacturing facilities, may apply to INTLREG for quality assurance assessment specified in Part-1, Ch-1, Sec-11(PQA).

Upon satisfactory assessment as stated in Part-1, Ch-1, Sec-11 (PQA), turbines produced in those facilities will not require a Surveyor's attendance at the tests and inspections indicated in [3.7.2.1] above. The manufacturer are required to execute such tests and inspections, whose quality control documents will be accepted and each engine will be certified on the basis of the verification of approval of the design and on the continued effectiveness of the quality assurance system. Refer Part-1, Ch-1, Sec-11

c) **Non-mass produced gas turbines:**

A manufacturer of non-mass produced turbines, who operates a quality assurance system in the manufacturing facilities, may apply to INTLREG for quality assurance assessment described in Part-1, Ch-1, Sec-11 (AQS) or Part-1, Ch-1, Sec-11(RQS). Certification to Part-1, Ch-1, Sec-11 (PQA) may also be considered in line with Chapter 1, Table 1.2.1.

d) **Type Approval Program.**

Turbine types which have their designs approved and the quality assurance system of their manufacturing facilities approved will be deemed Type Approved

3.7.3 Shipboard trials

After installation, each gas turbine, including all starting, control and safety system, is to be operated in the presence of the Surveyor to satisfactorily demonstrate function and freedom from harmful vibration at speeds within the operating range. Each gas turbine is also to operate to the over speed limit to test the function of the over speed governor. The means for the propulsion system to reverse are to be demonstrated and recorded

3.8 Spare parts

Spare parts are not required for the classification purpose. The owner bears the responsibility for the maintenance of spare parts aboard each vessel.

3.9 Plans and Data for Gas Turbines

For approval of each type of gas turbine, the data and drawings listed in the following table, and as applicable to the type of gas turbine, are to be submitted for approval (A) or for information (R) by each engine manufacturer. After the approval of an engine type has been given by INTLREG for the first time, only the documents listed in the table which have undergone substantial changes, will have to be submitted again for consideration by INTLREG. In cases where both (R) and (A) are shown, the first refers to cast components and the second to welded components. Bill of materials is to include material specification of the components, as listed.

No.	A/R	Item
1	A	Certified dimensional outline drawing and list of connections
2	A	Cross-sectional assembly drawing and bill of materials
3	A	Casings assembly and bill of materials
4	A	Foundations and fastening
5	A	Combustion chambers
6	A	Gasifiers
7	A	Regenerators or recuperators and Intercoolers and bill of materials

8	A	Turbine rotors and bill of materials
9	A	Compressor rotors and bill of materials
10	A	Compressor and turbine discs and bill of materials
11	A	Blading details and bill of material
12	A	Shafts and bill of materials
13	A	Bearing assembly and bill of materials
14	A	Thrust bearing assembly, performance data and bill of materials
15	A	Shaft coupling assembly including coupling alignment diagram and procedure and bill of
16	A	Clutches and brakes details and bill of materials
17	A	Starting arrangement
18	A	Fuel oil system including fuel injector system operational schematic and components drawing with connection schedule and bill of materials
19	A	Shielding of fuel oil service piping
20	A	Lubricating oil system schematic and bill of material
21	A	Air-intake system and air intake model test report
22	A	Exhaust system
23	A	Shielding and insulation of exhaust pipes, assembly
24	A	Governor arrangements including governor control and trip system data
25	A	Safety systems and devices and associated Failure Modes, Effects and Criticality Analysis
26	A	Control oil system assembly and arrangement drawing
27	R	Bleed/cooling/seal air schematic and bill of materials
28	A	Cooling system
29	A	Electrical and instrumentation schematics and arrangement drawings, list of terminations,
30	A	Accessory drive
31	A	Water wash
32	A	Enclosure arrangement
33	A	Fire protection
34	R	Gas turbine particulars (rated power, rated speed, max. temperature at which rated power
35	R	Speed vs power curves at site rated conditions
36	R	Ambient temperature vs power curves at site rated conditions
37	R	Output power vs shaft speed curves at site rated conditions
38	R	Heat rate correction factors
39	R	Type test schedule, measurements and data
40	R	Manufacturer's shop test schedule
41	R	Manufacturer's recommended overhaul schedule
42	R	Computer Steady State and Transient performance program (engine mounted system)
43	R	Engine Health Monitoring (EHM) equipment and program, where specified
44	R	Hot Section Repair Interval analyses
45	A	Welding procedures
46	R	B10 Bearing life analysis
47	R	Blading vibration analysis data
48	R	Lateral critical analysis
49	R	Torsional critical analysis report
50	R	Transient torsional analysis report
51	R	Allowable piping flange loading, as applicable
52	R	Spring mass model analysis, as applicable

3.10 Turning Gear:

Propulsion turbines are to be equipped with a slow turning gear for rotation in both directions. For auxiliary turbines, provisions to allow at least for shaft turning by hand are to be there.

For vessels equipped with remote propulsion control, the turning gear status is to be indicated at each of the remote propulsion control station. Besides that, an interlock is to be fitted to prevent operation of the turbine when the turning gear is engaged, and vice versa. Also refer Part 6, Chapter 8, Table-8.3.1.

3.11 Acoustic enclosures

Acoustic enclosures, where fitted, are to be provided with an access door, adequate internal lighting and one or more observation windows to allow the viewing of critical parts of the gas turbine.

A suitable ventilation system, designed to maintain all components within their safe working temperature under all operating conditions is to be provided.

The ventilation system is to be fitted with shut-off flaps arranged to close automatically upon activation of the enclosure's fire detection and extinguishing system.

Acoustic enclosure fire safety arrangements are to comply with the requirements of the *International Convention for the Safety of Life at Sea, 1974*, as amended (SOLAS 74).

SECTION 4 STEAM TURBINES

Contents

4.1.General	133
4.2.Materials	134
4.3.Design.....	135
4.4.Steam Turbine Accessories	137
4.5.Piping System for Steam Turbines.....	139
4.6.Steam Turbine Installation.....	139
4.7.Testing , Inspection and Certification of Steam Turbines.....	139
4.8.Guidance for Spare Parts	141

4.1 General**4.1.1 Application**

As per the requirements of this section, steam turbines with a rated power of 100 kW (135 hp) and over, intended for propulsion and for auxiliary services vital to propulsion, maneuvering and safety (Refer Chapter-1, Sec-1, [1.1]) of the vessel, are to be designed, constructed, tested, certified and installed.

Steam turbines with a rated power of less than 100 kW (135 hp) are not required to conform to the provisions of this section but shall be designed, constructed and equipped in line with good commercial and marine practice. Such steam turbines are accepted only after the attainment of manufacturer's affidavit, verification of steam turbines, nameplate data and subject to a satisfactory performance test after installation i.e. conducted in the presence of the Surveyor.

Steam turbines with a rated power of 100 kW (135 hp) and over, intended for services considered not vital to propulsion, maneuvering and safety, are not required to be designed, constructed and certified by INTLREG in line with the provisions of this section. They are to conform to safety features, such as over speed protection, etc., stated in [4.4] of this section hereunder, or as applicable, and are subject to a satisfactory performance test after installation, conducted in the presence of the Surveyor.

Provisions for piping systems of steam turbines specifically steam, condensate and lubricating oil systems are addressed in Chapter-8, Section 5

4.1.2 General Definitions

Following definitions will apply for this section

4.1.2.1 Rated power

For a turbine, rated power refers to the maximum power output at which the turbine is designed to continuously run at its rated speed.

4.1.2.2 Rated speed

The Rated Speed is the speed at which the turbine is designed to run continuously at its rated power. The rated speed is to be used for making strength calculations.

4.1.2.3 Turbine over speed limit

Over speed limit is the maximum permissible intermittent speed for a turbine in service and shall not exceed the rated speed by more than 15%. It is to be the maximum permissible setting of the over speed governor.

4.1.2.4 Operating temperature

The requirements for steam turbine rotors and blades stated in [4.3.2] and [4.3.3] of this section are based on a maximum operating temperature at the turbine inlet of 427°C (800°F).

Installations where this maximum operating temperature is exceeded will be subject to special consideration of the design criteria.

4.1.3 Documents to be submitted**4.1.3.1 Steam turbine construction**

- Sectional assembly
- Casings
- Foundation and fastening
- Turbine rotors

- Turbine discs
- Blading
- Shafts
- Bearing arrangements

4.1.3.2 Steam turbine systems and appurtenances

- Couplings
- Clutches
- Steam inlet and exhaust system
- Lubrication system
- Governor arrangements
- Monitoring and safety arrangements

4.1.3.3 Data

- Rated speed
- Rated power
- Mass and velocity of rotating elements
- Area of wheel
- Moment of inertia of wheel profile area
- Center of gravity of blade and root
- Balancing data
- Manufacturer's shop operating test schedule

4.1.3.4 Materials

Material specifications (including density, Poisson's ratio, range of chemical composition, room temperature physical properties and, where material is subject to temperatures exceeding 427°C (800°F), the high-temperature strength characteristics, as well as creep rate and rupture strength for the design service life).

4.1.3.5 Calculations and analyses

The basis for designing turbine rotors and blading along with calculations or test results is to validate the suitability and strength of components for the intended service.

For the torsional vibration analysis of the entire propulsion shafting system; refer [4.3.2.4] of this section and Chapter-4, Sec-4.

4.2 Materials

4.2.1 Material specifications and tests

Materials used in the construction of turbines are to conform to specifications approved for the design. For purposes of verification and information, copies of material specifications and purchase orders are to be submitted to the Surveyor.

Except as mentioned in [4.2.2] below, the following materials are to be tested in the presence of, inspected and certified by the Surveyor in line with the requirements of Part 2, Chapter 2 or of the specifications approved in connection with the design:

- a) Forgings: Discs and rotor drums, shafts and rotors, couplings, coupling bolts, integral gears and pinions for all turbines
- b) Castings: Turbine casings and maneuvering valves where the temperature exceeds 232°C (450°F) or where approved for use in place of any of the above forgings.
- c) Plates: Plates for turbine casings of fabricated construction where the casing pressure exceeds

41.4 bar (42.9 Kg/cm², 600 psi) or the casing temperature exceeds 371°C (700°F).

- d) Blade material: Material for all turbine blades (hardness or chemical composition checked)
- e) Pipes, pipe fittings and valves: Refer Chapter-8, Table 8.1.1 and Table 8.1.2, except for maneuvering valves as provided for in (b) above.

4.2.2 Alternative materials and tests

4.2.2.1 Alternative Specifications

Material manufactured to specifications except those given in Part 2, Chapter 2, may be accepted, provided that those are approved with respect to the design and that they are verified or tested by a Surveyor, as applicable, as conforming to the specifications.

4.2.2.2 Steel-bar stock

Hot-rolled steel bars up to 305 mm (12 in.) in diameter may be used when approved for use in place of any of the forgings mentioned in [4.2.1](a) above, under conditions outlined in Part-2, Ch-2, Sec-3.

4.2.2.3 Materials for turbines of 375 kW (500 hp) rated power or less

Materials for turbines with 375 kW (500 hp) rated power or less, including shafting, integral gears, pinions, couplings and coupling bolts will be accepted on the basis of the material manufacturer's certified test reports and a satisfactory surface inspection and hardness check witnessed by the Surveyor. On the other hand, coupling bolts manufactured to a recognized bolt standard do not require material testing.

4.2.2.4 Certification under quality assurance assessment

For steam turbines certified under quality assurance assessment as mentioned in [4.7.2.2(b)] of this section, material tests required by [4.2.1] above need not be witnessed by the Surveyor; rather those are to be conducted by the turbine manufacturer whose certified material test reports will be accepted instead.

4.3 Design

In place of the design rules provided hereunder, INTLREG will consider designs that are validated by sound engineering analyses which are done for all designed operating conditions, taking into consideration strength criteria such as fatigue, torsional vibration, high temperature creep, etc., as appropriate.

4.3.1 Casings

4.3.1.1 Castings

Turbine casings and associated fixtures subjected to pressure are to be of such design and made of materials that make them suitable to bear the stress and temperatures to which they may be exposed. Cast steel and cast iron may be considered suitable where the maximum operating temperature does not exceed 427°C (800°F) and 232°C (450°F), respectively. Heat treatment of all castings is to be done to remove internal stresses.

4.3.1.2 Seals and drains

Casings are to be provided with suitable seals. Drains are to be fitted in places where water or oil may collect.

4.3.1.3 Overpressure protection

Turbine casings are to be fitted with means to prevent overpressure; refer [4.4.6] of this section.

4.3.2 Rotor shafts

4.3.2.1 General

The diameter of a turbine rotor shaft is to be determined by the equations given below:

$$d_{sh} = K \cdot \sqrt[6]{(b T_{rs})^2 + (m M)^2}$$

$$b = 0.073 + \frac{n}{Y}$$

$$m = \frac{c_1}{c_2 + Y}$$

where

d_{sh} = Shaft diameter at section under consideration; mm (in.)

Y = Yield strength (Refer Pt 2, Ch 1, Sect [1.7.2]); N/mm² (Kgf/mm², psi)

T_{rs} = Torsional moment at rated speed; N-m (Kgf-cm, lbf-in)

M = Bending moment at section under consideration; N-m (Kgf-cm, lbf-in)

K , n , c_1 and c_2 are constants given in the following table:

	SI UNITS	MKS UNITS	US UNITS
K	5.25	2.42	0.10
n	191.7	19.5	27800
c ₁	1186	121	172000
c ₂	413.7	42.2	60000

4.3.2.2 Shaft diameters in way of rotors

The diameter of the shaft in way of the fitted member is to be increased not less than 10% where, rotor members are fitted with the help of a press or shrink fit, or by keying.

4.3.2.3 Astern power

The astern torque is to be considered, in determining the required size of coupling shafting transmitting astern power, when it exceeds the transmitted ahead torque.

4.3.2.4 Vibration

The designer or builder is to evaluate the shafting system for different modes of vibrations (tensional, axial, lateral) and their coupled effect, as appropriate.

4.3.3 Blades

Blades are to be so designed as to avoid abrupt changes in section and to provide an ample amount of stiffness to minimize deflection and vibration. The area at the root of the blade is not to be less than that given in the following equation based upon either the tensile strength or yield strength of the material

SI units	MKS units	US units

A	$4.39WN^2rF$	A	$0.45WN^2rF$	A	$114WN^2rF$

Notes:

- 1) These equations are based solely upon centrifugal stress consideration. Designers/manufacturers are to take into consideration vibrations at speeds within the operating range.
- 2) Where turbine blades are designed with $F = 2Y$ resulting in a safety factor against ultimate strength of less than four, a dye-penetrant or magnetic-particle inspection is to be made of each rotor blade.

A	=	Minimum blade root areas; cm^2 (in^2)
W	=	Mass of one blade; kg (lb)
N	=	RPM at rated speed divided by 1000
r	=	Radius of center of gravity of blade from centerline of shaft; cm (in.)
U	=	minimum tensile strength of material; N/mm^2 (Kgf/mm^2 , psi)
Y	=	Yield strength of material Pt 2, Ch1, Sect[1.7.2]; N/mm^2 (Kgf/mm^2 , psi)
F	=	U or optionally $2Y$ (Refer Note 2 under the equations above)

4.3.4 Discs or drums

Discs or drums are to be designed in line with sound engineering principles, considering criteria's such as fatigue, high temperature creep, etc. These design criteria along with engineering analyses validating the suitability of the design for the rated power and speed are to be submitted.

4.4 Steam Turbine Accessories

4.4.1 Over speed protective devices

An over speed protective device is to be provided to all propulsion and auxiliary turbines so as to prevent the rated speed from being exceeded by more than 15%.

In addition to cutting off the main steam supply, where steam from other systems or exhaust steam are admitted to the turbine lower stages, they are also to be cut off at the activation of over speed protective device.

Use of only one over speed protective device for all turbines may be considered where two or more turbines are coupled to the same output gear.

4.4.2 Operating governors for propulsion turbines

With the help of a separate independent speed governor system, in addition to the over speed protective device specified in [4.4.1] above, fitting of the propulsion turbines coupled to reverse gear, electric transmission, controllable-pitch propeller or similar are to be done.

Without bringing the over speed protective device into action, this governor system is to be capable of controlling the speed of the unloaded turbine

4.4.3 Operating governors for turbines driving electric generators

4.4.3.1 Speed governing

Fitting of an operating governor is to be done to each steam turbine driving propulsion or vessel service electric generator. Within the following limits, the governor is to be capable of automatically maintaining the turbine speed.

- a) The transient frequency variations in the electrical network when running at the indicated loads below are to be within $\pm 10\%$ of the rated frequency when:

- (i) Running at full load (equal to rated output) of the generator and the maximum electrical step load is suddenly thrown off;

A transient frequency variation in excess of 10% of the rated frequency may be acceptable in the case where a step load equivalent to the rated output of a generator is thrown off, provided that the over speed protective device fitted in addition to the governor, as required by [4.4.2] above, is not activated.

- (ii) Running at no load and 50% of the full load of the generator is suddenly thrown on, followed by the remaining 50% after an interval sufficient to restore the frequency to steady state. In all instances, the frequency is to return to within $\pm 1\%$ of the final steady state condition in no more than five (5) seconds.
- b) The permanent frequency variation is to be within $\pm 5\%$ of the rated frequency at any load between no load and the full load.

4.4.3.2 Load sharing

Steam turbines driving AC generators that operate in parallel are required to have the following governor characteristics. In the range between 20% and 100% of the combined rated load of all generators, the load on any individual generator will not differ from its proportionate share of the total combined load by more than the lesser of the following:

- 15% of the rated power of the largest generator
- 25% of the individual generator

4.4.3.3 Fine adjustments

In order to permit a load adjustment within the limits of 5% of the rated load at normal frequency, provisions are made for the sufficient adjustment of the governors.

4.4.3.4 Turbines driving electric propulsion generators

For steam turbines driving electric propulsion generators, where required by the control system, this governor is to be provided with means for local hand control as well as remote adjustment from the control station.

4.4.4 Hand and automatic tripping

Arrangements are to be provided for shutting off steam to propulsion turbines by suitable hand trip gear situated at the main control console and at the turbine itself. For auxiliary steam turbines, hand tripping is to be arranged in the vicinity of the turbine over speed protective device. The hand tripping gear is to shut off both the main and exhaust steam supplies to the turbines.

Automatic shutting off the steam supply (including exhaust steam supply) using a quick acting device is also to occur in all the steam turbines upon over speed (Refer [4.4.1] above) and failure of the lubricating oil system (Refer Chapter 8, Sec-5, [5.5]). Also refer [4.4.6] below for back-pressure trip.

4.4.5 Shaft turning gear

Propulsion turbines are to be equipped with a slow turning gear for rotation in both directions. For auxiliary turbines, provisions to allow at least for shaft turning by hand are to be there.

For vessels equipped with remote propulsion control, the turning gear status is to be indicated at each of the remote propulsion control station. Besides that, an interlock is to be fitted to prevent operation of the turbine when the turning gear is engaged, and vice versa. Also refer Part 6, Chapter 8, Table-8.3.1.

In the propulsion machinery space in use for centralized or unattended operation (CCS or UM notation), non-rotation of the propulsion shaft more than a predetermined duration on a standby or stop maneuver is to be alarmed at the centralized control station and other remote control

stations. Besides that, for the unattended propulsion machinery space (UM notation), whenever such duration is exceeded, means for automatic roll-over of the propulsion turbine shaft is to be fitted. Also refer Part 6, Chapter 8, Table-8.2.4.

4.4.6 Overpressure protection

Fitting of sentinel valves or equivalent are to be done to all main and auxiliary steam turbine exhausts so as to give a warning of excessive pressure to personnel in the vicinity of their exhaust ends. With the help of back-pressure trips or other approved protective device, fitting of auxiliary steam turbines sharing a common condenser are required to be done.

4.5 Piping System for Steam Turbines

The requirements of piping systems essential for operation of steam turbines for propulsion, electric power generation and vessel's safety are provided in Chapter 8, Section 5. These systems are:

- Steam piping for propulsion turbines: Chapter 8, Sec-5, [5.2.6]
- Steam piping for auxiliary turbines: Chapter 8, Sec-5, [5.2.7]
- Condensers: Chapter 8, Sec-5, [5.3.2.2]
- Lubricating oil system: Chapter 8, Sec-5, [5.5]
- Condenser cooling system: Chapter 8, Sec-5, [5.6]

4.6 Steam Turbine Installation

4.6.1 Exhaust steam to turbine

If exhaust steam is admitted to a turbine, means are to be provided to prevent water from entering the turbine.

4.6.2 Extraction of steam.

Where provision is made for extraction of steam, approved means are to be provided for preventing a reversal of flow to the turbine.

4.6.3 Pipe and duct connections

Any pipe or duct connections to the steam turbine casing are to be made in such that they prevent the transmission of excessive loads or moments to it.

4.6.4 Hot surfaces

Hot surfaces are to be suitably guarded or insulated to safeguard the crew who are likely to come in its contact. Hot surfaces whose temperature is likely to exceed 220 °C (428°F), and come into contact with any leakage, under pressure or otherwise, of fuel oil, lubricating oil or other flammable liquid, are to be suitably insulated with non-combustible materials that are impervious to such liquid. The insulation material that is not impervious to oil is to be encased in sheet metal or an equivalent impervious sheath.

4.7 Testing, Inspection and Certification of Steam Turbines

4.7.1 Shop Inspection and Tests

Following shop tests and inspections are to be witnessed by a Surveyor on all steam turbines required to be certified by INTLREG as per Section [4.1.1]

4.7.1.1 Material Tests

Materials used in the construction of turbines are to be tested in the presence of a Surveyor, as per the provisions of [4.2] of this section.

4.7.1.2 Welded fabrication

All welded fabrication is to be conducted using qualified welding procedures, by qualified welders and with welding consumables acceptable to the Surveyors. Refer Part 2 Ch-3, Sec-3.

4.7.1.3 Nondestructive examination of turbine blades

Where turbine blades are designed with $F = 2Y$ (refer [4.3.3] of this section), resulting in a safety factor against ultimate strength of less than 4, magnetic-particle or dye-penetrant inspection is to be made for each rotor blade.

4.7.1.4 Hydrostatic tests

Turbine casings and maneuvering valves are to be subjected to hydrostatic tests of 1.5 times the working pressure. Temporary diaphragms are to be provided in between turbine casings to allow for an even distribution of test pressures. Where it is not feasible to conduct hydrostatic tests, in each case, alternative tests to determine soundness and workmanship are to be submitted for consideration and approval.

Both the steam side and the water side of the condensers are to be hydrostatically tested to 1.5 times the design pressure; in any case, the test pressure on the steam side is not to be less than 1 bar (1 Kgf/cm², 15 lb/in²). Refer Chapter 8, Sec-5, [5.3.6.2].

4.7.1.5 Safety relief valves

All the safety relief valves are to be tested and fitted in the presence of the Surveyor.

4.7.1.6 Vibration and balancing

Excessive vibration shall not occur within the operating speed range of turbines. Discs and turbine rotors are to be dynamically balanced at a speed equal to the natural period of the balancing machine and rotor combined.

Care is to be taken in the design and manufacture of turbine rotors, rotor discs and blades to ensure freedom from undue vibration within the operating speed range

Consideration of blade vibration should include the effect of centrifugal force, blade root fixing, metal temperature and disc flexibility where appropriate.

4.7.1.7 Shop trial

After complete fabrication and assembly, each steam turbine is to be subjected to a shop trial as per the manufacturer's test schedule, which is to be submitted for review prior to the trial. The test schedule specifies the duration of tests and is to include full load test, half load response tests, full load thrown-off tests, etc. During the trial, the turbine is to be brought to its over speed limit to test the operation of the over speed protective device. If not feasible, the manufacturer may submit alternative testing methods for consideration

4.7.2 Certification of Steam Turbines

4.7.2.1 General

As required by [4.1.1] of this section, each steam turbine to be surveyed during its construction for compliance with the design approved, along with, but not restricted to, material and nondestructive tests, dynamic balancing, performance tests, hydrostatic tests, etc., as stipulated in [4.7.1] above, all to be executed to the satisfaction of the Surveyor.

4.7.2.2 Approval under Type Approval Program

- a) Product Design Assessment
Upon manufacturer's application, each model of a type of turbine may be design assessed as specified in Part-1, Ch-1, Sec-11. However, the type test is to be conducted in line with an approved test schedule and is to be witnessed by a Surveyor.
- b) Mass Produced Turbines
A manufacturer of mass-produced turbines who operates a quality assurance system in the manufacturing facilities may apply to INTLREG for quality assurance assessment described in Part-1, Ch-1, Sec-11, (PQA).
Upon satisfactory assessment under Part-1, Ch-1, Sec-11, (PQA), turbines produced in those facilities will not require a Surveyor's attendance at the tests and inspections indicated in [4.7.2.1] above. Such tests and inspections are to be carried out by the manufacturer whose quality control documents will be accepted.
Certification of each turbine will be based on verification of approval of the design and on continued effectiveness of the quality assurance system. Refer Part-1, Ch-1, Sec-11
- c) Non-Mass Produced Turbines
A manufacturer of non-mass produced turbines who operates a quality assurance system in the manufacturing facilities may apply to INTLREG for quality assurance assessment described in Part-1, Ch-1, Sec-11 (AQS) or Part-1, Ch-1, Sec-11(RQS). Certification to Part-1, Ch-1, Sec-11 (PQA) may also be considered in line with Chapter 1, Table 1.2.1.

4.7.3 Shipboard Trials

Prior to final acceptance, the installation of each steam turbine including all its control and safety equipment is to be operated in Surveyor's presence to demonstrate its full capability under operating conditions and its freedom from detrimental vibrations at speeds within the operating range. Each steam turbine is to be tested to the over speed limit to operate its over speed governor. The demonstration and record of reversing characteristics of propulsion turbine plants is also required.

4.8 Guidance for Spare Parts

4.8.1 General

Spare parts are basically not required for purposes of classification, but the spare parts list given below serve as guide for vessels intended for unrestricted service. Depending on the turbine design, spare parts such as electronic control cards (not included in the list), may also be considered.

4.8.2 Spare parts for Propulsion Steam Turbines

- a) One (1) set of springs for governor, relief and maneuvering valves
- b) Sufficient packing rings with springs to repack one gland of each kind and size
- c) One (1) set of thrust pads or rings, also springs where fitted, for each size turbine-thrust bearing.
- d) Bearing bushings sufficient to replace all of the bushings on every turbine rotor, pinion and gear for main propulsion, spare bearing bushings sufficient to replace all of the bushings on each non-identical auxiliary-turbine rotor, pinion and gear having sleeve-type bearings or complete assemblies consisting of outer and inner races and cages complete with rollers or balls where these types of bearings are used.

- e) One (1) set of bearing shoes for one face, for one single-collar type main thrust bearing where fitted. Where the ahead and astern pads differ, pads for both faces are to be provided.
- f) One (1) set of strainer baskets or inserts for filters of special design of each type and size, for oil filters.
- g) Necessary special tools.

4.8.3 Spare parts for steam turbines driving electric generators

a)	Main bearings	Bearing bushes or roller bearings of each size and type fitted for the shafts of the turbine rotor and of the reduction gearing, if any, for one engine	1 Set
b)	Turbine thrust bearing	Pads for one face of tilting pad type thrust, with liners, or rings for turbine adjusting block with assorted liners, for one engine	1 Set
c)	Turbine shaft sealing rings	Carbon sealing rings where fitted, with springs for each size and type of gland, for one engine	1 Set
d)	Oil filters	Strainer baskets or inserts, for filters of special design, of each type and size	1 Set

CHAPTER 3 REDUCTION GEARS

CONTENTS

SECTION 1 GENERAL REQUIREMENTS	144
SECTION 2 MATERIALS	149
SECTION 3 DESIGN OF GEARS	151
SECTION 4 CONSTRUCTION.....	165
SECTION 5 PIPING SYSTEMS	168
SECTION 6 TESTING, INSPECTION AND CERTIFICATION OF GEARS	170
SECTION 7 SPARE PARTS.....	182

SECTION 1 GENERAL REQUIREMENTS

Contents

1.1.Application	145
1.2.General Definitions	145
1.3.Documents to be submitted.....	146

1.1. Application

Gears with rated power of 100 kW (135 hp) and over and intended for propulsion and for auxiliary services essential for propulsion, maneuvering and safety (Refer Chapter-1, Sec-1, [1.2]) of the ship, are required to be designed, constructed and certified as per INTLREG Rules and provisions furnished in this section. If similar gears with rated power of 100 kW (135 hp) and over and also intended for propulsion and for auxiliary services are not essential for propulsion, maneuvering and safety of the ship, are not required to abide by the provisions of this section. However, such gears are to be installed and tested to a Surveyor's satisfaction.

Gears with rated power of less than 100 kW (135 hp) are not required to conform to the provisions of this Section but are to be designed, constructed and equipped in line with good commercial and marine practices. Acceptance of such gears will be based on the manufacturer's affidavit, verification of gear nameplate data and subject to a satisfactory performance test after installation conducted in the presence of the Surveyor.

Piping systems of gears, in particular, lubricating oil and hydraulic oil are addressed to in Chapter-8, [4.3], [5.5] & [6.2].

1.2. General Definitions

1.2.1. Gears

Gears as covered in this section includes external and internal involute spur and helical cylindrical gears with parallel axis and also bevel gears used for either main propulsion or auxiliary services.

1.2.2. Rated Power

The rated power of a gear is the maximum transmitted power at which it is designed to run continuously at the rated speed.

1.2.3. Rated Torque

The rated torque and is the torque used in the gear rating calculations and is defined by the rated power and speed.

1.2.4. Gear Rating

At this rating, the gear is designed to run at its rated torque

1.2.5. Intermittent Duty

1.2.5.1 Gear units that are used for intermittent duty, that is at a higher rating than the rated power defined in [1.2.2] above (the rated power at which the gear is designed to operate continuously at its rated speed), are to meet the requirements given in [1.2.5.2] below in addition to all applicable requirements contained in this chapter. When such gear units are installed on a ship, its classification and operating profile shall reflect the intermittent rating which normally would only be considered for non-commercial services or if for commercial service then with limited operating time in the intermittent duty service, as defined by the mission profile.

1.2.5.2 Gears intended for intermittent duty are to have clearly defined conditions associated with the intermittent rating and listed as part of the rating. These conditions include, but are not limited to, the specific intermittent rating (power and rpm) or ratings if there will be multiple intermittent ratings, the limit on the number of hours at the rating, both continuous per 24 hour period and total hours, the time between overhaul and servicing of the unit, and any other conditions that the manufacturer places on the unit.

- 1.2.5.3 Calculations supporting the intermittent rating or ratings are to be submitted by the manufacturer to INTLREG for review. The calculations are to be based on ISO 6336-6 Calculation of local capacity of spur and helical gears – Calculation of service life under variable load, or an equivalent recognized national standard that uses a fatigue cycle approach

1.3. Documents to be submitted

1.3.1 Gear Construction

- General arrangement
- Sectional assembly
- Details of gear casings
- Bearing load diagram
- Quill shafts, gear shafts and hubs
- Shrink fit calculations and fitting instructions
- Pinions
- Wheels and rims
- Details of welded construction of gears

1.3.2 Gear Systems and Appurtenances

- Couplings
- Coupling bolts
- Lubricating oil system and oil spray arrangements

1.3.3 Data

- Transmitted rated power for each gear
- Revolutions per minute for each gear at rated transmitted power
- Bearing lengths and diameters
- Length of gap between helices, if any
- Distance between inner ends of bearing
- Tooth form layout (Refer Sec-3, Figure 3.3.1) or calculated data
- Face widths, net and total
- Width of tooth at highest stressed section
- Helix angle at reference and at pitch diameter
- Helix deviation
- Normal pressure angle
- Transverse pressure angle at reference cylinder
- Transverse pressure angle at working pitch cylinder
- Middle cone distance for gears
- Normal module
- Transverse module
- Bending moment arm for tooth root bending stress for application of load at the point of single tooth pair contact

- Reference cone angle for gears
- Tip angle for gears
- Cone distance for gears
- Pair contact
- Working pitch diameter of gears
- Reference diameters
- Addendum
- Tip diameter of gears
- Root diameter of gears
- Transverse diametric pitch
- Normal base pitch
- Addendum modification coefficient of gears
- Dedendum
- Number of gear teeth
- Virtual number of spur teeth for gears
- Center distance between mating gear
- Length of contact in plane of rotation
- Root fillet radius of gears in the critical section
- Axial lead modification or lead mismatch, if any, for reference
- Method of cutting and finishing gear teeth
- Tooth thickness modification coefficient (midface)
- Sketch of basic rack tooth form
- Root radius, addendum, and dedendum of basic rack
- Degree of finish of tooth flank
- Grade of accuracy
- Tooth hardness range, including core hardness and total depth of hardness surface to core
- Mean peak-to-valley roughness of tooth root fillets
- Mass of rotating parts
- Balancing data
- Spline data
- Shrink allowance for rims and hubs
- Type of coupling between prime mover and reduction gears
- Type and viscosity of lubricating oil recommended by manufacturer
- For a comprehensive listing of data

1.3.4 **Materials**

Following typical properties of gear materials are to be submitted:

- Physical properties at room temperature
- Endurance limits for pitting resistance, contact stress & tooth root bending stress
- Range of chemical composition

- Heat treatment of gears, shafts, quill shafts, coupling elements and gear cases

1.3.5 Hardening Procedure

The hardening procedure for surface hardened gears is to be submitted for review with materials, procedural details, quality assurance procedures and testing procedures included. The testing procedures are to include surface hardness, surface hardness depth (e.g., case depth) and core hardness. Core hardness (their shape) and surface hardness depth are to be determined from sectioned test samples. The test samples are to be of adequate size to provide for determination of core hardness and are to be of the same material and heat treated as the gears that they represent. Forgings are to be tested as per Part 2, Chapter 2.

1.3.6 Calculations and Analyses

- Tooth coupling and spline connection calculations
- Bearing life calculations

SECTION 2 MATERIALS

Contents

2.1.Material Specifications and Test Requirements..... 150

2.2.Requirements for Alternative Material Test..... 150

2.1. Material Specifications and Test Requirements

2.1.1 Material Certificates

In each case, material for gears and gear units is to conform to specifications approved in connection with the design. For information purposes, copies of material specifications and purchase orders are to be submitted to the Surveyor.

2.1.2 Material Tests

Following materials are to be tested and inspected in the presence of the Surveyor except as noted in [2.2] below. The materials are required to meet the specifications in Part 2, Chapter 2 or that approved in connection with the design.

- Forgings for shafting, couplings, coupling bolts.
- Forgings for through hardened, induction hardened, and nitrided gears
- Castings approved for use in place of any of the above forgings
- Forgings for carburized gears. Refer Part-2, Ch-2, Sec-6, [6.1.8.1](g)

2.2. Requirements for Alternative Material Test

2.2.1 Alternative Specifications

The Surveyor will inspect and test the material manufactured following specifications other than those given in Part 2, Chapter 2, provided that those specifications are approved in connection with the designs and that they are distinctively indicated on purchase orders furnished for the Surveyor's information.

2.2.2 Gears Certified Under Quality Assurance Assessment

For gear units certified under quality assurance assessment provided in Sec-6, [6.5] of this chapter, material tests and inspections required as per [2.1] above need not be witnessed by the Surveyor; instead these tests and inspections are to be executed by the gear manufacturer who's certified material test reports will be acceptable.

2.2.3 Steel-bar Stock

Hot-rolled steel bars with up to 305 mm (12 in.) diameter may be used when approved for use instead of any of the forgings as outlined in [2.2.1] above and following conditions furnished in Part-2, Ch-2, Sec-3.

2.2.4 Gear Units of 375 kW (500 hp) or Less

Material for gear units of 375 kW (500 hp) or less, including shafting, gears, couplings, and coupling bolts etc. will be accepted on the basis of manufacturer's certified material test reports, surface inspection and hardness checks witnessed by the Surveyor. Coupling bolts manufactured as per a recognized bolt standard, do not material testing.

2.2.5 Power Takeoff Gears and Couplings

Materials for power takeoff gears and couplings include:

- For transmission of power to drive auxiliaries that are for use in port only (e.g., cargo oil pump),
- De-clutchable from propulsion shafting

May be treated in the same fashion as [2.2.4] above, regardless of power rating

SECTION 3 DESIGN OF GEARS

Contents

3.1.Symbols.....	151
3.2.Tooth Form.....	154
3.3.Tooth loading factors.....	154
3.4.Tooth loading for surface stress.....	156
3.5.Tooth loading for bending stress.....	157
3.6.Factors of safety.....	161
3.7.Calculation of Shafts for Gears.....	162
3.8.Rating of Gears.....	163
3.9.Gears with Multiple Prime Mover Inputs.....	164
3.10.Couplings, Coupling Bolts, Flexible Coupling and Clutches.....	164

3.1. Symbols

Following symbols are applicable for the purposes of this Chapter only:

- a = centre distance, in mm
- b = face width, in mm
- d_{re} = reference diameter, in mm
- d_a = tip diameter, in mm
- d_{an} = virtual tip diameter, in mm
- d_b = base diameter, in mm
- d_{bn} = virtual base diameter, in mm
- d_{en} = virtual diameter to the highest point of single tooth pair contact, in mm
- d_f = root diameter, in mm
- d_{fn} = virtual root diameter, in mm
- d_n = virtual reference diameter, in mm
- d_s = shrink diameter, in mm
- d_w = pitch circle diameter, in mm
- f_{ma} = tooth flank misalignment due to manufacturing errors, in µm
- f_{pb} = maximum base pitch deviation of wheel, in µm
- f_{sh} = tooth flank misalignment due to wheel and pinion deflections, in µm
- f_{Sho} = intermediary factor for the determination of f_{sh}
- g_α = length of line of action for external gears, in mm:

$$= 0.5 \sqrt{(d_{a1}^2 - d_{b1}^2)} + 0.5 \sqrt{(d_{a2}^2 - d_{b2}^2)} - a \sin \alpha_{tw}$$

for internal gears:

$$= 0.5 \sqrt{(d_{a1}^2 - d_{b1}^2)} - 0.5 \sqrt{(d_{a2}^2 - d_{b2}^2)} + a \sin \alpha_{tw}$$

- h = total depth of tooth, in mm
- h_{ao} = basic rack addendum of tool, in mm
- h_F = bending moment arm for root stress, in mm
- h_w = sum of actual tooth addenda of pinion and wheel, in mm
- m_n = normal module, in mm
- n = rev/min of pinion
- q = machining allowances, in mm
- q_s = notch parameter
- q' = intermediary factor for the determination of C_γ
- u = gear ratio = ≥1
- v = linear speed at pitch circle, in m/s
- x = addendum modification coefficient
- y_α = running in allowance, in µm
- y_β = running in allowance, in µm
- z = number of teeth
- z_n = virtual number of teeth = $\frac{z}{\cos^2 \beta_b \cos \beta}$
- C_γ = tooth mesh stiffness (mean total mesh stiffness per unit face width), in N/mm µm
- F_t = nominal tangential tooth load, in N = $\frac{P}{n d_{re}} \times 19.098 \times 10^6$
- F_β = total tooth alignment deviation (maximum value specified), in µm
- F_{βx} = actual longitudinal tooth flank deviation before running in, in µm
- F_{βy} = actual longitudinal tooth flank deviation after running in, in µm
- HV = Vickers Hardness Number
- K_A = application factor
- K_{Fα} = transverse load distribution factor
- K_{Fβ} = longitudinal load distribution factor

$K_{H\alpha}$	=	transverse load distribution factor
$K_{H\beta}$	=	longitudinal load distribution factor
K_v	=	dynamic factor
$K_{v\alpha}$	=	dynamic factor for spur gears
$K_{v\beta}$	=	dynamic factor for helical gears
K_γ	=	load sharing factor
P	=	transmitted power, in kW
P_r	=	radial pressure at shrinkage surface, in N/mm ²
P_{ro}	=	protuberance of tool, in mm
Q	=	accuracy grade derived from ISO 1328 – Cylindrical gears – ISO system of accuracy
R_a	=	surface roughness – arithmetical mean deviation (C.L.A.) as determined by an instrument having a minimum wavelength cut-off of 0.8 mm and for a sampling length of 2.5 mm, in μm
S_{pr}	=	residual undercut left by protuberance in mm
SF_{min}	=	minimum factor of safety for bending stress
SF_n	=	tooth root chord in the critical section, in mm
S_{Hmin}	=	minimum factor of safety for Hertzian contact stress
Y_D	=	design factor
Y_F	=	tooth form factor
$Y_{R\ rel\ T}$	=	relative surface finish factor
Y_S	=	stress concentration factor
Y_{ST}	=	stress correction factor
Y_x	=	size factor
Y_β	=	helix angle factor
$Y_{\delta\ rel\ T}$	=	relative notch sensitivity factor
Z_E	=	material elasticity factor
Z_H	=	zone factor
Z_R	=	surface finish factor
Z_V	=	velocity factor
Z_X	=	size factor
Z_β	=	helix angle factor
Z_ϵ	=	contact ratio factor
α_{en}	=	pressure angle at the highest point of single tooth contact, in degrees
α_n	=	normal pressure angle at reference diameter, in degrees
α_t	=	transverse pressure angle at reference diameter, in degrees
α_{tw}	=	transverse pressure angle at pitch circle diameter, in degrees
α_{Fen}	=	angle for application of load at the highest point of single tooth contact, in degrees
β	=	helix angle at reference diameter, in degrees
β_b	=	helix angle at base diameter, in degrees
γ	=	intermediary factor for the determination of f_{Sh}
ϵ_α	=	transverse contact ratio $= \frac{g \alpha \cos \beta}{\pi m_n \cos \alpha_t}$
ϵ_{an}	=	virtual transverse contact ratio
ϵ_β	=	overlap ratio $= \frac{b \sin \beta}{\pi m_n}$
ϵ_γ	=	total contact ratio
ρ_{ao}	=	tip radius of tool, in mm
ρ_c	=	relative radius of curvature at pitch point, in mm $= \frac{a \sin \alpha_{tw} u}{\cos \beta_b (1+u)^2}$
ρ_F	=	tooth root fillet radius at the contact of the 30° tangent, in mm
σ_y	=	yield or 0.2 per cent proof stress, in N/mm ²
σ_B	=	ultimate tensile strength, in N/mm ²
σ_F	=	bending stress at tooth root, in N/mm ²
σ_{Flim}	=	endurance limit for bending stress in N/mm ²
σ_{FP}	=	allowable bending stress at the tooth root, in N/mm ²
σ_H	=	Hertzian contact stress at the pitch circle, in N/mm ²
$\sigma_{H\ lim}$	=	endurance limit for Hertzian contact stress, in N/mm ²

σ_{HP} = allowable Hertzian contact stress, in N/mm²

Subscript:

1 = pinion

2 = wheel

0 = tool

3.2. Tooth Form

- 3.2.1. The tooth profile in the transverse section is to be of involute shape, and the roots of the teeth are to be formed with smooth fillets of radii not less than 0.25 m_n .
- 3.2.2. All sharp edges left on the tips and ends of pinion and wheel teeth after hobbing and finishing are to be removed.

3.3. Tooth loading factors

- 3.3.1. For values of application factor, K_A Refer Table 3.3.1.

Table 3.3.1 Values of K_A

Main and Auxiliary Gears	K_A
Main propulsion oil engine reduction gears:	
Hydraulic coupling or equivalent on input	1.10
High elastic coupling on input	1.30
Other coupling	1.50
Auxiliary gears:	
Electric and diesel engine drives with hydraulic coupling or equivalent on input	1.00
Diesel engine drives with high elastic coupling on input	1.20
Diesel engine drives with other couplings	1.40

- 3.3.2. Load sharing factor, K_V .

The value for K_V is to be taken as 1.15 for multi-engine drives or split torque arrangements. Otherwise K_V is to be taken as 1.0. Alternatively, where measured data exists, a derived value will be considered.

- 3.3.3. Dynamic factor, K_v :

For helical gears with $\epsilon_\beta \geq 1$:

$$K_V = 1 + Q^2 v z_1 10^{-5} = K_{v\beta}$$

For helical gears with $\epsilon_\beta < 1$:

$$K_V = K_{v\alpha} - \epsilon_\beta (K_{v\alpha} - K_{v\beta})$$

For spur gears:

$$K_V = 1 + 1.8 Q^2 v z_1 10^{-5} = K_{v\alpha}$$

Where $\frac{v z_1}{100} > 14$ for helical gears, and

$\frac{v z_1}{100} > 10$ for spur gears the value of K_v will be specially considered.

3.3.4. Longitudinal load distribution factors, $K_{H\beta}$ and $K_{F\beta}$:

$$K_{F\beta} = K_{H\beta} \cdot n$$

$$\text{where } n = \frac{\left(\frac{b}{h}\right)^2}{1 + \frac{b}{h} + \left(\frac{b}{h}\right)^2}$$

Notes:

a) $\frac{b}{h}$ is to be taken as the smaller of or $\frac{b_1}{h_1}$ or $\frac{b_2}{h_2}$

b) For double helical gears $\frac{b}{2}$ is to be substituted for b in the equation for n .

$$K_{H\beta} = 1 + \frac{b F_{\beta\gamma} C_{\gamma}}{2 F_t K_A K_{\gamma} K_V}$$

Calculated values of $K_{H\beta} > 2$ are to be reduced by improved accuracy and helix correction as necessary:

where

$$F_{\beta\gamma} = F_{\beta X} - \gamma_{\beta} \quad \text{and} \quad F_{\beta X} = 1.33 f_{Sh} + f_{ma}$$

$$f_{ma} = \frac{2 F_{\beta}}{3} \quad \text{at the design stage, or}$$

$$f_{ma} = \frac{F_{\beta}}{3} \quad \text{where helix correction has been applied}$$

$$f_{Sh} = f_{Sho} \frac{F_t K_A K_{\gamma} K_V}{b} \quad \text{where}$$

$$f_{Sho} = 23 \gamma 10^{-3} \mu\text{m mm/N for gears without helix correction and without end relief, or}$$

$$= 23 \gamma 10^{-3} \mu\text{m mm/N for gears without helix correction but with end relief, where}$$

$$\gamma = \left(\frac{b}{d_{re1}}\right)^2 \quad \text{for single helical and spur gears}$$

$$= 3 \left(\frac{b}{2 d_{re1}}\right)^2 \quad \text{for double helical gears}$$

The following minimum values are applicable, these also being the values where helix correction has been applied:

$$f_{Sho} = 10 \times 10^{-3} \mu\text{m mm/N for helical gears, or}$$

$$= 5 \times 10^{-3} \mu\text{m mm/N for spur gears}$$

For through-hardened steels and surface hardened steels running on through-hardened steels:

$$y_{\beta} = \frac{320}{\sigma_{H \text{ lim}}} F_{\beta X} \quad \text{when } y_{\beta} \leq \frac{12800}{\sigma_{H \text{ lim}}} \mu\text{m and}$$

For surface hardened steels, when

$$y_{\beta} = 0.15 F_{\beta X} \quad \dots\dots\dots y_{\beta} \leq 6 \mu\text{m}$$

3.3.5. Transverse load distribution factors, $K_{H\alpha}$ and $K_{F\alpha}$

$$K_{H\alpha} = K_{F\alpha} \geq 1.00$$

where $\varepsilon_{\gamma} \leq 2$

$$K_{H\alpha} = \left\{ 0.9 + \frac{0.4 C_{\gamma} (f_{pb} - \gamma_{\alpha}) b}{F_t K_A K_{\gamma} K_V K_{H\beta}} \right\}$$

where $\varepsilon_{\gamma} > 2$

$$K_{H\alpha} = 0.9 + 0.4 \sqrt{\frac{2(\varepsilon_Y - 1)}{\varepsilon_Y}} \left\{ \frac{C_Y(f_{pb} - y_\alpha)b}{F_t K_A K_Y K_V K_{H\beta}} \right\}, \text{ but}$$

$$K_{H\alpha} \leq \frac{\varepsilon_Y}{\varepsilon_\alpha Z_\varepsilon^2} \text{ and}$$

$$K_{F\alpha} \leq \frac{\varepsilon_Y}{0.25\varepsilon_Y + 0.75}$$

When tip relief is applied f_{pb} is to be half of the maximum specified value:

$$y_\alpha = \frac{160}{\sigma_{H \text{ lim}}} f_{pb} \text{ for through-hardened steels, when } y_\alpha \leq \frac{6400}{\sigma_{H \text{ lim}}} \mu\text{m}$$

and

$$y_\alpha = 0.075 f_{pb} \text{ for surface hardened steels, when } y_\alpha \leq 3 \mu\text{m}$$

When pinion and wheel are manufactured from different materials:

$$y_\alpha = \frac{y_{\alpha 1} + y_{\alpha 2}}{2}$$

3.3.6. Tooth Mesh Stiffness, C_Y

$$C_Y = \frac{0.8}{q'} \cos \beta (0.75 \varepsilon_a + 0.25) \text{ N/mm } \mu\text{m}$$

Where

$$q' = 0.04723 + 0.04723 + \frac{0.1551}{z_{n1}} + \frac{0.25791}{z_{n2}} - 0.00635 x_1 - \frac{0.11654x_1}{z_{n1}} - 0.00193x_2 - \frac{0.24188x_2}{z_{n2}} + 0.00529x_1^2 + 0.00182x_2^2$$

For internal gears $z_{n2} = \infty$

Other calculation methods for C_Y will be specially considered.

3.4. Tooth loading for surface stress

3.4.1. The Hertzian contact stress, σ_H , at the pitch circle is not to exceed the allowable Hertzian contact stress, σ_{HP} .

$$\sigma_H = Z_H Z_E Z_\varepsilon Z_\beta \sqrt{\frac{F_t(u+1)}{d_1 b u}} K_A K_Y K_V K_{H\beta} K_{H\alpha} \text{ and}$$

$$\sigma_{HP} = \frac{\sigma_{H \text{ lim}} Z_R Z_V Z_X}{S_{H \text{ min}}} \text{ for the pinion/wheel combination}$$

where

$$Z_H = \sqrt{\frac{2 \cos \beta_b \cos \alpha_{tw}}{\cos^2 \alpha_t \sin \alpha_{tw}}}$$

$$Z_E = 198.8 \text{ for steel}$$

$$Z_\varepsilon = \sqrt{\frac{4 - \varepsilon_\alpha}{3} (1 - \varepsilon_\beta) + \frac{\varepsilon_\beta}{\varepsilon_\alpha}} \text{ for } \varepsilon_\beta < 1 \text{ and}$$

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}} \text{ for } \varepsilon_\beta \geq 1$$

$$Z_\beta = \sqrt{\cos \beta}$$

$$Z_R = \left(\frac{1}{R_a} \right)^{0.11} \text{ but } Z_R \leq 1.14$$

where R_a is the surface roughness value of the tooth flanks.

When pinion and wheel tooth flanks differ then the larger value of R_a is to be taken.

$$Z_V = 0.88 + 0.23 \left(0.8 + \frac{32}{V}\right)^{-0.5}$$

Z_x values are given in Table 3.3.2.

$\sigma_{H \text{ lim}}$ values are given in Table 3.3.3.

$S_{H \text{ lim}}$ values are given in Table 3.3.5.

Table 3.3.2 Values of Z_x

Pinion heat treatment		Z_x
Carburised and induction-hardened	$m_n \leq 10$	1.00
	$10 < m_n < 30$	$1.05 - 0.005m_n$
	$30 \leq m_n$	0.9
Nitrided	$m_n < 7.5$	1.00
	$7.5 < m_n < 30$	$1.08 - 0.011m_n$
	$30 \leq m_n$	0.75
Through-hardened	All modules	1.00

Table 3.3.3 Values of endurance limit for Hertzian contact stress, $\sigma_{H \text{ lim}}$

Heat treatment		$\sigma_{H \text{ lim}}$ N/mm ²
Pinion	Wheel	
Through-hardened	Through-hardened	$0.46 \sigma_{B2} + 255$
Surface-hardened	Through-hardened	$0.42 \sigma_{B2} + 415$
Carburised, nitrided or induction hardened	Soft bath nitrided (Tuffirided)	1000
Carburised, nitride or induction hardened	Induction hardened	$0.88 H V_2 + 675$
Carburised or nitrided	Nitrided	1300
Carburised	Carburised	1500

3.5. Tooth loading for bending stress

- 3.5.1. The bending stress at the tooth root, σ_F is not to exceed the allowable tooth root bending stress σ_{FP}

$$\sigma_F = \frac{F_t}{b m_n} Y_F Y_S Y_\beta K_A K_V K_{F\beta} K_{F\alpha} \quad \text{N/mm}^2$$

$$\sigma_{FP} = \frac{\sigma_{F \text{ lim}} Y_{ST} Y_{\delta \text{ rel } T} Y_{R \text{ rel } T} Y_X}{S_{F \text{ min}} Y_D} \quad \text{N/mm}^2$$

$S_{F \text{ min}}$ values are given in Table 3.3.5.

$\sigma_{F \text{ lim}}$ values are given in Table 3.3.4.

Y_{ST} = Stress correction factor = 2.

Table 3.3.4 Values of endurance limit for bending stress, σ_F lim

Heat treatment	σ_F lim N/mm ²
Through-hardened carbon steel	$0.09\sigma_B + 150$
Through-hardened alloy steel	$0.1\sigma_B + 185$
Soft bath nitrided (Tufftrided)	330
Induction hardened	$0.35 \text{ HV} + 125$
Gas nitrided	390
Carburised	A 450
Carburised	B 410
Notes	
1. A is applicable for Cr Ni Mo carburising steels.	
2. B is applicable for other carburising steels.	

3.5.2. Tooth form factor, Y_F :

$$Y_F = \frac{6 \frac{h_F}{m_n} \cos \alpha_{F en}}{\left(\frac{S_{Fn}}{m_n}\right)^2 \cos \alpha_n}$$

where

h_F , $\alpha_{F en}$ and S_{Fn} are shown in Fig. 3.3.1.

$$\frac{S_{Fn}}{m_n} = z_n \sin \left(\frac{\pi}{3} - v \right) + \sqrt{3} \left(\frac{G}{\cos v} - \frac{\rho_{ao}}{m_n} \right)$$

where

$$v = \frac{2G}{z_n} \tan v - H$$

$$G = \frac{\rho_{ao}}{m_n} - \frac{h_{ao}}{m_n} + X$$

$$H = \frac{2}{z_n} \left(\frac{\pi}{2} - \frac{E}{m_n} \right) - \frac{\pi}{3}$$

$$E = \frac{\pi}{4} m_n - h_{ao} \tan \alpha_n + \frac{S_{pr}}{\cos \alpha_n} - (1 - \sin \alpha_n) \frac{\rho_{ao}}{\cos \alpha_n}$$

E , h_{ao} , α_n , S_{pr} and ρ_{ao} are shown in Fig. 3.3.2

$$\frac{\rho_F}{m_n} = \frac{\rho_{ao}}{m_n} + \frac{2G^2}{\cos v (z_n \cos^2 v - 2G)}$$

$$\frac{h_F}{m_n} = \frac{1}{2} \left[(\cos \gamma_\epsilon - \sin \gamma_\epsilon \tan \alpha_{F en}) \frac{d_{en}}{m_n} - z_n \cos \left(\frac{\pi}{3} - v \right) - \frac{G}{\cos v} + \frac{\rho_{ao}}{m_n} \right]$$

$$d_{en} = \frac{2z}{|z|} \left\{ \left[\sqrt{\left(\frac{d_{an}}{2}\right)^2 - \left(\frac{d_{bn}}{2}\right)^2} - \frac{\pi d \cos \beta \cos \alpha_n}{|z|} (\varepsilon_{an} - 1) \right]^2 + \left(\frac{d_{bn}}{2}\right)^2 \right\}^{1/2}$$

where

$$d_{an} = d_n + d_a - d_{re}$$

$$d_n = \frac{d_{re}}{\cos^2 \beta_b}$$

$$d_{bn} = d_n \cos \alpha_n$$

$$\varepsilon_{an} = \frac{\varepsilon_a}{\cos^2 \beta_b}$$

$$\gamma_e = \frac{\frac{\pi}{2} + 2x \tan \alpha_n}{z_n} + \text{inv. } \alpha_n - \text{inv. } \alpha_{en}$$

where

$$\alpha_{en} = \arccos \frac{d_{bn}}{d_{en}}$$

$$\alpha_{Fen} = \alpha_{en} - \gamma_e$$

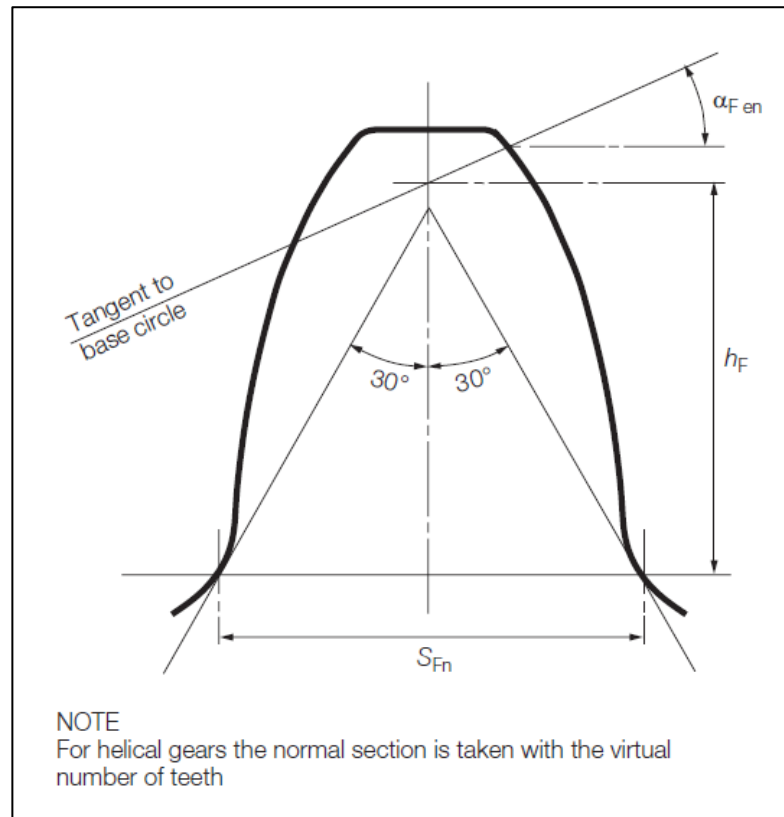


Figure 3.3.1: Normal Tooth Section

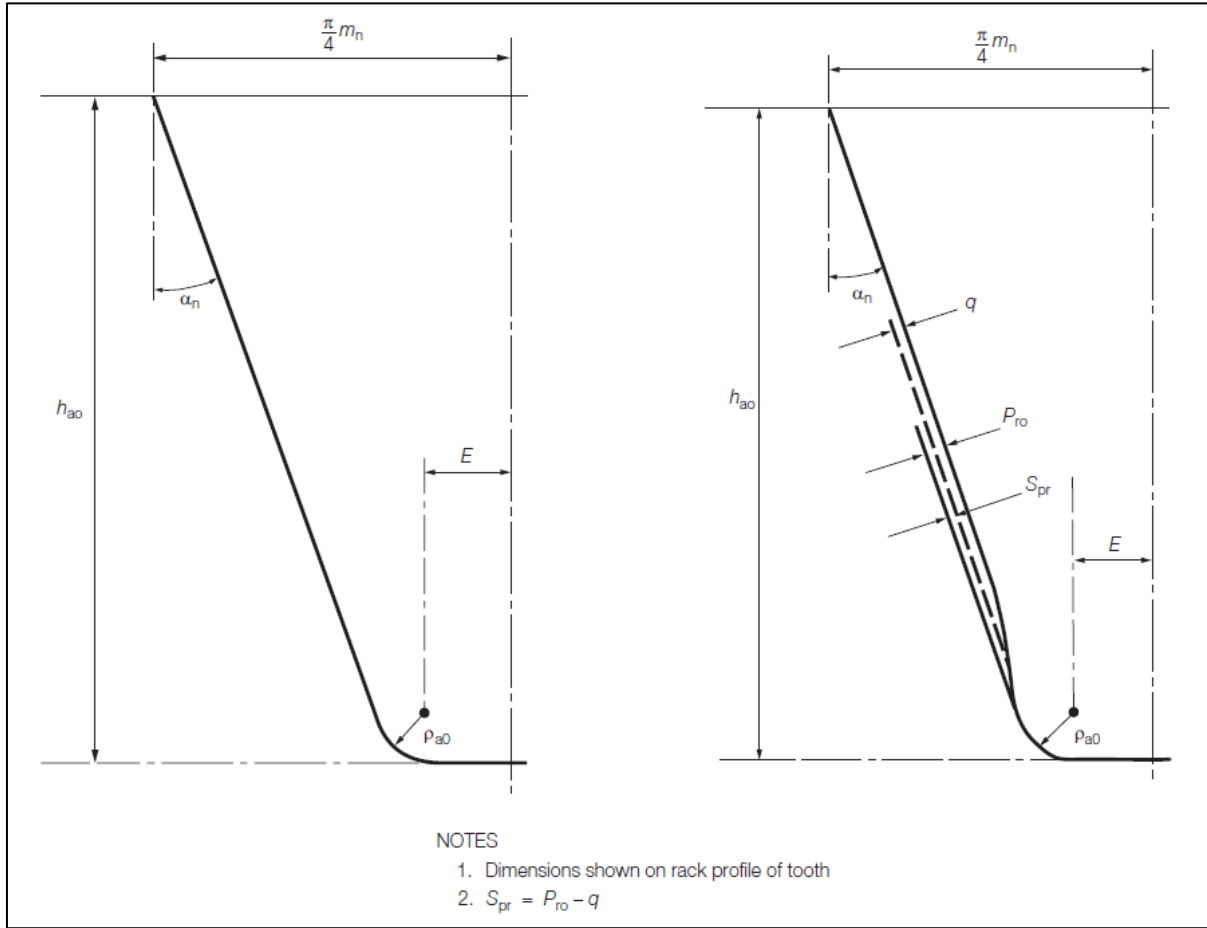


Figure 3.3.2: External Tooth Forms

- 3.5.3. For internal tooth forms the form factor is calculated, as an approximation, for a substitute gear rack with the form of the basic rack in the normal section, but having the same tooth depth as the internal gear:

$$\frac{S_{Fn2}}{m_n} = 2 \left[\frac{\pi}{4} + \tan \alpha \left(\frac{h_{ao2} - \rho_{ao2}}{m_n} \right) + \left(\frac{\rho_{ao2} - S_{pr}}{m_n \cos \alpha_n} \right) - \frac{\rho_{ao2}}{m_n} \cos \frac{\pi}{6} \right]$$

and

$$\frac{h_{F2}}{m_n} = \frac{d_{en2} - d_{fn2}}{2m_n} - \left[\frac{\pi}{4} + \left(\frac{h_{ao2}}{m_n} - \frac{d_{en2} - d_{fn2}}{2m_n} \right) \tan \alpha_n \right] \tan \alpha_n - \frac{\rho_{ao2}}{m_n} \left(1 - \sin \frac{\pi}{6} \right)$$

Where

$\alpha_{F\text{ en}}$ is taken as being equal to α_n

$$\rho_{F2} = \frac{\rho_{ao2}}{2}$$

d_{en2} is calculated as d_{en} for external gears, and

$$d_{fn} = d_{re} - d_f - d_n$$

- 3.5.4. Stress concentration factor, Y_s

$$Y_s = (1.2 + 0.13 L) q_s^{\left(\frac{1}{1.21+2.3/L} \right)}$$

where

$$L = \frac{S_{Fn}}{h_F}$$

$$q_s = \frac{S_{Fn}}{2\rho_F}$$

when $q_s < 1$ the value of Y_s is to be specially considered.

The formula for Y_s is applicable to external gears with $\alpha_n = 20^\circ$ but may be used as an approximation for other pressure angles and internal gears.

3.5.5. Helix angle factor Y_β

$$Y_\beta = 1 - \left(\varepsilon_\beta \frac{\beta}{120} \right), \text{ if } \varepsilon_\beta > 1 \text{ let } \varepsilon_\beta = 1$$

but $Y_\beta \geq 1 - 0.25\varepsilon_\beta \geq 0.75$.

3.5.6. Relative notch sensitivity factor, $Y_{\delta \text{ rel } T}$

$$Y_{\delta \text{ rel } T} = 1 + 0.036 (q_s - 2.5) \left(1 - \frac{\sigma_y}{1200} \right) \text{ -- for through hardened steels}$$

$$Y_{\delta \text{ rel } T} = 1 + 0.008 (q_s - 2.5) \text{ -- for carburised and induction hardened steels, and}$$

$$Y_{\delta \text{ rel } T} = 1 + 0.04 (q_s - 2.5) \text{ -- for nitrided steels.}$$

3.5.7. Relative surface finish factor, $Y_{R \text{ rel } T}$

$$Y_{R \text{ rel } T} = 1.674 - 0.529 (6R_a + 1^{0.1}) \text{ -- for through-hardened, carburised and induction hardened steels, and}$$

$$Y_{R \text{ rel } T} = 4.299 - 3.259 (6R_a + 1)^{0.005} \text{ -- for nitrided steels.}$$

3.5.8. Size factor, Y_x

$$Y_x = 1.00, \text{ when } m_n \leq 5$$

$$Y_x = 1.03 - 0.006m_n \text{ for through hardened steels}$$

$$Y_x = 0.85, \text{ when } m_n \geq 30$$

$$Y_x = 1.05 - 0.01m_n \text{ for surface-hardened steels}$$

$$Y_x = 0.80, \text{ when } m_n \geq 25.$$

3.5.9. Design factor, Y_D

$$Y_D = 0.83 \text{ -- for gears treated with a controlled shot peening process}$$

$$Y_D = 1.5 \text{ -- for idler gears}$$

$$Y_D = 1.25 \text{ -- for shrunk on gears, or}$$

$$Y_D = 1 + \frac{0.2 d_S^2 d_{re} P_r b}{F_t \sigma_{F \text{ lim}} (d_t^2 - d_S^2)}, \text{ otherwise}$$

$$Y_D = 1.00.$$

3.6. Factors of safety

Factors of safety are shown in Table 3.3.5.

Table 3.3.5 Factors of safety

	$S_{H \text{ min}}$	$S_{F \text{ min}}$
Main propulsion gears	1.4	1.8
Auxiliary gears	1.15	1.40

3.7. Calculation of Shafts for Gears

3.7.1 General

Calculation for the diameter of shafts for gears is by the following equations:

$$d = k \sqrt[6]{(b T)^2 + (m M)^2}$$

$$b = 0.073 + \frac{n}{Y}$$

$$m = \frac{c_1}{c_2 + Y}$$

where, (in SI (MKS and US units), respectively):

d = shaft diameter at section under consideration; mm (in.)

Y = yield strength (Refer Part-2, Ch-1, Sec-1, [1.7.2]); N/mm² (kgf/mm², psi)

T = torsional moment at rated speed; N-m (kgf-cm, lbf-in) (Refer also Sect [3.7.6] below to account for effect of torsional vibrations, where applicable.)

M = bending moment at section under consideration; N-m (kgf-cm, lbf-in)

k, n, c₁ and c₂ are constants given in the following table:

	SI Units	MKS Units	US Units
k	5.25	2.42	0.10
n	191.7	19.5	27800
c	1186	121	172000
c	413.7	42.2	60000

3.7.2 Shaft Diameter in way of Gear Wheel

Where gear wheels are fitted by a shrink fit or press, or by keying, shaft diameter in way of the fitted member is to be increased by not less than 10%.

3.7.3 Astern Power

While determining the required gear size and coupling and shafting transmitting astern power, the astern torque is given due consideration when it exceeds the transmitted ahead torque. Also refer Ch-1, Sec-4, [4.3].

3.7.4 Quill Shafts

In the specific case of quill shafts subjected to no bending moments but only small stress raisers, least diameter may be determined by the equation given below:

SI Units	MKS Units	US Units
$d = 5.25 \sqrt[3]{b T}$	$d = 2.42 \sqrt[3]{b T}$	$d = 0.1 \sqrt[3]{b T}$

$b = 0.053 + \frac{187.8}{Y}$	$b = 0.053 + \frac{19.1}{Y}$	$b = 0.053 + \frac{27200}{Y}$

3.7.5 Shaft Couplings

For coupling bolts, shaft couplings, clutches and flexible coupling, refer Ch-4, Sec-3, [3.10].
For keys, refer Ch-4, Sec-3, [3.4].

3.7.6 Vibration

The builder or designer is to evaluate:

- The shafting system for different vibration modes (torsional, lateral, axial) and the their coupled effect, as appropriate,
- The shafts diameters considering maximum total torque (steady and vibratory torque),
- The gears for harmful torsional vibrations stresses and gear chatter. Also refer Ch-4, Sec-4, [4.3.9].

3.7.7 Shrink Fitted Pinions and Wheels

For review, pinions and wheels shrink-fitted on shafts, preloading, fitting instructions and stress calculations are to be submitted. In general, the torsional holding capacity is to be at least 2.8 times the transmitted mean torque plus vibratory torque due to torsional vibration. For purpose of calculation and to take account of torsional vibratory torque, following factors may be applied to the transmitted torque, unless the actual measured vibratory torque is higher, and where the actual vibratory torque is to be used.

- For direct diesel engine drives: 1.2
- For all other including diesel engine drives with elastic couplings: 1.0

The preload stress based on the maximum pull-up length or maximum available interference fit is not to exceed 90% of the minimum specified yield strength.

The friction coefficients to be used are given below:

- Dry method of fit: 0.18
- Oil injection method of fit: 0.13

3.7.8 Shrink Fitted Wheel Rim

For shrink-fitted wheel rims, preloading, fitting instructions and stress calculations are to be submitted for consideration. In general, preloading stress based on the maximum interference fit or maximum pull-up length is not to exceed 90% of the minimum specified yield strength.

3.8. Rating of Gears

- The Procedure for calculation of the rating of involute spur and helical cylindrical gears both external and internal having parallel axes and of bevel gears, with regard to surface durability (pitting) and tooth root bending strength, given in this section are to be in substantial agreement with ISO 6336 and ISO-DIS 10300 for cylinder and bevel gears, respectively.

3.8.2 Alternative Gear Rating Standards

Due consideration will be given to gears that are rated on the basis of any of the alternative standards given below. In such a case, gear rating calculations and justification of the applied gear design coefficients as per the applicable design standard are to be submitted for review to INTLREG.

Cylindrical Gears	Bevel Gears
AGMA 6032-A94	AGMA 2003-A86
ISO 6336	ISO-DIS 10300
DIN 3990, Part 31	DIN 3991

3.8.3 Rating for Intermittent Duty

The Gears intended for intermittent duty are to have the conditions associated with the intermittent rating clearly defined and listed as part of the rating. These conditions must include the followings:

- a) the specific intermittent rating (power and rpm) or ratings if there will be multiple intermittent ratings
- b) the limit on the number of hours at the rating, both continuous per 24 hour period and total hours
- c) the time between overhaul and servicing of the unit, and
- d) any other conditions that the manufacturer places on the unit

The Calculations are to be submitted by the manufacturer supporting the intermittent rating or ratings for review to the INTLREG. The calculations are to be based on ISO 6336-6 Calculation of local capacity of spur and helical gears – Calculation of service life under variable load, or an equivalent recognized national standard that uses a fatigue cycle approach.

3.9. Gears with Multiple Prime Mover Inputs

For single helical gears with arrangements using multiple prime mover inputs, and single or multiple outputs, analyses for all operating modes are to be conducted, as given below:

- a) All bearing reactions
- b) Tooth modifications
- c) Load distributions on the gear teeth
- d) Contact and tooth root bending stresses

For review, summary of the results of these analyses for each operating mode is to be submitted.

3.10. Couplings, Coupling Bolts, Flexible Coupling and Clutches

For shaft couplings, coupling bolts, flexible coupling and clutches, Refer Chapter 4, [3.4] and [3.10].

SECTION 4 CONSTRUCTION

Contents

4.1.Gear wheels and pinions..... 166

4.2.Accuracy of gear cutting and alignment..... 166

4.3.Bearings 166

4.4.Gear Cases 167

4.5.Access for Inspection of gear cases 167

4.1. Gear wheels and pinions

- 4.1.1. Fitting of any radial slots in the periphery with permanent chocks are to be done before shrinking-on the rim, where castings are used for wheel centers.
- 4.1.2. The bolts are required to be a tight fit in the holes and the nuts are required to be suitably locked by means other than welding in place where bolts are used to secure side plates to rim and hub.
- 4.1.3. Before the work is commenced, the Surveyors shall approve the welding procedure in a place where welding is employed in the construction of wheels. For this purpose, welding procedure approval tests are to be carried out with satisfactory results. Such tests are to be a representative of the joint configuration and materials. After welding, the wheels are required to be stress relieved. It is required for all welds to have a satisfactory surface finish and contour. To meet the satisfaction of the Surveyors, magnetic particle or liquid penetrant examination of all important welded joints is to be carried out.
- 4.1.4. In order to examine the interior structure of the wheel, generally arrangements are required to be made. Special consideration of alternative proposals will be done.

The surface texture of the Tooth flank shall be no worse than 0.6 μm Ra and in the roots no worse than 2.0 μm Ra, where Ra is Surface Roughness (average from centerline)

4.2. Accuracy of gear cutting and alignment

- 4.2.1. Demonstration of the machining accuracy (Q grade i.e. The Q-Number for a gear is a measure of the geometric accuracy level of teeth on the gear.) of pinions and wheels is to be done in order to meet the satisfaction of the Surveyor. For this purpose, on requesting the Surveyor should be provided with the records of measurement for review.
- 4.2.2. The normal shop meshing tests are to be supplemented by tooth alignment traces or other approved means to demonstrate the effectiveness of such modifications where allowance has been given for end relief or helix correction.

4.3. Bearings

Bearings of gear units are required to be so designed and arranged in such a way that their design lubrication rate is assured in service under working conditions.

4.3.1. Journal Bearings

The maximum bearing pressures, minimum oil film thickness, maximum predicted internal bearing temperature and the maximum static unit load for journal bearings are required to be in accordance with an applicable standard such as ISO 12130-1:2001 (plain tilting plain thrust bearings), ISO 12131-1:2001 (plain thrust pad bearings), ISO 12167-1:2001 (plain journal bearings with drainage grooves), ISO 12168-1:2001 (plain journal bearings without drainage grooves), ANSI/AGMA 6032-A94, etc.

4.3.2. Roller Bearings

The minimum L10 bearing life is not to be less than 20,000 hours for ahead drives and 5,000 hours for astern. Shorter life may be considered in conjunction with an approved bearing inspection and replacement program reflecting the actual calculated bearing life. For application to thrusters Refer Ch-7, Sec-3/ [3.5]. In accordance with an applicable standard such as ISO 76:1987, ISO 281:1990 (rolling bearings, for static and dynamic ratings, respectively), calculations are to be done.

4.3.3. Alternative Designs

Bearing pressures exceeding the limits in the standards listed in Sect [4.3.1] & [4.3.2] above shall be considered provided that the manufacturer can demonstrate a reliable operating history with similar designs.

4.3.4. Shaft Alignment Analysis

The load on the gear shaft bearings is to be evaluated by taking into consideration the loads resulting from the shafting alignment condition for gear-shafts which are directly connected to the propulsion shafting.

4.4. Gear Cases

4.4.1. In order to avoid misalignment at the mesh due to movements of the external foundations and so that the thermal effects under all conditions of service do not disturb the overall tooth contact, the gear cases and their supports are required to be designed sufficiently stiff.

4.4.2. Generally, the carbon content of steel should not exceed 0.23% for gear cases fabricated by fusion welding. Approval of steels with higher carbon content may be subjected to satisfactory results from weld procedure tests.

4.4.3. On completion of all welding, gear cases are required to be stress relief heat treated.

4.4.4. In order to enable the teeth of pinions and wheels to be readily examined, inspection openings are required to be provided at the peripheries of gear cases. Access openings of adequate size are also to be provided at the ends of the gear cases to permit examination of the structure of the wheels where the construction of gear cases is such that sections of the structure cannot readily be moved for inspection purposes. Their attachment to the shafts is to be capable of being examined by removal of bearing caps or by equivalent means.

4.5. Access for Inspection of gear cases

4.5.1. The gear cases are to be constructed such that a sufficient number of access points are provided for adequate inspection of gears, checking of gear teeth contacts and measurement of thrust bearing clearance. Consideration may be made for alternative methods such as use of special viewing devices.

SECTION 5 PIPING SYSTEMS

Contents

5.1.Gear Piping Systems.....	169

5.1. Gear Piping Systems

For diesel engine and gas turbine installations, the requirements of piping systems essential for operation of gears for propulsion, maneuvering, electric power generation and vessel's safety are in given Chapter-8, Sec-4 and for steam turbine installations the above mentioned requirements are given in Chapter-8, Sec-5. Additionally for hydraulic and pneumatic systems, the requirements are provided in Chapter-8, Sec-6. Specifically, the following references are applicable:

Lubricating oil system:	Chapter-8, [4.3] and [5.5]
Cooling system:	Chapter-8, [4.4] and [5.6]
Hydraulic system:	Chapter-8, Sec-6, [6.2]
Pneumatic system:	Chapter-8, Sec-6, [6.3]
Piping system general requirements:	Chapter-8, Sec-1 and Sec-2

SECTION 6 TESTING, INSPECTION AND CERTIFICATION OF GEARS

Contents

6.1. Dynamic Balancing	171
6.2. Material Tests	171
6.3. Non-destructive tests	171
6.4. Shop Inspection	171
6.5. Certification of Gears	171
6.6. Shipboard Trials	172
6.7. Gear Parameters	173

6.1. Dynamic Balancing

Dynamical balancing of the finished pinions and wheels are to be done in two planes where their pitch line velocity exceeds 25 m/s (4920 ft/min).

The parts may be statically balanced in a single plane where their pitch line velocity does not exceed 25 m/s (4920 ft/min) or where dynamic balance is impracticable due to size, weight, speed or construction of units.

The residual unbalance in each plane is not to exceed the value determined by the following equations:

SI units	MKS units	US units
$B_{am} = \frac{24 W}{N}$	$B_{am} = \frac{24000 W}{N}$	$B_{am} = \frac{15.1 W}{N}$

Where;

B_{am} = maximum allowable residual unbalance; N-mm (gf-mm, oz-in)

W = weight of rotating part; N (kgf, lbf)

N = rpm at rated speed

6.2. Material Tests

For testing of materials intended for gear construction, Refer Sec-2, [2.1] & [2.2].

6.3. Non-destructive tests

The finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm; an ultrasonic examination is required to be carried out on all gear blanks.

On all surface-hardened teeth, magnetic particles or liquid penetrant examination is required to be carried out. A request of this examination may also be made on the finished machine teeth of through-hardened gears.

6.4. Shop Inspection

During manufacturing, inspection of each gear unit that is required to be certified by Sec-1, [1.1] is to be carried out by the Surveyor for conformance with the approved design. This is to include but not limited to checks on gear teeth hardness, and surface finish and dimension checks of main load bearing components. Verification of the accuracy of meshing for all meshes and the checking of the initial tooth contact pattern is to be done by the Surveyor.

The surveyor shall be provided with the reports on pinions and wheels balancing as per [6.2] above for verification.

6.5. Certification of Gears**6.5.1. General**

Each gear required to be certified by Sec-1, [1.1] is:

- i) For the purpose of receiving approval of design by INTLREG, plans and data as required by Sec-1, [1.3] are to be submitted to INTLREG for approval

- ii) To be surveyed during its construction, which is to include, but not limited to, material tests as indicated in [6.2] of this section, meshing accuracy and tooth contact pattern checks as indicated in [6.3] above, and verification of dynamic balancing as indicated in [6.1] of this section.

6.5.2. Approval under the Type Approval Program

6.5.2.1. Product design assessment

As described in Part-1, Ch-1, Sect 11[11.1.3.1], each rating of a type of gear may be design assessed; upon the application by the manufacturer and for this purpose, each rating of a gear type is to be approved in accordance with [6.5.1] (i) above. The Surveyor shall witness the type test which is required to be conducted in accordance with an approved test schedule. Application to the INTLREG for listing may be done for gear that is approved on the INTLREG website as Assessment of Product Design. Once listed, and subject to renewal and updating of certificate as required by Part-1, Ch-1, Sec-11, submission of the gear particulars will not be required to be submitted to INTLREG each time the gear is proposed for use onboard a vessel.

6.5.2.2. Mass produced gears

Application for quality assurance assessment as described in Part-1, Ch-1, Sec-11, (PQA), may be done to INTLREG by a manufacturer of mass-produced gears, who operates a quality assurance system in the manufacturing facilities. Upon satisfactory assessment under Part-1, Ch-1, Sec-11, (PQA), attendance of the Surveyor at the tests and inspections as indicated in [6.5.1](ii) above will not be required for gears produced in those facilities. Manufacturer shall carry out such tests and inspections whose quality control documents will be accepted. On the basis of the verification of approval of the design and on continued effectiveness of the quality assurance system, each gear shall be certified. Refer Part-1, Ch-1, Sec-11.

6.5.2.3. Non-mass Produced Gears

As described in Part-1, Ch-1, Sec-11, or Part-1, Ch-1, Sec-2, (RQS), a manufacturer of non-mass produced gears, who operates a quality assurance system in the manufacturing facilities, may apply to INTLREG for quality assurance assessment. In accordance with Ch-1, Table 1.2.2, certification to Part-1, Ch-1, Sec-11, (PQA) may also be considered.

6.5.2.4. Type Approval Program

Gear types which have their ratings approved in accordance with Sect-[6.5.2.1] and the quality assurance system of their manufacturing facilities approved in accordance with [6.5.2.2]or [6.5.2.3] will be deemed Type Approved and will be eligible for listing on the INTLREG website as Type Approved Product.

6.6. Shipboard Trials

After installation on board a vessel, the gear unit is to be operated in the presence of the Surveyor to demonstrate its ability to function satisfactorily under operating conditions and its freedom from harmful vibration at speeds within the operating range. The Surveyor is to ascertain that no gear-tooth chatter occurs throughout the operating range, when the propeller is driven through reduction gears; otherwise, a barred speed range, as specified in Chapter-4, Sec-3, [4.3.4], is to be provided.

At trial, a record of gear-tooth contact is to be made for conventional propulsion gear units above 1120 kW (1500 hp). Beforehand coating with copper or layout dye is to be done to the selected bands of pinion or gear teeth on each meshing in order to facilitate the survey of extent and uniformity of gear-tooth contact.

Main propulsion gear-tooth contact is to be examined at the time of the first Annual Survey after the vessel enters service, or after replacement gears have been placed in service

Post-trial examination of spur and helical type gears is to indicate essentially uniform contact across 90% of the effective face width of the gear teeth, excluding end relief.

The gear-tooth examination for spur and helical type gear units of 1120 kW (1500 hp) and below, all epicyclical gear units and bevel type gears will be subject to special consideration. Recommendations of the gear manufacturer will be considered.

6.7. Gear Parameters

For purposes of submitting gear design for review, the following data and parameters may be used as a guide.

Gear manufacturer.....	Year of build.....
Shipyard	Hull number.....
Ship's name.....	Shipowner.....
GENERAL DATA	
Gearing type	
..... (non reversible, single reduction, double reduction, epicyclic, etc.)	
Total gear ratio.....	
Manufacturer and type of the main propulsion plant (or of the auxiliary machinery).....	
Power ⁽²⁾ kW, (PS, hp) Rotational speed ⁽²⁾ RPM	
Maximum input torque for continuous service N-m, (kgf-m, lbf-ft)	
Maximum input rotational speed for continuous service..... RPM	
Type of coupling: (stiff coupling, hydraulic or equivalent coupling, high-elasticity coupling, other couplings, quill shafts, etc.).....	
Specified grade of lubricating oil.....	
Expected oil temperature when operating at the classification power (mean values of temperature at inlet and outlet of reverse and/or reduction gearing).....	
Value of nominal kinematic viscosity, ν , at 40°C or 50°C of oil temperature (mm ² /s)	

CHARACTERISTIC ELEMENTS OF PINIONS AND WHEELS		First Gear Drive	Second Gear Drive	Third Gear Drive	Fourth Gear Drive
Gear drive designation					
Transmitted rated power, input in the gear drive – kW (mhp, hp) (Refer note 3)	P_{TrR}				
Rotational speed, input in the gear drive (RPM) (Refer note 2)	n				
Nominal transverse tangential load at reference cylinder – N, (kgf, lbf) (Refer note 4)	F_{tc}				
Number of teeth of pinion	z_1				
Number of teeth of wheel	z_2				
Gear ratio	u				
Center distance – mm (in.)	a				
Facewidth of pinion – mm (in.)	b_1				
Facewidth of wheel – mm (in.)	b_2				
Common facewidth – mm (in.)	b				
Overall facewidth, including the gap for double helical gears – mm (in.)	B_{fw}				

CHARACTERISTIC ELEMENTS OF PINIONS AND WHEELS		First Gear Drive	Second Gear Drive	Third Gear Drive	Fourth Gear Drive
Gear drive designation					
Is the wheel an external or an internal teeth gear?	-				
Number of pinions	-				
Number of wheels	-				
Is the wheel an external or an internal teeth gear	-				
Is the pinion an intermediate gear?	-				
Is the wheel an intermediate gear?	-				
Is the carrier stationary or revolving (star or planet carrier)? (Refer note 5)	-				
Reference diameter of pinion – mm (in.)	d_1				
Reference diameter of wheel – mm (in.)	d_2				
Working pitch diameter of pinion – mm (in.)	d_{w1}				
Working pitch diameter of wheel – mm (in.)	d_{w2}				
Tip diameter of pinion – mm (in.)	d_{a1}				
Tip diameter of wheel – mm (in.)	d_{a2}				
Base diameter of pinion – mm (in.)	d_{b1}				
Base diameter of wheel – mm (in.)	d_{b2}				
Tooth depth of pinion – mm (in.) (Refer note 6)	h_1				
Tooth depth of wheel – mm (in.) (Refer note 6)	h_2				
Addendum of pinion – mm (in.)	h_{a1}				
Addendum of wheel – mm (in.)	h_{a2}				
Addendum of tool referred to normal module for pinion	h_{a01}				
Addendum of tool referred to normal module for wheel	h_{a02}				
Dedendum of pinion – mm (in.)	h_{f1}				
Dedendum of wheel – mm (in.)	h_{f2}				
Dedendum of basic rack [referred to $m_n (=h_{a01})$] for pinion	h_{fp1}				
Dedendum of basic rack [referred to $m_n (=h_{a02})$] for wheel	h_{fp2}				
Bending moment arm of tooth – mm (in.) (Refer note 7)	h_F				
Bending moment arm of tooth – mm (in.) (Refer note 8)	h_{F2}				
Bending moment arm of tooth – mm (in.) (Refer note 9)	h_{Fa}				
Width of tooth at tooth-root normal chord – mm (in.)	S_{Fn}				
Width of tooth at tooth-root normal chord – mm (in.)	S_{Fn2}				
Angle of application of load at the highest point of single tooth contact (degrees)	α_{Fen}				
Pressure angle at the highest point of single tooth contact (degrees)	α_{en}				
Normal module – mm (in.)	m_n				
Outer normal module – mm (in.)	m_{na}				
Transverse module	m_t				
Addendum modification coefficient of pinion	x_1				

INTLREG Rules and Regulations for Classification of Steel Vessels

Addendum modification coefficient of wheel	X_2				
Addendum modification coefficient refers to the midsection ⁽⁹⁾	X_{mn}				
Tooth thickness modification coefficient (midface) ⁽⁹⁾	X_{sm}				
Addendum of tool – mm (in.)	h_{a0}				
Protuberance of tool – mm (in.)	P_{r0}				
Machining allowances – mm (in.)	q				
Tip radius of tool – mm (in.)	ρ_{∞}				
Profile form deviation – mm (in.)	f_{fa}				
Transverse base pitch deviation – mm (in.)	f_{pb}				
Root fillet radius at the critical section – mm (in.)	ρ_F				
Root radius of basic rack [referred to $m_n (= \rho_{\infty})$]-mm (in.)	ρ_{fp}				
Radius of curvature at pitch surface – mm (in.)	ρ_c				
Normal pressure angle at reference cylinder (degrees)	α_n				
Transverse pressure angle at reference cylinder (degrees)	α_t				
Transverse pressure angle at working pitch cylinder (degrees)	α_{tw}				
Helix angle at reference cylinder (degrees)	β				
Helix angle at base cylinder (degrees)	β				
Transverse contact ratio	ϵ_{α}				
Overlap ratio	ϵ_{β}				
Total contact ratio	ϵ_{γ}				
Angle of application of load at the highest point of single tooth contact (degrees) ⁽⁹⁾	α_{Fan}				
Reference cone angle of pinion (degrees) ⁽⁹⁾	δ_1				
Reference cone angle of wheel (degrees) ⁽⁹⁾	δ_2				
Shaft angle (degrees) ⁽⁹⁾	Σ				
Tip angle of pinion (degrees) ⁽⁹⁾	$\delta_{\alpha 1}$				
Tip angle of wheel (degrees) ⁽⁹⁾	$\delta_{\alpha 2}$				
Helix angle at reference cylinder (degrees) ⁽⁹⁾	β_m				
Cone distance pinion. wheel – mm (in.) ⁽⁹⁾	R				
Middle cone distance – mm (in.) ⁽⁹⁾	R_m				
Outer normal module – mm (in.)	m_{na}				
Transverse module	m_t				
Addendum modification coefficient of pinion	X_1				
Addendum modification coefficient of wheel	X_2				
Addendum modification coefficient refers to the midsection ⁽⁹⁾	X_{mn}				
Tooth thickness modification coefficient (midface) ⁽⁹⁾	X_{sm}				
Addendum of tool – mm (in.)	h_{a0}				
Protuberance of tool – mm (in.)	P_{r0}				
Machining allowances – mm (in.)	q				
Tip radius of tool – mm (in.)	ρ				
NOTES:					
1. The manufacturer can supply values, if available, supported by documents for stress numbers σ_{Hlim} and σ_{FE} involved in the formulas for gear strength with respect to the contact stress and with respect to the tooth root bending stress. Refer Sec-3, [3.4] & [3.5].					
2. Maximum continuous performance of the machinery for which classification is requested.					
3. It is intended the power mentioned under note (2) or fraction of it in case of divided power.					
4. The nominal transverse tangential load is calculated on the basis of the above mentioned maximum continuous performance or on the basis of astern power when it gives a higher torque.					

In the case of navigation in ice, the nominal transverse tangential load is to be increased as required by Sec-3, [3.1].
5. Only for epicyclic gears.
6. Measured from the tip circle (or circle passing through the point of beginning of the fillet at the tooth tip) to the beginning of the root fillet.
7. Only for external gears.
8. Only for internal gears.
9. Only for bevel gears

MATERIALS

First Gear Drive

Pinion: Material grade or specification
Complete chemical analysis.....
Minimum ultimate tensile strength (Refer note a) N/mm ² , (kgf/mm ² , lbf/in ²)
Minimum yield strength (Refer note a) N/mm ² , (kgf/mm ² , lbf/in ²)
Elongation (A ₅) % Hardness (HB, HV10 or HRC).....
Heat treatment.....
Description of teeth surface-hardening
.....
Specified surface hardness (HB, HV10 or HRC).....
Depth of hardened layer versus hardness values (if possible in diagram)
.....
Finishing method of tooth flanks (hobbed, shaved, lapped, ground or shot-peened teeth).....
.....
Specified surface roughness R _z or R _a relevant to tooth flank and root fillet
Amount of tooth flank corrections (tip-relief, end-relief, crowning and helix correction) if any.....
Specified grade of accuracy (according to ISO 1328).....
Amount of shrinkage with tolerances specifying the procedure foreseen for shrinking and measures proposed to ensure the securing of rims (Refer note b)

Wheel: Material grade or specification
Complete chemical analysis.....
Minimum ultimate tensile strength (Refer note a) N/mm ² , (kgf/mm ² , lbf/in ²)
Minimum yield strength (Refer note a) N/mm ² , (kgf/mm ² , lbf/in ²)
Elongation (A ₅) % Hardness (HB, HV10 or HRC).....
Heat treatment
Description of teeth surface-hardening
.....
Specified surface hardness (HB, HV10 or HRC).....
Depth of hardened layer versus hardness values (if possible in diagram)
.....
Finishing method of tooth flanks (hobbed, shaved, lapped, ground or shot-peened teeth).....
.....
Specified surface roughness R _z or R _a relevant to tooth flank and root fillet
Amount of tooth flank corrections (tip-relief, end-relief, crowning and helix correction) if any.....
Specified grade of accuracy (according to ISO 1328)

Amount of shrinkage with tolerances specifying the procedure foreseen for shrinking and measures proposed to ensure the securing of rims. (Refer note b)

NOTES:

- a) Relevant to core of material
- b) In case of shrink-fitted pinions, wheel rims or hubs

MATERIALS**Second Gear Drive**

Pinion: Material grade or specification

Complete chemical analysis.....

Minimum ultimate tensile strength (Refer note a) N/mm², (kgf/mm², lbf/in²)

Minimum yield strength (Refer note a) N/mm², (kgf/mm², lbf/in²)

Elongation (A₅) % Hardness (HB, HV10 or HRC).....

Heat treatment.....

Description of teeth surface-hardening

.....

Specified surface hardness (HB, HV10 or HRC).....

Depth of hardened layer versus hardness values (if possible in diagram)

.....

Finishing method of tooth flanks (hobbed, shaved, lapped, ground or shot-peened teeth).....

.....

Specified surface roughness R_z or R_a relevant to tooth flank and root fillet

Amount of tooth flank corrections (tip-relief, end-relief, crowning and helix correction) if any.....

Specified grade of accuracy (according to ISO 1328).....

Amount of shrinkage with tolerances specifying the procedure foreseen for shrinking and measures proposed to ensure the securing of rims (Refer note b)

Wheel: Material grade or specification

Complete chemical analysis.....

Minimum ultimate tensile strength (Refer note a) N/mm², (kgf/mm², lbf/in²)

Minimum yield strength (Refer note a) N/mm², (kgf/mm², lbf/in²)

Elongation (A₅) % Hardness (HB, HV10 or HRC).....

Heat treatment

Description of teeth surface-hardening

.....

Specified surface hardness (HB, HV10 or HRC).....

Depth of hardened layer versus hardness values (if possible in diagram)

.....

Finishing method of tooth flanks (hobbed, shaved, lapped, ground or shot-peened teeth).....

.....

Specified surface roughness R_z or R_a relevant to tooth flank and root fillet

Amount of tooth flank corrections (tip-relief, end-relief, crowning and helix correction) if any.....

Specified grade of accuracy (according to ISO 1328)

Amount of shrinkage with tolerances specifying the procedure foreseen for shrinking and measures proposed to ensure the securing of rims. (Refer note b)

NOTES:

- a) Relevant to core of material
- b) In case of shrink-fitted pinions, wheel rims or hubs

MATERIALS	
Third Gear Drive	
Pinion:	Material grade or specification
	Complete chemical analysis.....
	Minimum ultimate tensile strength (Refer note a) N/mm ² , (kgf/mm ² , lbf/in ²)
	Minimum yield strength (Refer note a) N/mm ² , (kgf/mm ² , lbf/in ²)
	Elongation (A ₅) % Hardness (HB, HV10 or HRC).....
	Heat treatment.....
	Description of teeth surface-hardening
	
	Specified surface hardness (HB, HV10 or HRC).....
	Depth of hardened layer versus hardness values (if possible in diagram)
	
	Finishing method of tooth flanks (hobbed, shaved, lapped, ground or shot-peened teeth).....
	
	Specified surface roughness R _Z or R _a relevant to tooth flank and root fillet
	Amount of tooth flank corrections (tip-relief, end-relief, crowning and helix correction) if any.....
	Specified grade of accuracy (according to ISO 1328).....
	Amount of shrinkage with tolerances specifying the procedure foreseen for shrinking and measures proposed to ensure the securing of rims (Refer note b)
Wheel:	Material grade or specification
	Complete chemical analysis.....
	Minimum ultimate tensile strength (Refer note a) N/mm ² , (kgf/mm ² , lbf/in ²)
	Minimum yield strength (Refer note a) N/mm ² , (kgf/mm ² , lbf/in ²)
	Elongation (A ₅) % Hardness (HB, HV10 or HRC).....
	Heat treatment
	Description of teeth surface-hardening
	
	Specified surface hardness (HB, HV10 or HRC).....
	Depth of hardened layer versus hardness values (if possible in diagram)
	
	Finishing method of tooth flanks (hobbed, shaved, lapped, ground or shot-peened teeth).....
	
	Specified surface roughness R _Z or R _a relevant to tooth flank and root fillet
	Amount of tooth flank corrections (tip-relief, end-relief, crowning and helix correction) if any.....
	Specified grade of accuracy (according to ISO 1328)
	Amount of shrinkage with tolerances specifying the procedure foreseen for shrinking and measures proposed to ensure the securing of rims. (Refer note b)
NOTES:	
a) Relevant to core of material	
b) In case of shrink-fitted pinions, wheel rims or hubs	

MATERIALS**Fourth Gear Drive**

Pinion: Material grade or specification

Complete chemical analysis.....

Minimum ultimate tensile strength (Refer note a) N/mm², (kgf/mm², lbf/in²)

Minimum yield strength (Refer note a) N/mm², (kgf/mm², lbf/in²)

Elongation (A₅) % Hardness (HB, HV10 or HRC).....

Heat treatment.....

Description of teeth surface-hardening

.....

Specified surface hardness (HB, HV10 or HRC).....

Depth of hardened layer versus hardness values (if possible in diagram)

.....

Finishing method of tooth flanks (hobbed, shaved, lapped, ground or shot-peened teeth).....

.....

Specified surface roughness R_z or R_a relevant to tooth flank and root fillet

Amount of tooth flank corrections (tip-relief, end-relief, crowning and helix correction) if any.....

Specified grade of accuracy (according to ISO 1328).....

Amount of shrinkage with tolerances specifying the procedure foreseen for shrinking and measures proposed to ensure the securing of rims (Refer note b)

Wheel: Material grade or specification

Complete chemical analysis.....

Minimum ultimate tensile strength (Refer note a) N/mm², (kgf/mm², lbf/in²)

Minimum yield strength (Refer note a) N/mm², (kgf/mm², lbf/in²)

Elongation (A₅) % Hardness (HB, HV10 or HRC).....

Heat treatment

Description of teeth surface-hardening

.....

Specified surface hardness (HB, HV10 or HRC).....

Depth of hardened layer versus hardness values (if possible in diagram)

.....

Finishing method of tooth flanks (hobbed, shaved, lapped, ground or shot-peened teeth).....

.....

Specified surface roughness R_z or R_a relevant to tooth flank and root fillet

Amount of tooth flank corrections (tip-relief, end-relief, crowning and helix correction) if any.....

Specified grade of accuracy (according to ISO 1328)

Amount of shrinkage with tolerances specifying the procedure foreseen for shrinking and measures proposed to ensure the securing of rims. (Refer note b)

NOTES:

- a) Relevant to core of material
- b) In case of shrink-fitted pinions, wheel rims or hubs

VARIOUS ITEMS (indicate other elements, if any, in case of particular types of gears)

Date :

SECTION 7 SPARE PARTS

Contents

7.1. General	183
7.2. Spare Parts for Gears	183

7.1. General

While spare parts are not needed for classification, the ones listed in [7.2] below are provided as guidance for ships intended for unrestricted service. It is owner's responsibility to do the maintenance of spare parts aboard each ship.

7.2. Spare Parts for Gears

The following spare parts are required for gears:

- a) Adequate packing rings with springs to repack one gland of each size and kind.
- b) One (1) set of thrust pads or rings, also springs where fitted, for each size.
- c) Bearing bushings sufficient to substitute all the bushings on every pinion, and gear for main propulsion; spare bearing bushings adequate to replace all of the bushings on each non-identical pinion and gear having sleeve-type bearings or complete assemblies consisting of outer and inner races and cages complete with rollers or balls where these types of bearings are used.
- d) One (1) set of bearing shoes for one face, for one single-collar type main thrust bearing, where fitted. Where the ahead and astern pads vary, pads for both faces are to be made available.
- e) One (1) set of strainer baskets or inserts for oil filters of special design of each size and type.
- f) Essential special tools.

CHAPTER 4 PROPULSION SHAFTING

CONTENTS

SECTION 1 GENERAL REQUIREMENTS.....	185
SECTION 2 MATERIALS.....	188
SECTION 3 DESIGN AND CONSTRUCTION	190
SECTION 4 ALIGNMENT AND VIBRATIONS OF PROPULSION SHAFT	201
SECTION 5 TESTING, INSPECTION AND CERTIFICATION	209
SECTION 6 INSTALLATIONS AND TRIALS.....	211

SECTION 1 GENERAL REQUIREMENTS

Contents

1.1. Scope 186

1.2. General Definitions..... 186

1.3. Documents to be submitted 186

1.1. Scope

The provisions of this section apply to clutches, couplings, shafts and other power transmitting components that are meant for propulsion purposes.

These components are used for transmission of power and are vital to the vessel's propulsion. They are to be so designed and constructed that they bear the maximum working stresses to which they may be subjected in all service conditions.

As an alternative to the provisions of this section, consideration may be given to designs based on engineering analyses, including fatigue considerations. It is required that all the alternative calculation methods take into account design criteria for continuous and transient operating loads (dimensioning for fatigue strength) and peak operating loads (dimensioning for yield strength).

1.2. General Definitions

1.2.1. Main Propulsion Shafting

Shafting which transmits power from the main engine or gearbox output flange to the propulsor, and transmits thrust from the propulsor to the hull via the thrust block.

1.2.2. Thrust Shaft

Thrust Shaft is that part of the propulsion shaft which transmits thrust to the thrust bearing.

1.2.3. Tail Shaft

Tail Shaft is the part of the propulsion shaft aft of the forward end of the propeller end bearing.

1.2.4. Line Shaft

Line Shaft is the part of the propulsion shaft in-board of the vessel.

1.2.5. Stern Tube Shaft

Stern Tube Shaft or Tube Shaft is the part of the propulsion shaft passing through the stern tube from the forward end of the propeller end bearing to the in-board shaft seal.

1.2.6. Oil Distribution Shaft

Oil Distribution Shaft is a hollow propulsion shaft where the bore and radial holes are used for distribution of hydraulic oil in Controllable Pitch Propeller installations.

1.3. Documents to be submitted

For review, following plans and particulars together with the necessary particulars of the machinery, including the maximum power and revolutions per minute, are to be submitted for approval before the work is commenced.

1.3.1. For Propulsion Shafting

Shafting arrangement indicating the relative position of the main engines, flywheel, flexible coupling, gearing, thrust block, line shafting and bearings, stern tube, 'A' brackets and propeller, as applicable, is to be submitted for information

Rated power of main engine and shaft rpm

Thrust, line, tube and tail shafts, as applicable

Couplings – integral, demountable, keyed, or shrink-fit, coupling bolts* and keys

Engineering analyses and fitting instructions for shrink-fit couplings / propellers

Shaft bearings Stern tube Shaft seals

Shaft lubricating system

Flexible coupling including constructional details, static and dynamic torsional stiffness, damping characteristic, rated power, torque and RPM, allowable vibratory torque for continuous and transient operation and allowable misalignment for continuous operations;

Cardan shafts, if fitted

Power take-off to shaft generators, propulsion boosters, or similar equipment, rated 100 kW (135 hp) and over, as applicable

Materials

The specified minimum tensile strength of each shaft is to be stated

Note: Specific details regarding the interference fit of the coupling bolts are to be submitted. In addition, calculations and detail design basis for the sizing of the fitted bolts are to be submitted if the sizing of the bolts as per Sect [3.10.1] of this chapter of the Rules is not based on as-built line shaft diameter "D".

1.3.2. For Clutches

Construction details of torque transmitting components, housing along with their materials and dimensions.

Rated power and rpm

Engineering analyses

Clutch operating data

1.3.3. For Flexible Couplings

Construction details of torque transmitting components, housing, their dimensions and materials

Static and dynamic torsional stiffness and damping characteristics

Rated power, torque, and rpm.

Engineering analyses

Allowable vibratory torque for continuous and transient operation.

Allowable power loss (overheating)

Allowable misalignment for continuous operation

1.3.4. For Cardan Shafts

Dimensions of all torque transmitting components and their materials

Rated power of main engine and shaft rpm

Engineering analyses

Clutch operating data

1.3.5. Calculations

Propulsion shaft alignment calculations where propulsion shaft is sensitive to alignment (Refer [4.2] of this chapter). Torsional vibration analyses

Axial and lateral (whirling) vibration calculations where there are barred speed ranges within engine operating speed range. The results of calculations, together with recommendations for any speed restrictions found necessary. Engine builder's recommendation for axial vibration amplitude limits at the non-driving end of the crankshaft or at thrust collar. Estimate of flexibility of the thrust bearing and its supporting structure. The requirement for calculations to be submitted may be waived upon request provided evidence of satisfactory service experience of similar dynamic installations is submitted. Calculations of the lateral vibration characteristics of shafting systems having supports outboard of the hull or incorporating cardan shafts are to be submitted.

SECTION 2 MATERIALS

Contents

2.1. General 189

2.2. Shaft Liners 189

2.3. Weldability 189

2.1. General

Materials for propulsion shafts, couplings and coupling bolts, keys and clutches are to be of rolled bars or forged steel or, as appropriate, and in line with Part 2, Ch-2, Sec-6 and Part 2, Ch-2, Sec-3 or other specifications as may be specially approved with a specific design. Where materials other than those specified in the Rules are proposed, their detailed chemical composition, heat treatment and mechanical properties, as appropriate, are to be submitted for approval.

2.1.1. Ultimate Tensile Strength

In general, the minimum specified ultimate tensile strength of steel used for propulsion shafting is to be selected within the following general limits:

- a) Carbon and carbon-manganese steel – 400 to 760 N/mm² (41 to 77.5 kgf/mm²).
- b) Alloy steel – not exceeding 800 N/mm² (82 kgf/mm²).

Where it is proposed to use alloy steel, details of the chemical composition, heat treatment and Mechanical properties are to be submitted for approval.

Where shafts may experience vibratory stresses close to the permissible stresses for transient operation, the materials are to have a specified minimum tensile strength of 500 N/mm² (51 kgf/mm²).

2.1.2. Elongation

Carbon Steel with elongation ($L_0/d = 4$) of less than 16% or ($L_0/d = 5$) of less than 15% is not to be used for any shafting component, with the exception that material for non-fitted alloy steel coupling bolts manufactured to a recognized standard may have elongation ($L_0/d = 4$) of not less than 10% or ($L_0/d = 5$) 9%.

Subject to approval, alloy steels with elongation less than ($L_0/d = 4$) 16% or ($L_0/d = 5$) 15% may be applied.

2.2. Shaft Liners

Shaft liners may be of stainless steel, bronze, or other approved alloys free from porosity and other defects. Continuous liners are to be in one piece or, if made of more, joining of the separate pieces is to be done by an approved method of welding through not less than two-thirds ($2/3^{\text{rd}}$) the thickness of the liner or by an approved rubber seal arrangement.

2.3. Weldability

Where repair by welding or where cladding by welding is planned, steel used for propulsion shafts is to have carbon content as per Part 2, Ch-2, Sec-6 [6.1.3] and [6.3]. The process; tests; inspections etc of repairing are to be made in consultation with INTLREG & approved prior implementation.

SECTION 3 DESIGN AND CONSTRUCTION

Contents

3.1	Calculation of Shaft Diameter.....	191
3.2	Diameter of Hollow Shafts.....	193
3.3	Alternative design Criteria	193
3.4	Key	193
3.5	Cardan Shaft	193
3.6	Tail Shaft Propeller-end Design	194
3.7	Propeller-end Seal.....	194
3.8	Tail Shaft Bearings	195
3.9	Tail Shaft Liners.....	196
3.10	Couplings and Coupling Bolts	197

3.1 Calculation of Shaft Diameter

Using the following equation, the minimum diameter of propulsion shafting is to be determined:

$$D = 100K \times \sqrt[3]{\frac{H}{R} \left(\frac{c_1}{U + c_2} \right)}$$

where

D = Greater of the required solid shaft diameter as required by [3.1] or [4.3] through [4.5] of this chapter (reflective of static and dynamic stresses), except hollow shaft; mm (in.)

H = Power at rated speed; kW (PS, hp) (1 PS = 735 W; 1 hp = 746 W)

K = Shaft design factor, Refer Table 4.3.1 or Table 4.3.2 of this section

R = Rated speed rpm

U = Minimum specified ultimate tensile strength of shaft material (regardless of the actual minimum specified tensile strength of the material, the value of U used in these calculations is not to exceed that indicated in Table 4.3.3; N/mm² (kgf/mm², psi) c₁ and c₂ are given below:

	SI UNITS	MS UNITS	US UNITS
c ₁	560	41.95	3.695
c ₂	160	16.3	23180

Table 4.3.1: Shaft Design Factors K and C_K for Line Shafts and Thrust Shafts

Factor	Propulsion drives	Design Features ⁽¹⁾							
		Integral flange	Shrink fit coupling	Key ways ⁽²⁾	Radial holes, transverse holes ⁽³⁾	Longitudinal slots ⁽⁴⁾	On both sides of thrust collars	In way of axial bearings used as thrust bearings	Straight sections
K	Type A	0.95	0.95	1.045	1.045	1.14	1.045	1.045	0.95
	Type B	1	1	1.1	1.1	1.2	1.1	1.1	1
C _K		1	1	0.6	0.5	0.3	0.85	0.85	1

Type A: Turbine drives; electric drives; diesel drive through slip couplings (electric or hydraulic).

Type B: All other diesel drives.

Notes

- Geometric features other than those listed, will be specially considered.
- After a length of not less than 0.2D from the end of the keyway, the shaft diameter may be reduced to the diameter calculated for straight sections.
Fillet radii in the transverse section of the keyway are not to be less than 0.0125D.
- Diameter of bore not more than 0.3D.
- Length of the slot not more than 1.4D and width of slot not more than 0.2D, whereby D is calculated with K = 1.0.

Table: 4.3.2, Shaft Design Factors K and CK for Tail Shafts and Stern Tube Shafts ⁽¹⁾

Factor	Propulsion drive	Stern tube configuration	Tail shafts: propeller attachment method (Refer note 2)			Stern tube shafts (7,8)
			Keyed (3)	Keyless attachment by shrink fit (4)	Flanged (5)	
K	All	Oil lubricated bearings	1.26	1.22	1.22	1.15
	All	Water lubricated bearings: continuous shaft liners or equivalent (Refer [3.9.6] of this section)	1.26	1.22	1.22	1.15
	All	Water lubricated bearings: non-continuous shaft liners (6)	1.29	1.25	1.25	1.18
CK			0.55	0.55	0.55	0.8

Notes:

1. Tail shaft may be reduced to stern tube shaft diameter forward of the bearing supporting the propeller, and the stern tube shaft reduced to line shaft diameter inboard of the forward stern tube seal.
2. Other attachments are subject to special consideration.
3. Fillet radii in the transverse section at the bottom of the keyway are not to be less than 0.0125D.
4. Refer also [3.5] of this section and Ch-5, Sec-3, [3.7.2].
5. For flange fillet radii and flange thickness, Refer [3.10.3] of this section.
6. For Great Lakes Service, K factor corresponding to continuous liner configuration may be used.
7. K factor applies to shafting between the forward edge of the propeller-end bearing & inboard stern tube seal.
8. Where keyed couplings are fitted on stern tube shaft, the shaft diameters are to be increased by 10% in way of the coupling. Refer Note 2 of Table 4.3.1 of this section.

Table 4.3.3: Maximum Values of U to be used in Shaft Calculations

	SI units N/mm ²	MKS units kgf/mm ²	US units (psi)
1. For all alloy steel shafts except tail shafts and tube shafts stated in 3 and 4 below.	800	81.5	116,000
2. For all carbon and carbon-manganese shafts except tail shafts and tube shafts stated in 3 and 4 below.	760	77.5	110,200
3. For tail shafts and tube shafts in oil lubricated bearings or in saltwater lubricated bearings but fitted with continuous liner or equivalent (Refer [3.9.6] of this section).	600	61.2	87,000
4. For tail shafts and tube shafts in saltwater lubricated bearings fitted with non-continuous liners.	415	42.2	60,000

3.2 Diameter of Hollow Shafts

For hollow shafts where the bore exceeds 40% of the outside diameter, the minimum outside shaft diameter is not to be less than that determined through successive approximation utilizing the equation given below:

$$D_o = D \sqrt[3]{\frac{1}{1-(D_i/D_o)^4}}$$

Where

D_o = required outer diameter of shaft; mm (in.)

D = solid shaft diameter required by [3.1] of this section; mm (in.)

D_i = actual inner diameter of shaft; mm (in.)

3.3 Alternative design Criteria

As an alternative to the design equations given in [3.1] and [3.2] of this section, shafting design may be considered for approval on the basis of axial and torsional loads to be transmitted, bending moment and resistance against fatigue. A detailed stress analysis that describes a factor of safety of at least 2.0 for fatigue failure in detail is to be submitted for approval with all supporting data.

3.4 Key

The key material is to be of equal or higher strength than the shaft material. The effective area of the key in shear is to be not less than A , given below. It is also to be the gross area subtracted by materials removed by saw cuts, set screw holes, chamfer, etc., and is to exclude the portion of the key in way of spooning of the key way.

Note: In general, keyways are not to be used in installations with slow speed, crosshead or two-stroke engines with a barred speed range.

$$A = \frac{D^3}{5.1r_m} \times \frac{Y_s}{Y_k}$$

where

A = shear area of key; mm² (in²)

D = line shaft diameter; mm (in.); as determined by [3.1] of this section

r_m = shaft radius at mid-length of the key; mm (in.)

Y_s = specified yield strength of shaft material; N/mm² (kgf/mm², psi)

Y_k = specified yield strength of key material; N/mm² (kgf/mm², psi)

3.5 Cardan Shaft

Cardan shafts are to be designed as per the equation for propulsion shaft in [3.1] of this section, and flanges and bolts are to be in line with [3.10.1], [3.10.2] and [3.10.3] of this section. The design of splines, yokes and cross-members are to be evaluated based on engineering analyses which are to be submitted for review.

Where applicable, cardan shaft assembly is to have provisions for bearing thrust or pull from the propeller

3.6 Tail Shaft Propeller-end Design

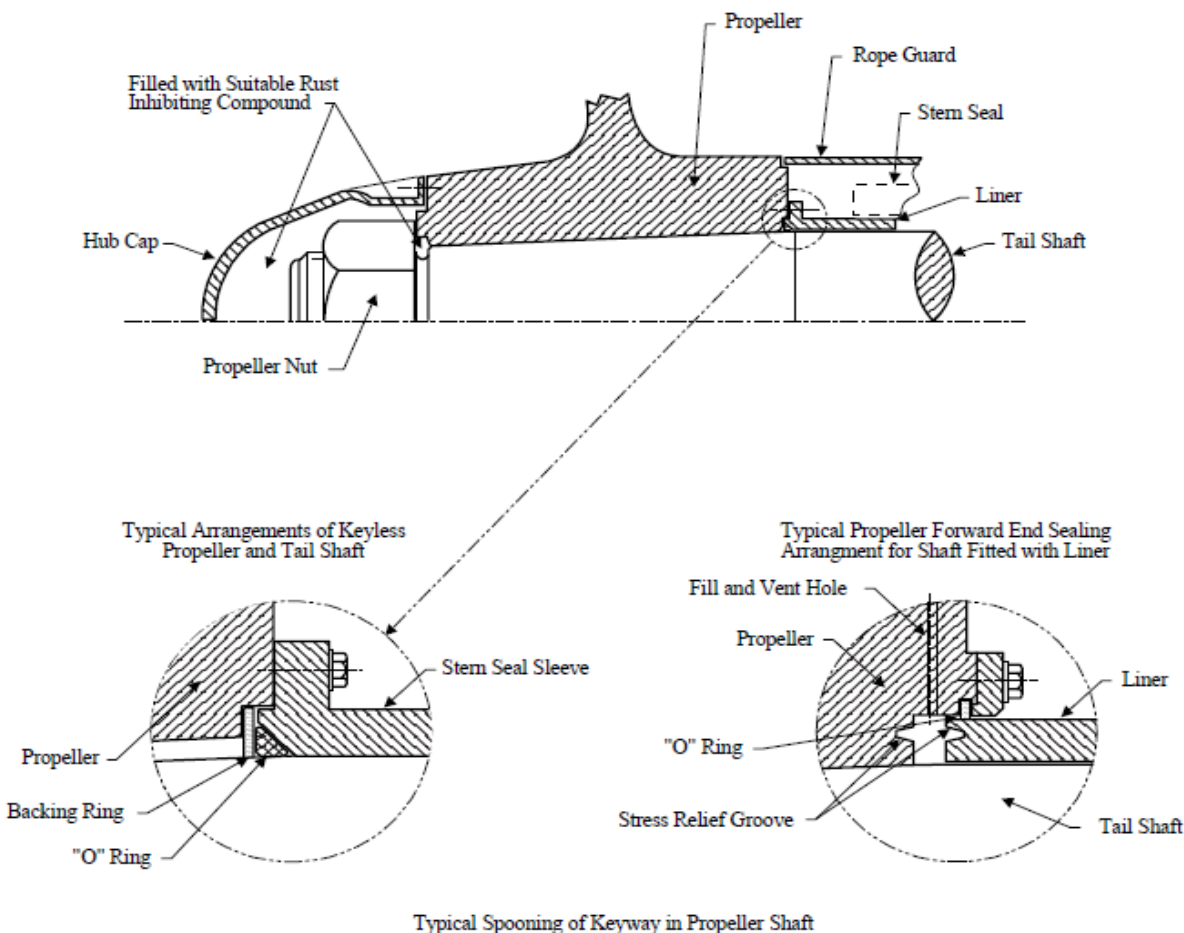
Tail shafts are to be provided with an accurate taper fit in the propeller hub, particular attention being given to the fit at the large end of the taper. In general, the actual contact area is to be at least 70% of the theoretical contact area. The key is to fit tightly in the keyway and be of sufficient size Refer [3.4] of this section to transmit the full torque of the shaft, but it is not to extend into the propeller hub counter bore (to accommodate the liner) on the forward side of the propeller hub. The forward end of the keyway is to be so cut in the shaft as to give a gradual rise from the bottom of the keyway to the surface of the shaft (Refer Figure 4.3.1) of this section. Ample fillets (Refer Note 2 of Table 4.3.1) are to be provided in the corners of the keyway and, in general, stress concentrations are to be reduced as far as practicable.

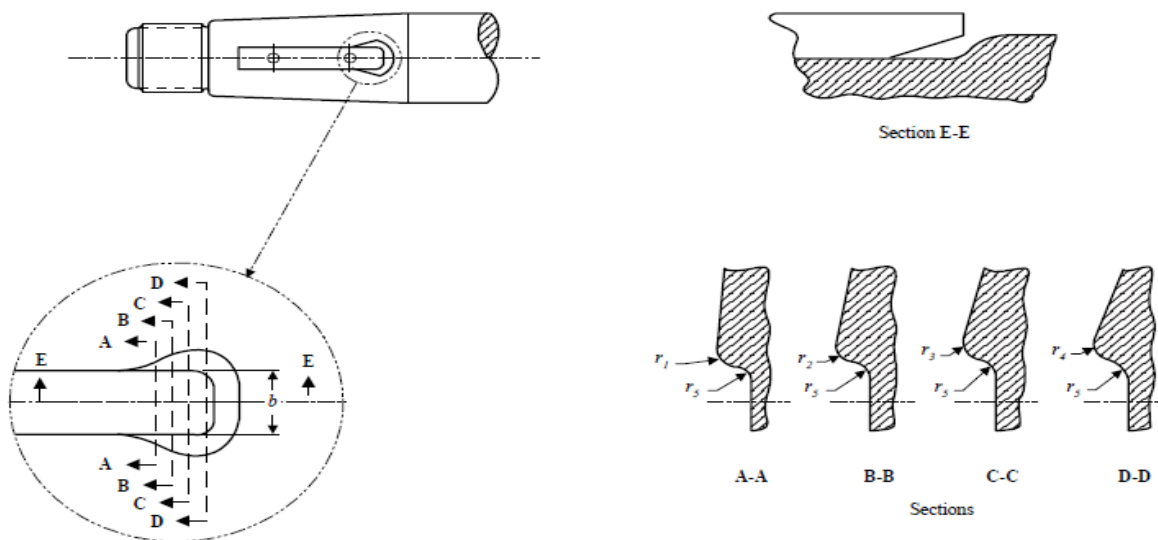
3.7 Propeller-end Seal

Effective means are to be provided to prevent water having access to the shaft at the part between the after end of the liner and the propeller hub and between the shaft and the propeller. Refer typical sealing arrangements in Figure [4.3.1]. Refer also Ch-5, Sec -5 (5.3)

FIGURE 4.3.1

Typical Arrangements and Details of Fitting of Tail Shaft and Propeller





3.8 Tail Shaft Bearings

3.8.1 Water-lubricated Bearings

The length of the bearing, next to and supporting the propeller is not to be less than 4 times the required tail-shaft diameter. However, for bearings of reinforced resins, or plastic materials and rubber, its length, next to and supporting the propeller, may be less than 4 times, but not less than 2 times the required tail shaft diameter, provided the bearing design is validated by experimental tests to the satisfaction of INTLREG.

3.8.2 Oil-lubricated Bearings

- a) **White metal.** The length of white-metal-lined, oil-lubricated propeller-end bearings fitted with an approved oil-seal gland is not to be less than twice the required tail shaft diameter. The bearing length may be reduced, provided the nominal bearing pressure is not more than 0.80 N/mm^2 (0.0815 kgf/mm^2 , 116 psi), as determined by static bearing reaction calculation taking into account shaft and propeller weight which is deemed to be exerted solely on the aft bearing, divided by the projected area of the bearing surface. However, the minimum length is not to be less than 1.5 times the actual diameter.
- b) **Synthetic material.** The length of synthetic rubber, reinforced resin or plastic oil lubricated propeller end bearings fitted with an approved oil-seal gland is not to be less than twice the required tail shaft diameter. The length of bearing may be reduced, provided the nominal bearing pressure is not more than 0.60 N/mm^2 (0.0611 kgf/mm^2 , 87 psi), as determined by static bearing reaction calculation taking into account shaft and propeller weight which is deemed to be exerted solely on the aft bearing, divided by the projected area of the bearing surface. However, the minimum length, is not to be less than 1.5 times the actual diameter. Where the material has been satisfactorily tested and operated, consideration may be given to increased bearing pressure.
- c) **Cast iron or bronze.** The length of oil-lubricated cast iron or bronze bearings which are fitted with an approved oil-seal gland is not to be less than 4 times the required tail shaft diameter.

- d) **Stern tube bearing oil lubricating system sampling arrangement.** An arrangement for readily obtaining accurate oil samples is required to be provided. The sampling point is to be taken from the lowest point in the oil lubricating system, as much as feasible. Also, the arrangements are to be such as to allow to effectively removing contaminants from the oil lubricating system.

3.8.3 Grease-lubricated Bearings

Grease-lubricated bearings length is not to be less than 4 times the diameter of required tail shaft dia.

3.9 Tail Shaft Liners

3.9.1 Thickness at Bearings

- a) **Bronze liner.** The thickness of bronze liners to be fitted to tail shafts or tube shafts is not to be less than that given by the equation given below:

$$t = \frac{T_{ts}}{25} + 5.1 \text{ mm or } t = \frac{T_{ts}}{25} + 0.2 \text{ in.}$$

Where

t = thickness of liner; mm (in.)

T_{ts} = required diameter of tail shaft; mm (in.)

- b) **Stainless steel liner.** The thickness of stainless steel liners to be fitted to tail shafts or tube shafts is not to be less than one-half that required for bronze liners or 6.5 mm (0.25 in.), whichever is greater.

3.9.2 Thickness Between Bearings

The thickness of a continuous bronze liner between bearings is not to be less than three-fourths of the thickness required in way of bearings.

3.9.3 Liner Fitting

All liners are to be carefully shrunk or forced upon the shaft by pressure and are not to be secured by pins. If the liner does not fit the shaft tightly between the bearing portions, the space between them is to be filled by pressure with an insoluble non-corrosive compound.

3.9.4 Glass Reinforced Plastic Coating

Glass reinforced plastic coatings may be fitted on propulsion shafting when applied by an approved procedure to Surveyor's satisfaction. Such coatings are to have at least 4 plies of cross-woven glass tape impregnated with resin, or an equivalent process. Prior to coating, shaft is to be cleaned using a suitable solvent and grit-blasted and it is to be examined also and the first layer of the shaft is to be applied in the presence of the Surveyor. After coating, the finished shaft is to be subjected to a spark test or equivalent to validate freedom from porosity to the satisfaction of the Surveyor. Where reinforced plastic coatings are used, means to prevent water from gaining access to the metal of the shaft are to be employed. Provisions are to be made for overlapping and bonding the coating to fitted or clad liners. The end of the liner is to be stepped and tapered to protect the end of the wrapping, or as required.

3.9.5 Stainless Steel Cladding

Stainless steel cladding of shafts is to be executed in consultation with INTLREG & approved prior implementation.

3.9.6 Continuous Liner or Equivalent

Stainless steel cladding in [3.9.5] of this section and metallic liners in [3.9.1] of this section, if of non-continuous construction but if the exposed shaft is secured with fiber glass reinforced plastic coating in line with [3.9.4] of this section, may be credited as “continuous” liners for the purpose of

- Determining required tail shaft and tube shaft diameters (Refer [3.1] and [3.2] of this section), and
- Periodical tail shaft survey [refer Part 1, Ch-3].

3.10 Couplings and Coupling Bolts

3.10.1 Fitted Bolts

The minimum diameter of fitted shaft coupling bolts to be determined using the equation given below. The bolts are required to be assembled with an interference fit.

$$d_b = 0.65 \sqrt{\frac{D_{shm}^3 (U + c)}{N B_{bc} U_b}}$$

Where B_{bc} = Bolt circle diameter; mm (in.)

c = Constant, as given on the right side

	SI unit	MKS unit	US unit
c	160	16.3	23,180

d_b = Diameter of bolt at joints; mm (in.)

D_{shm} = Minimum required shaft diameter designed considering the largest combined torque (static and dynamic), acting at the shaft in vicinity of the respective coupling flanges; mm (in), Refer [4.3] of this chapter but not less than the minimum required line shaft diameter (Refer [3.1] of this section); mm (in.)

N = number of bolts fitted in one coupling

U = minimum specified tensile strength of shaft material defined in [3.1] of this section; N/mm² (kgf/mm², psi)

U_b = minimum specified tensile strength of bolt material; N/mm² (kgf/mm², psi), subject to following conditions:

- Selected bolt material is to have minimum specified tensile strength U_b at least equal to U .
- Regardless of the actual minimum tensile strength, the value of U_b used in these calculations is
- not to exceed 1.7U nor 1000 N/mm² (102 kgf/mm², 145,000 psi).

3.10.2 Non-fitted Bolts

The diameter of pre-stressed non-fitted coupling bolts will be considered upon the submittal of detailed preloading and stress calculations and fitting instructions. The tensile stress of the bolt due to pre-stressing and astern pull shall not exceed 90% of the minimum specified yield strength of the bolt material. In addition, the bearing stress on any member such as the flange, bolt head, threads or nut is not to exceed 90% of the minimum specified yield strength of the material of that member.

For calculation, account of torsional vibratory torque is taken and the following factors may be applied to the transmitted main torque, unless the actual measured vibratory torque is higher, in which case, the actual vibratory torque is to be used:

- For direct diesel engine drives: 1.2
- For rest of the drives and for diesel engine drives with elastic coupling: 1.0

3.10.2.1 **Torque transmission by friction.** Where torque is to be transmitted by friction provided by pre-stressed non-fitted bolts only and the bolts are under pure tension, the factor of safety against slip under the worst operating conditions, including mean transmitted torque plus torque due to torsional vibration, is to be at least as follows:

- Inaccessible couplings (external to the hull or not easily accessible): 2.8
- Accessible couplings (internal to the hull): 2.0

3.10.2.2 **Torque transmission by combined friction and shear. Where torque is to be transmitted by combination of fitted bolts and pre-stressed non-fitted bolts, the components are required to meet the criteria given below:**

- **Fitted bolts.** Shear stress under the maximum torque corresponding to the worst loaded condition shall not be more than 50% of the minimum specified tensile yield strength of the bolt material.
- **Non-fitted bolts.** The factor of safety against slip, under the maximum torque corresponding to the worst loaded condition and the specified bolt tension, is to be at least 1.6 for inaccessible couplings and 1.1 for accessible couplings.

3.10.2.3 **Torque transmission by dowels.** Dowels connecting the tail shaft flange to the controllable pitch propeller hub, utilized with pre-stressed non-fitted bolts to transmit torque, are considered equivalent to fitted bolts and are to conform to [3.10.1] of this section and, if applicable, [3.10.2.2] above. The dowels are to be precisely fitted and effectively secured against axial movement.

3.10.3 Flanges

a) **Flange thickness.** The thickness of coupling flanges integral to the shaft shall not be less than the minimum required diameter of the coupling bolts or $0.2D$, where D is as defined in [3.1] of this section, whichever is greater.

The fillet radius at the base of a coupling flange shall not be less than 0.08 times the actual shaft diameter. Consideration will be given to fillets of multiple radii design; and such fillet is to have a cross-sectional area of not less than that of a required single-radius fillet. The surface finish for fillet radii is not to be rougher than $1.6\text{ }\mu\text{m}$ ($63\text{ }\mu\text{in}$) RMS. Alternatively, $1.6\text{ }\mu\text{m}$ CLA (center line average) may be accepted.

- b) Flange thickness – connection to controllable pitch propeller. Thickness of the coupling flange integral to the tail shaft for connection to the forward face of the controllable pitch propeller hub is not to be less than $0.25D$, and D is as defined in [3.1] of this section.

For the tail shaft flange supporting the propeller, the fillet radius at the base of the flange is to be at least $0.125D$. Special consideration will be given to fillets of multiple-radius design; refer (a) above. During tail shaft surveys, the fillet radius is to be accessible for nondestructive examination.

3.10.4 Demountable Couplings

The strength of demountable couplings and keys is to be equivalent to that of the shaft and couplings are to be accurately fitted to the shaft. Where required, provisions for resisting thrust loading are to be provided.

Upon submission of detailed preload, stress calculations and fitting instructions, hydraulic and other shrink fit couplings will be specially considered. For inaccessible couplings (external to the hull or not readily accessible), the torsional holding capacity under nominal working conditions are based on the minimum available interference fit (or minimum pull-up length) i.e. to be at least 2.8 times the transmitted mean torque plus torque due to torsional vibration (Refer [3.10.2] of this section). For accessible couplings (internal to hull), this factor may be reduced 2.0 times. Under normal working conditions, the preload stress is based on the maximum available interference fit (or maximum pull-up length) i.e. not to exceed 70% of the minimum specified yield strength.

The following friction coefficients are to be used:

- Oil injection method of fit: 0.13
- Dry method of fit: 0.18

3.10.5 Flexible Couplings

- a) **Design.** Flexible couplings intended for use in propulsion shafting are to be of approved designs for the rated torque, fatigue and avoidance of overheating. Where elastomeric material is used as a torque-transmitting component, it is to be capable of bearing environmental and service conditions all through the design life of the coupling, taking into consideration the full range of maximum to minimum vibratory torque. On the basis of submission of engineering analyses, flexible coupling design will be evaluated.
- b) **Torsional displacement limiter.** Flexible couplings with spring type or elastomer or flexible members, whose failure will result in total loss of vessel's propulsion capability, such as that used in the line shaft of a single propeller vessel, are to be provided with a torsional displacement limiter. This displacement limiter is to lock the coupling or prevent excessive torsional displacement when a pre-determined torsional displacement limit is exceeded. Vessel shall be operated at reduced power under such circumstances and with the help of warning notices posted at all propulsion control stations, this is to be informed.
- c) **Barred range.** In normal operating range of the engine, conditions where the allowable vibratory torque or allowable dissipated power may be exceeded are to be identified and marked as a barred range to avoid continual operation within this range.
- d) **Diesel generators.** Flexible couplings for diesel generator sets shall absorb short time impact torque due to electrical short-circuit up to 6 times the nominal torque.

3.10.6 **Clutches**

- a) **Design.** Clutches to be used in propulsion shafting are to be of approved design as they are designed to transmit the maximum power at rated speed. The minimum service factor, i.e. determined by the ratio of the clutch static holding capacity to the rated torque, is as given below:

Clutch Design Type	Minimum Service Factor
Drum-type clutch or Disc type, air-actuated, air cooled clutches	
Shafting system fitted with fixed pitch propeller	1.7
Shafting system fitted with fixed pitch propeller and shaft brake	1.5
Shafting system fitted with controllable pitch propeller	1.5
Hydraulically-actuated, oil cooled multiple-plate clutches	1.7

The minimum service factor will be increased only if:

- The shafting vibratory torque is excessive;
- Clutch thermal capacity is exceeded because of frequent clutch engagements during vessel operations; and
- The clutch shoe material used has limited service experience or the clutch will be allowed to slip during vessel operations.

For review purposes, calculations are to be submitted.

- b) **System arrangements.** Arrangements are to be made so that in case a failure of the clutch actuating system occurs, each clutch remains engaged and transmits an adequate power, considered necessary for propulsion and maneuvering of the vessel.
- c) **Coupling bolts.** Coupling bolts are to comply with [3.10.1] & [3.10.2] of this section and are to be of adequate strength to support the weight of the elements and also transmit all necessary forces.

3.10.7 **Locking Arrangement**

Locking arrangements are to be fitted to all coupling bolts and associated nuts after the assembly.

SECTION 4 ALIGNMENT AND VIBRATIONS OF PROPULSION SHAFT

Contents

4.1. General.....	202
4.2. Shaft Alignment Calculations	202
4.3. Torsional Vibrations.....	203
4.4. Axial Vibrations.....	208
4.5. Lateral (Whirling) Vibrations	208

4.1. General

Apart from the design requirements stated above, additional stresses in the shafting system that given rise by shaft alignment in relation to location and spacing of the shaft bearings, and by axial, lateral and torsional vibrations are also given due consideration.

4.2. Shaft Alignment Calculations

Shaft alignment calculations, alignment procedures, and stern tube boring details, as applicable, are to be submitted for review .

- i) Propulsion shafting of diameter greater than 300 mm (11.81 in.).
- ii) Propulsion shafting with no forward stern tube bearing Propulsion shafting with power take-off or with booster power arrangements.
- iii) Propulsion shafting for which the tail shaft bearings are to be slope-bored.
- iv) All systems where the screw shaft has a diameter of 800 mm or greater in way of the aft most bearing.
- v) All direct drive installations which incorporate 3 or less bearings supporting the intermediate and screw shaft aft of the prime mover.
- vi) Where prime movers or shaft line bearings are installed on resilient mountings

Calculations, alignment procedures, and stern tube boring details for these shafting arrangements are to comply Sect [4.2.1] through [4.2.3] below

Shaft alignment calculations for all other types of installations are only required to be submitted for reference

4.2.1

- a) The alignment calculations are to include bearing reactions, shear forces and bending moments along the shafting and are to be performed for the maximum allowable alignment tolerances.

The analysis is to show that:

- Bearing loads under all operating conditions are within the acceptable limits specified by the bearing manufacturer.
- Bearing reactions are always positive (i.e., supporting the shaft)
- Shear forces and bending moments on propulsion equipment are within the limits specified by manufacturers.
- Shear forces and bending moments at the crankshaft flange are in accordance with the engine manufacturer's limits.

Moreover, the shaft alignment calculation has to include the following (as applicable):

- **Geared Systems.** In case of geared systems, the calculated misalignment between main gear and pinion is to be less than $0.1 \cdot 10^{-3}$ [rad], unless specifically approved otherwise.
- **Misalignment Slope.** The designed relative misalignment slope between the shaft and the tail shaft bearing is to be positive (the forward end of the bearing is to be above, or on the same elevation as the aft end of the bearing), and not to exceed $0.3 \cdot 10^{-3}$ [rad]

- **Stern Tube Bearing Fitting.** Based on the actual interference fit tolerances, the stern tube bearing fitting calculation, including fitting pressure and push-in distance, is to be submitted for review.
- **Tail Shaft Bearing Clearance Calculation.** The clearance calculation, on aft and forward stern tube bearing, with alignment model showing only the propeller shaft on two stern tube bearings, is to be included in the shaft alignment analysis report and submitted to INTLREG for review.

In addition, the shaft alignment analysis is to identify:

- Sag and gap data and temporary support location corresponding to the condition(s) in which they will be measured
- Jack up locations

b) **Hull Deflections Accounted for in the Analysis.**

The vessel conditions to be considered in the analysis should account for the following:

- Dry-dock or after launching draft at cold static condition
- Full ballast draft at hot static condition
- Fully laden draft at hot static condition

c) **Hull Deflections NOT Accounted for in the Analysis.**

- Where the hull deflections are not accounted for in the analysis then the shaft alignment verification is to be done.
- Vessels where cargo/ballast load change is not significantly affecting the draft of the ship will be given special consideration.

However, calculated bearing reactions not to exceed 80% of maximum allowable manufacturer's limit.

4.2.2 **Stern Tube Slope Boring**

In general, if the calculated relative misalignment slope between the shaft and the tail shaft bearing is greater than 0.3×10^{-3} [rad], then consideration is to be given to reducing the relative misalignment slope by means of slope-boring or bearing inclination.

On alignment sensitive installations (e.g., tankers, bulkers and twin screw vessels) it is recommended to apply the double slope design on the tail shaft bearings.

The slope boring angle calculation (single or double slope) is to be based on the static afloat conditions with hot engine fully immersed propeller.

The slope boring verification procedure is to be submitted for review

4.2.3 **Shaft Alignment Procedure**

The shaft alignment procedure is to be submitted for review and is to be based on the submitted shaft alignment calculations. As a minimum, the shaft alignment procedure is to include

- a) **Bore Sighting.** The bore sighting procedure is to be conducted in two stages, as follows:
- Bore sighting before bearings fitting (not applicable for stern tube bearings installed by resin chocking), is to be conducted on the stern tube bore to verify:
 - The stern tube bore dimensions; in order to define dimensions and tolerance for the aft and the forward stern tube bush outside diameters machining
 - The stern tube bore misalignment, vertical and horizontal; in order to define angular corrections for stern tube bearing outside diameter machining

Whenever applicable, it is recommended that all corrections are done by machining the outside bush diameter, rather than correcting the stern tube bore

- Bore sighting after the stern tube bearings are fitted, is to verify:
 - The aft bush slope, as-installed. The measurement is to be taken with reference to the forward stern tube bush.
 - The horizontal misalignment between aft and the forward stern tube bearing

In cases with no forward stern tube bearing, the intermediate shaft bearing should serve as a referent point to conduct sighting.

Sufficient number of targets should be utilized during the sighting through to ensure accuracy in verification of bearing slopes. Target arrangement is to be included in the procedure submitted for review.

The bore sighting is to confirm:

- The horizontal misalignment of all bearings is to be minimized and is not to exceed the clearance of adjacent bearings.
 - The slope boring angle is to be verified relative to the straight line connecting both stern tube bearings. Acceptable tolerance is up to $\pm 0.1 \cdot 10^{-3}$ [rad], with the following restrictions:
 - The measured slope boring angle is never to result in misalignment greater than $0.3 \cdot 10^{-3}$ [rad].
 - In case of a propulsion installation with no forward stern tube bearing, the intermediate shaft bearing should be chocked and its offset not changed after the bore sighting is complete.
- b) **Stern Tube Bearing Fitting Pressure Verification.** The stern tube bearing fitting pressure should be verified to comply with calculated values.
- c) **Tail Shaft Bearing Clearance Measurement.** The clearance measurements should be verified after the propeller shaft is fitted (before propeller is installed, and with shaft unrestrained on the forward flange).
- d) **Sag and Gap.** The sag and gap procedure is to be verified against the respective analysis (e.g., based on dry dock or light ship draft condition). Acceptable tolerances are ± 0.1 mm.

- e) Bearing Load Measurements. Identification of the bearings at which the measurements are to be taken, the jack up locations, the data to be recorded and the procedures to be followed should be reported in the submittal.
- f) Stern Tube Bearing Run-in Procedure. For alignment sensitive installation (e.g. tankers, bulkers and twin screw vessels), it is recommended to conduct a run-in procedure before the stern tube bearings are exposed to higher service speeds and rudder angles.

4.3. Torsional Vibrations

4.3.1 Allowable Torsional Vibration Stress

In the propulsion shafting system, the torsional vibration stress shall not exceed the allowable vibratory stress, S, given in Table 4.4.1 of this section. The analysis of torsional vibrations shall account for stresses resulting from vector summation of responses (synthesis) of all relevant excitation harmonics.

The stress limit S is applicable for propulsion shafting systems, including types of couplings, dampers, clutches, etc., where torsional vibratory torque is the only load of significance.

The stress limit S does not apply for propulsion shafts, and equipment integral to the shaft, where vibratory torque is not the only significant source of load. Design criteria of such shafts are contained in the following applicable sections:

- Crankshafts: Refer Ch-2, Sec-1, [1.3.5],
- Turbine rotor shafts: Refer Ch-2, Sec-3, [3.3.1], and Ch-2, Sec-4, [4.3.2]
- Gear shafts: Refer Ch-3, Sec-3, [3.7]
- Other shafts and equipment that falls under the subject criteria need to be designed considering maximum combined load acting within operating speed range of the propulsion system.

4.4.1: Allowable Torsional Vibratory Stress

	SI UNITS	MKS UNITS	USUNITS
S= Allowable Vibratory Stress	$\frac{U+160}{18} C_K C_d C_r$ N/mm ²	$\frac{U+16.3}{18} C_K C_d C_r$ kgf/mm ²	$\frac{U+23180}{18} C_K C_d C_r$ psi
U= Minimum Tensile Strength of haft Material	To be taken as not more than 600N/mm ² (Refer Note)	To be taken as not more than 61.2kgf/mm ² (Refer Note)	To be taken as not more than 87,000psi (Refer Note)
C _K = Shaft Design Factor	Refer Table 4.3.1 and Table 4.3.2.		
C _D =size factor	$0.35 + \frac{0.93}{\sqrt[5]{d}}$	$0.35 + \frac{0.93}{\sqrt[5]{d}}$	$0.35 + \frac{0.487}{\sqrt[5]{d}}$
d= Actual Shaft Diameter	mm	mm	in.
C _r = Speed Ratio Factor	3-2λ ² for λ<0.9;1.38for0.9≤λ≤1.05		
λ	λ= $\frac{\text{Critical Speed (RPM) at which vibratory stress is calculated}}{\text{rated speed (RPM)}}$		
Note: Regardless of the actual minimum specified tensile strength of the shaft (tail shaft, tube shaft, line shaft and crankshaft, as applicable) material, the value of U used in these calculations is not to exceed the values indicated. Higher values of U, but not exceeding 800 N/mm ² (81.5 kgf/mm ² , 116,000 psi), may be specially considered for the line shaft, as example by satisfactory fatigue assessment for the line shaft			

4.3.2 Scope of calculations

- 4.3.2.1 Calculations are to be carried out, by recognized techniques, for the full dynamic system formed by the oil engines, turbines, motors, generators, flexible couplings, gearing, shafting and propeller, where applicable, including all branches.
- 4.3.2.2 Calculations are to give due consideration to the potential deviation in values used to represent component characteristics due to manufacturing/service variability.
- 4.3.2.3 The calculations carried out on oil engine systems are to be based on the Engine builders' harmonic torque data. The calculations are to take account of the effects of engine malfunctions commonly experienced in service, such as a cylinder not firing (i.e. no injection but with compression) giving rise to the highest torsional vibration stresses in the shafting. Calculations are also to take account of a degree of imbalance between cylinders, which is characteristic of the normal operation of an engine under service conditions.
- 4.3.2.4 Whilst limits for torsional vibration stress in crankshafts are no longer stated explicitly, calculations are to include estimates of crankshaft stress at all designated operating/service speeds, as well as at any major critical speed.
- 4.3.2.5 Calculations are to take into account the possible effects of excitation from propeller rotation. Where the system shows some sensitivity to this phenomenon, propeller excitation data for the installation should be used as a basis for calculation, and submitted.
- 4.3.2.6 Where the torsional stiffness of flexible couplings varies with torque, frequency or speed, calculations should be representative of the appropriate range of effective dynamic stiffness.

4.3.3 Diesel Engine Installations

The vibratory stresses for diesel engine installations are required to be calculated with any one cylinder not firing and the calculations are to be submitted for information.

4.3.4 Barred Speed Ranges

A barred range is required to be provided when torsional vibratory stresses exceed the foregoing limits at an rpm within the operating range but less than 80% of rated speed. The allowable vibratory stress in a barred range due to the alternating torsional vibrations is not to exceed the values given by the following:

$$S_2 = \frac{1.7S}{\sqrt{C_k}} \text{ for } \lambda \leq 0.8$$

Where S_2 = allowable vibratory stress within a barred range, N/mm² (kgf/mm², psi)

λ , S , C_k are as defined in [4.3.1] of this section.

Where shafts may experience vibratory stresses close to the permissible stresses for transient operation, the shaft material is to have a specified minimum ultimate tensile strength of not less than 500 N/mm² (50.9 kgf/mm², 72,500 psi), else materials having a specified minimum ultimate tensile strength of not less than 400 N/mm² (40.8 kgf/mm², 58,000 psi) may be used.

Barred ranges are not acceptable in the speed range between 0.8 and 1.05 of the rated speed. The existence of a barred range at speeds less than 0.8 of the rated speed is to be considered in establishing standard operating speeds for the vessel. The width of the barred range is to take into consideration the breadth and severity of the critical speed but is not to be less than the following limits:

$$\frac{16n_c}{18-\lambda} \geq n_\ell \quad \text{and} \quad \frac{(18-\lambda)n_c}{16} \leq n_u$$

Where

N_c = Critical speed

N_ℓ = Lower limit

N_u = Upper limit

λ is as defined in Table 4.4.1 of this section.

4.3.5 Marking of Tachometer and Alarms

Where a barred speed range is identified as in [4.3.3] of this section, the tachometer is to be marked and a warning notice is to be displayed at all propulsion control stations (local and remote) to caution that operation in the barred range is to be avoided except for passing through. Where remote propulsion control is fitted on the navigation bridge or where a centralized control station is fitted, means are to be provided at these remote propulsion control stations to alert the operator of any operation of the propulsion drive within the barred range. This may be achieved by a visual display or alarm.

4.3.6 Other Effects

Because critical torsional vibration has deleterious effects other than shafting fatigue, the limits in [4.3.1] of this section are not intended for direct application as design factors, and it is desirable that the service range above 90% of rated speed be kept clear of torsional critical speeds insofar as practicable.

4.3.7 Torsiograph Tests

When the calculation indicates that critical occur within the operating range, whose severity approaches or exceeds the limits in Sect[4.3.1] torsiograph tests may be required to verify the calculations and to assist in determining ranges of restricted operation.

4.3.8 Vibration Dampers

When torsional vibratory stresses exceed the limits specified in [4.3.1] of this section and a barred range is unacceptable, then in order to reduce the stresses, propulsion system is required to be redesigned or vibration dampers are to be fitted.

4.3.9 Gear

When the propeller is driven through reduction gear, or when geared booster power or power take-off is provided, a barred range is to be provided at the acceptable critical speed if gear tooth chatter occurs during continuous operation at this speed.

In cases where the proposed transmission torque loading on the gear teeth is less than the maximum allowable, special consideration will be given to the acceptance of additional vibratory loading on the gears.

Where calculations indicate the possibility of torque reversal, the operating speed range is to be determined on the basis of observations during sea trials.

4.3.10 Measurements

Where calculations indicate that the limits for torsional vibration within the range of working speeds are exceeded, measurements, using an appropriate technique, may be taken from the machinery installation for the purpose of approval of torsional vibration characteristics, or determining the need for restricted speed ranges, and the confirmation of their limits.

Where differences between calculated and measured levels of stress, torque or angular amplitude arise, the stress limits are to be applied to the stresses measured on the completed installation.

The method of measurement is to be appropriate to the machinery components and the parameters which are of concern. Where shaft stresses have been estimated from angular amplitude measurements, and are found to be close to limiting stresses as defined, strain gauge techniques may be required. When measurements are required, detailed proposals are to be submitted.

4.4. Axial Vibrations

The builder or the designer is to evaluate the shafting system to ensure that axial vibration characteristics in association with diesel engine or propeller blade-rate frequency forces will not result in deleterious effects throughout the engine operating speed range, with consideration also given to the possibility of the coupling of torsional and axial vibration, unless experience with similar shafting system installations makes it unnecessary. The axial vibrations may be controlled by axial vibration detuners to change the natural frequency of the system or by axial vibration dampers to limit the amplitude of axial vibrations to an acceptable level.

When on the basis of axial vibration calculations the designer or builder proposed to provide barred speed ranges within the engine operating speed range, the calculations are to be submitted for information. The barred speed ranges due to axial vibrations are to be verified and established by measurement.

4.5. Whirling Vibrations

4.5.1 General

Calculations are to be carried out for all main propulsion shafting systems and are to ensure that whirling vibration characteristics are satisfactory throughout the speed range. In addition, calculations of the whirling vibrations for the following arrangements are to be submitted for review:

- i) Shafting systems without a forward stern tube bearing or without an intermediate bearing.
- ii) Shafting systems whose bearing span exceeds $450 \sqrt{d}$, where d is the actual shaft diameter in mm of the tail shaft or intermediate shaft, whichever is less.
- iii) Shafting systems having supports outboard of the hull (e.g., A-or P-brackets).
Shafting systems incorporating Cardan shafts

4.5.2 Calculations

- a) The calculations mentioned in Sect [4.5.1] are to take into account bearing and oil-film stiffness and are to investigate the excitation frequencies giving rise to all critical speeds which may result insignificant vibration amplitudes within the speed range.
- b) $\sqrt{}$ Where calculations mentioned in Sect [4.5.2] (a), indicate the possibility of significant whirling vibration responses within the range of $\pm 20\%$ of maximum continuous ratings (M.C.R.) speed, measurements using an appropriate recognized technique may be required to be taken from the shafting system for the purpose of determining the need for barred speed ranges.

SECTION 5 TESTING, INSPECTION AND CERTIFICATION

Contents

5.1. General	210
5.2. Material Tests	210
5.3. Inspection of Propulsion Shafts and Associated Parts	210
5.4. Flexible Couplings, Clutches, Cardan shafts, etc.	210

5.1. General

Shafting components are to be tested, inspected and certified by a Surveyor at the manufacturer's facility in line with the requirements given hereunder.

5.2. Material Tests

5.2.1. General

Materials for all torque-transmitting parts, including clutches, shafts, couplings, coupling bolts and keys are to be tested in the Surveyor's presence. The materials are to meet the specifications of Part 2, Ch-2, Sec-6, [6.3] & [6.4] and Part 2, Ch-2, Sec-3, [3.2] or other specifications approved for design.

5.2.2. Alternative Test Requirements

- a) 375 kW (500 hp) or less. Surveyor may accept materials for parts transmitting 375 kW (500 hp) or less based on verification of manufacturer's certification and witnessed hardness check.
- b) Coupling bolts. Material testing is not required for coupling bolts manufactured and marked to a recognized standard.

5.2.3. Inspections and Nondestructive Tests

Surveyor has to do the surface examination of shafting and couplings.

Ultrasonic examination as per Part 2, Ch-2, Sec-6, [6.1.9.2] is to be done for forgings for tail shafts 455 mm (18 in.) and over in finished diameter. Plus, tail shafts in the finished machine condition are to be subjected to dye penetrant, magnetic particle or other nondestructive examinations. Shafts are to be free of linear discontinuities greater than 3.2 mm (1/8 in.), and for the following locations, they are to be free of all linear discontinuities:

- (a) Tapered tail shafts: the forward one-third (1/3rd) length of the taper, including the forward end of any keyway and an equal length of the parallel part of the shaft immediately forward of the taper.
- (b) Flanged tail shafts: the flange fillet area.

5.3. Inspection of Propulsion Shafts and Associated Parts

5.3.1. Power Transmitting Parts

All propulsion shafts and associated parts, like the coupling bolts, are to be visually examined to check for unwanted surface flaws, out of roundness, straightness, and dimensional tolerances. If a doubt arises, the Surveyor, may require additional nondestructive testing. Refer to [5.2.3] of this chapter for tail shaft requirements

5.3.2. Liners

Shaft liners are to remain tight under hydrostatic test of 1.0 bar (1 kgf/cm², 15 psi). After the assembly, fit of the liner to the shaft is to be checked for freedom from voids. Any void in way of bearings is to be dealt with as in Sect [3.9.3] of this chapter.

5.4. Flexible Couplings, Clutches, Cardan shafts, etc.

All the manufactured torque transmitting parts, such as flexible couplings, clutches (independent of the gear assembly), cardan shafts, etc. are to be tested, inspected and certified by a Surveyor at the manufacturing facility. Alternatively, these parts may be certified under Type Approval Program, Refer Part-1, Ch-1, Sec-11.

SECTION 6 INSTALLATIONS AND TRIALS

Contents

6.1. Alignment of Shafts	212
6.2. Vibration Measurement	212
6.3. Circulating Currents.....	213
6.4. Sea Trial	213
6.5. Tail shaft Condition Monitoring – TCM.....	213
6.6. Surveys	214

6.1. Alignment of Shafts

6.1.1 Alignment

Shaft alignment is to be done in the presence of a Surveyor and the final alignment is to be verified in the afloat condition with superstructure in place and major welding work done. When alignment calculations are required to be submitted as per Sect [4.2] of this chapter, the alignment calculated data is to be verified and recorded using appropriate measurement procedures in the presence and to the satisfaction of a Surveyor, and as per (a), (b) and (c) below, or as applicable.

- (a) **Bearing Reaction.** Bearing reactions are required to be verified by hydraulic jack method and/or strain gauge method on all the accessible shafting bearings given below:
 - I) Forward stern tube bearing
 - II) Intermediate shaft bearing(s)
 - III) Minimum 3 aft most main engine bearings (for only directly coupled propulsion systems)
 - IV) Main-gear shaft bearings
- (b) **Vessels with Hull Deflections not accounted.** For such vessels in which hull deflections are not explicitly accounted for in alignment design, and the shaft alignment analysis is based on a ship structure and remains unaffected by deflection, additional alignment verification is a prerequisite, and is to comprise of:
 - I) A validation of the bearing reactions for at least 1 service-draft condition of the vessel.
- (c) **Sighting Through and Bearing Positioning Conducted in Block Stage.** Where sighting through and bearing positioning are conducted in block stage of the vessel construction, and a monitoring system to validate shaft-bearing alignment is not installed, the verification of the given below procedures is required:
 - i) Slope boring angle (or as applicable)
 - ii) Bearing vertical offset positioning
 - iii) Engine vertical offset positioning
 - iv) Sag and gap procedure

6.1.2 Cast Resin Chocks

Resin chocks, intended for chocking of the stern tube or shaft bearing foundation, are to be of approved type (refer Part-1, Ch-1, Sect-11 for type approval). It is to be kept in mind that resin chocks do not reliably maintain watertight integrity of the hull or the oil-tight integrity of the lubricating oil system. Therefore, direct contact of resin chocks with water or oil is to be circumvented. Where utilized, arrangements and installation procedures are to be in compliance with the manufacturer's recommendations.

Following data to be submitted for review in each case:

- Arrangements of the proposed installation with installation parameters such as deadweight, holding-down bolt tightening torque, etc., and
- Calculations that show that the specified allowable pressure is not exceeded (specified by manufacturer).

6.2. Vibration Measurement

6.2.1 Torsional Vibration

Where torsionograph measurement is required as per Sect [4.3.7] of this chapter, the measurement is to be taken in Surveyor's presence.

Where a barred speed range is provided as given in Sect [4.3.4] of this chapter, warning notice, tachometer marking, and alarms at remote control stations (where fitted), as detailed in Sect [4.3.5] of this chapter, are to be fitted. In addition to the warning notice, electronic speed regulating devices may be preset to step-pass the barred range.

When the propeller is driven through reduction gears, Surveyor is to ensure that no gear-tooth chatter is occurring all through the operating range, else, a barred speed range as given in Sect [4.3.4] of this chapter is to be provided. Also refer Sect [4.3.9] & [4.3.10] of this chapter.

6.2.2 Axial and Lateral Vibrations

When calculations indicate that barred speed ranges are present as in Sect [4.4] and [4.5] of this chapter, these are to be duly validated and recorded using appropriate measurement procedures to the satisfaction of a Surveyor.

6.3. Circulating Currents

Some protective means to prevent circulating currents from passing between the propeller, shaft and the hull are to be provided and to indicate it, a warning notice plate in an easily visible place is to be set that cautions against the risk in removal of this protection.

6.4. Sea Trial

During sea trial under maneuvering conditions, the shafting installation is to be tested and it is to be ascertained that it is free from dangerous vibration and is to the satisfaction of the Surveyor

6.5. Tail shaft Condition Monitoring – TCM

6.5.1 Notation

Where requested by the Owner, the class notation **TCM (Tail shaft Condition Monitoring)** may be assigned to a vessel with tail shafts specifically arranged with oil-lubricated stern tube bearings, provided the following requirements are complied with

6.5.2 System Requirements

In addition to the requirements for propulsion shafting, the following design requirements are to be complied with and relevant drawing(s) and data are to be submitted for review and approval prior to commencement of the initial surveys.

6.5.2.1 Temperature Monitoring and Alarm

The vessel is to be provided with a temperature monitoring and alarm system for the tail shaft stern tube aft bearing. The system is to be arranged with a high temperature alarm and two sensors. One easily interchangeable sensor may be installed in lieu of the two sensors. Where one interchangeable sensor is installed, one spare sensor is to be carried onboard the vessel.

The monitoring and alarm system is to have the following features:

- 1) The main alarm system is to be provided with a power failure alarm.
- 2) An alarm that indicates an open circuit, a short circuit, or an earth fault in the temperature sensor circuit is to be provided
- 3) An alarm indicating that the sensor's temperature signal is outside the set points of the unit is to be provided.

Temperature monitoring and the alarm system are to be located in the propulsion machinery spaces. For machinery spaces assigned with (CCS, Centralized Control Station notation), the temperature monitoring and alarm system is to be incorporated with the required control and monitoring system.

When a centralized control or monitoring station is installed, the alarms are to be activated in such a station

6.5.2.2 Oil Seal Design

Approved type oil seals are to be used which will allow for replacement without the shaft withdrawal or removal of the propeller.

6.5.2.3 Bearing Wear Down Measurement

Arrangements and means are to be provided for bearing wear down measurement.

6.5.3 Management of the Monitored Data

The following management of the monitored data is to be implemented.

6.5.3.1 Lubrication Oil Sampling

Stern tube bearing lubricating oil is to be sampled monthly under service conditions, and analyzed for water content using a suitable on-board test kit. Additionally, at least every six months, oil samples are to be submitted for analysis to a recognized laboratory where testing is to be conducted for the following:

- 1) Free water content in oil, if present
- 2) Bearing metals content (Pb, Fe, Cu, Al, Cr, Sn, Si, Ni)
- 3) Viscosity at 40°C

6.5.3.2 Stern Tube Bearings Operating Condition

Stern tube bearing temperatures are to be monitored and temperature recorded daily. The system's oil consumption is to be recorded monthly.

6.5.3.3 Recording and Analysis

The chief engineer is responsible for recording and maintaining a file of the shipboard performed lubricating oil sampling and analysis results, as well as stern tube bearings operating condition.

Also, the results of the laboratory analysis are to be stored within the file onboard. All documentation is to be available to the Surveyor to allow for trend assessment of the measured parameters.

The shipboard record is to contain conclusions regarding the condition of the oil and whether it remains suitable for further use. Conclusions are to be supported by comparative parameters.

In case of oil replacement, a record containing the reason for replacement of the oil is to be maintained for Surveyor's review at the next Annual Survey.

6.6. Surveys

6.6.1 Initial Survey

All systems in Section 6[6.2] are to be examined and tested to the satisfaction of the attending Surveyor in accordance with the approved plans.

For initial survey of existing vessels, refer to Part 1, Ch 3, Sect-5/[5.2] of the *INTLREG Rules for Survey After Construction*

6.6.1 Survey after construction

Refer to Section Part1,Ch-3,Sect-7, of the *INTLREG Rules for Survey After Construction* .

CHAPTER 5 PROPELLERS

CONTENTS

SECTION 1 GENERAL REQUIREMENTS	216
SECTION 2 MATERIALS	219
SECTION 3 DESIGN	221
SECTION 4 INSPECTION, TESTING AND CERTIFICATION.....	233
SECTION 5 INSTALLATION AND TRIAL	235

SECTION 1 GENERAL REQUIREMENTS

Contents

1.1. Application 217

1.2. General Definitions 217

1.3. Documents to be submitted..... 218

1.1. Application

This chapter applies to propellers intended for propulsion. It covers fixed pitch and controllable pitch propellers. Propellers for thrusters that are used for maneuvering and dynamic positioning is covered in Part 5A chapter 7. Performance of propellers, in respect to developing the designed output, is to be demonstrated during sea trials..

1.2. General Definitions**1.2.1 Skew Angle**

Skew Angle (θ) of a propeller is the angle measured from ray 'A' passing through the tip of blade at mid-chord line to ray 'B' tangent to the mid-chord line on the projected blade outline. Refer: Figure: 5.1.1.

1.2.2 Highly Skewed Propeller

A Highly Skewed Propeller is one whose skew angle is more than 25° .

1.2.3 Propeller Rake

- a) *Rake*: Rake is the distance at the blade tip between the generating line and the line perpendicular to the propeller axis that meets the generating line at the propeller axis. Refer Figure 5.1.2.
- b) *Rake angle* (ϕ): Rake Angle of a propeller is the angle measured from the plane perpendicular to shaft centerline to the tangent to the generating line at a specified radius ($0.6 \times$ radius for the purpose of this chapter). Refer Figure:5.1.2

1.2.4 Wide Tipped Blade Propeller

A propeller blade is to be considered as a wide tipped blade if the maximum expanded blade cord length occurs at or above $0.8R$, with R being the distance measured from the centerline of the propeller hub.

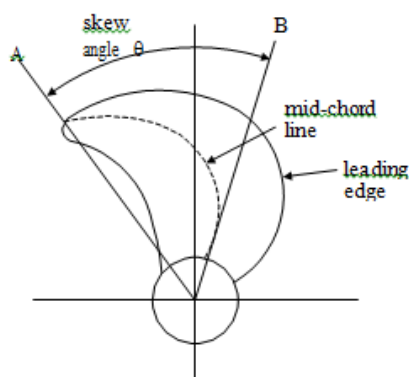


Figure: 5.1.1, Maximum Skew Angle

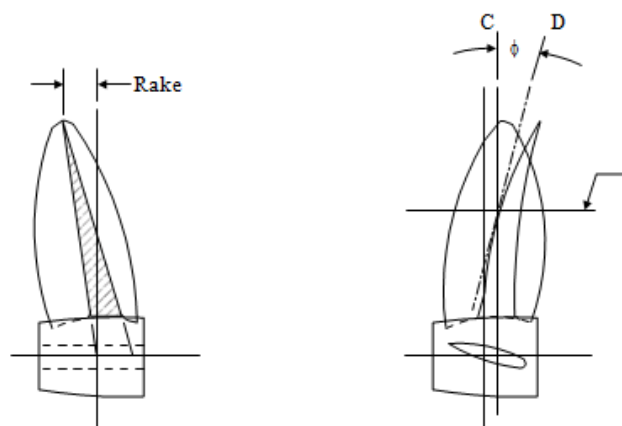


Figure: 5.1.2, Rake and Rake Angle

1.3. Documents to be submitted

1.3.1 Fixed Pitch Propeller of Conventional Design

- Material
- Design characteristics of propeller
- Dimensions and tolerances
- Propeller plan
- Blade thickness calculations

1.3.2 Controllable Pitch Propeller of Conventional Design

- All documents as per item Sect [1.3.1]
- Hub and hub to tail shaft flange attachment bolts
- Propeller blade flange and bolts
- Internal mechanism
- Hydraulic piping control system
- Instrumentation and alarm system
- Strength calculations for internal mechanism

1.3.3 Highly Skewed Propeller and Other Unconventional Designs

In addition to the foregoing, where propeller blade designs are of the types for which the rules do not provide simplified blade thickness calculations, such as

- Highly skewed propellers with $\theta > 50^\circ$;
- High skewed propellers made up of other than Type 4 materials, with $50^\circ \geq \theta > 25^\circ$;
- Controllable pitch propellers with $\theta > 25^\circ$;
- Cycloidal propellers;

Propeller load and stress analyses demonstrating adequacy of blade strength are to be submitted

1.3.4 Keyless Propeller

Keyless Propellers are types of propellers fitted to the shaft without keys. Stress calculations for hub stresses and holding capacity along with fitting instructions are to be submitted.

SECTION 2 MATERIALS

Contents

2.1. Propeller Materials	220
2.2. Stud Materials	220
2.3. Material Testing.....	220

2.1. Propeller Materials

Table 5.2.1 shows the properties of materials normally used for propellers. Refer Part-2, Ch-4, Sec-6, [6.2] and Part-2, Ch-2, Sec-8 for full details of the materials.

Where an alternative material specification is proposed, detailed chemical composition and mechanical properties are to be submitted for approval (for example, Refer Part-2, Ch-4, Sec-6 and Part-2, Ch-2, Sec-8). The **f** and **w** values of such materials to be used in the equations hereunder will be specially considered upon the submission of complete material specifications including corrosion fatigue data to 10^8 cycles.

Table: 5.2.1: Propeller Materials

Type	Material	Tensile strength			Yield strength			Elongation, %	
								Gauge Length	
		N/mm ²	kgf/mm ²	lb/in ²	N/mm ²	kgf/mm ²	lb/in ²	4d	5d
2	Manganese Bronze	450	46	65,000	175	18	25,000	20	18
3	Nickel – Manganese Bronze	515	53	75,000	220	22.5	32,000	18	16
4	Nickel – Aluminum Bronze	590	60	86,000	245	25	36,000	16	15
5	Manganese – Nickel Aluminum Bronze	630	64	91,000	275	28	40,000	20	18
CF-3	Stainless Steel	485	49	70,000	205	21	30,000	35	32

2.2. Stud Materials

The material of the studs securing detachable blades to the hub should be of at least Grade 2 forged steel or equally satisfactory material. Refer Part-2, Ch-2, Sec-6/ [6.4] for specifications of Grade 2 forged steel).

2.3. Material Testing

Materials of propellers cast in one piece and materials of blades, hubs, studs and other load – bearing parts of controllable pitch propellers are required to be tested in the presence of a Surveyor. For requirements of material testing, refer Part-2, Ch-4, Sec-6, [6.2] and Part-2, Ch-2, Sec-8 and Part-2, Ch-2, Sec-6/ [6.4].

SECTION 3 DESIGN

Contents

3.1. Blade Thickness – Fixed Pitch Propeller	221
3.2. Blade Thickness – Controllable-pitch Propellers.....	223
3.3. Blade Thickness – Highly Skewed Fixed-pitch Propellers	225
3.4. Blades of Unusual Design	226
3.5. Blade-root Fillets	226
3.6. Controllable Pitch Propellers- Pitch Actuation System	226
3.7. Propeller Fitting	229

3.1. Blade Thickness – Fixed Pitch Propeller

- 3.1.1 The thickness of the propeller blades for solid propeller (fillet at the root of the blades is not to be considered in the determination of blade thickness) are not to be less than obtained from the formula in Table 5.3.1.

Where, the minimum blade thickness of high speed ship is to be required the more.

- 3.1.2 The thickness of the propeller blades of conventional design ($\theta \leq 25^\circ$) should not be less than that determined by the equations given in Table 5.3.1

- 3.1.3 Propeller blades of thrusters (as defined in Ch-7, Sec-1, [1.3]) and wide – tip blades of ducted propellers are required to be in accordance with the provisions of chapter 7 of this part.

- 3.1.4 Consideration

For the blades of different materials from those specified in Table 5.3.1, the value of K will be determined by the Society in each case. For propellers having a diameter of 2.5 meters and less, the value of K may be taken as the value in Table 5.3.1 multiplied by the following factors.

For $D \leq 2.0$ m : 1.2
For $D > 2.0$ m : $2.0 - 0.4 D$

Propeller blades of thrusters (as defined in Ch-7, Sec-1, [1.3]) and wide – tip blades of ducted propellers are required to be in accordance with the provisions of chapter 7 of this part.

The thickness of the propeller blades of conventional design ($\theta \leq 25^\circ$) should not be less than that

determined by the equations given below

$$t_{0.25} = S \left[K_1 \sqrt{\frac{AH}{C_n C_{RN}}} \pm \left(\frac{C_s}{C_n} \right) \left(\frac{BK}{4C} \right) \right]$$

$$A = 1.0 + \frac{6.0}{P_{0.70}} + 4.3 P_{0.25}$$

$$B = \left(\frac{4300 wa}{N} \right) \left(\frac{R}{100} \right)^2 \left(\frac{D}{20} \right)^3$$

$$C = (1 + 1.5 P_{0.25}) (Wf - B)$$

where (units of measures are given in SI (MKS, and US) units respectively):

a = expanded blade area divided by disc area

a_s = area of expanded cylindrical section at 0.25 radius; mm² (in²)

C_n = section modulus coefficient at the 0.25 radius. C_n is to be determined by the following equation:

$$C_n = \frac{I_0}{U_f W T^2}$$

If the calculated C_n value exceeds 0.10, the required thickness is to be computed with $C_n = 0.10$.

C_s = section area coefficient at 0.25 radius and is to be determined by the following equation:

$$C_s = \frac{a_s}{WT}$$

The values of C_s and C_n , computed as stipulated above, are to be indicated on the propeller drawing.

D = propeller diameter; m (ft)

f, w = material constants from the following table:

Material type	SI and MKS units		US units	
	f	w	f	w
2	2.10	8.3	68	0.30
3	2.13	8.0	69	0.29
4	2.62	7.5	85	0.27
5	2.37	7.5	77	0.27
CF - 3	2.10	7.75	68	0.28
<i>Note:</i> The f and w values of materials not covered will be specially considered upon submittal of complete material specifications including corrosion fatigue data to 10^6 cycles.				

H = Power at rated speed; kW (PS, hp)

I_0 = Moment of inertia of expanded cylindrical section at 0.25 radius about a straight line through the center of gravity parallel to the pitch line or to the nose-tail line; mm⁴ (in⁴)

K = Rake of propeller blade, in mm (in.) (positive for aft rake and negative for forward rake)

K_1 = Coefficient as given below

	SI	MKS	US
K_1	337	289	13

N = Number of blades

$P_{0.25}$ = Pitch at 1/4 radius divided by propeller diameter, corresponding to the design ahead condition

$P_{0.70}$ = Pitch at 7/10 radius divided by propeller diameter, corresponding to the design ahead condition

R = RPM at rated speed

S = Factor, as given below. If greater than 1.025,

SI & MKS units	US units
1.0 for $D \leq 6.1$ m	1.0 for $D \leq 20$ ft
$\sqrt{\frac{(D+24)}{30.1}}$ for $D > 6.1$ m	$\sqrt{\frac{(D+79)}{99}}$ for $D > 20$ ft

$t_{0.25}$ = Minimum required thickness at the thickest part of the blade section at 1/4 radius; mm (in.)

T = maximum designed thickness of blade section at 0.25 radius from propeller drawing; mm (in.)

Uf = maximum nominal distance from the moment of inertia axis to points of the face

W = expanded width of a cylindrical section at 0.25 radius; mm (in.)

3.2. Blade Thickness – Controllable-pitch Propellers

- 3.2.1 The thickness of the propeller blades for built-up propeller and controlled pitch propellers are not to be less than obtained from the formula in Table 5.3.1. Fillet at the root of the blades is not to be considered in the determination of blade thickness.
- 3.2.2 The thickness of the propeller blades of conventional design ($\theta \leq 25^\circ$) should not be less than that determined by the equations given in Table 5.3.1
- 3.2.3 Propeller blades of thrusters (as defined in Ch-7, Sec-1, [1.3]) and wide – tip blades of ducted propellers are required to be in accordance with the provisions of chapter 7 of this part

3.2.4 The consideration for the calculation of blade thickness for built-up propeller and controlled pitch propellers will be same as mentioned in Sect [3.1.4] above.

Table 5.3.1: Thickness of Blade

	Radial Position	Solid Propeller	Built-up Propellers & Controllable Pitch Propellers
Thickness of Blade (mm)	0.25 R	$t = \sqrt{\frac{K_1 \cdot P}{K_2 \cdot Z \cdot N \cdot l_{25}}}$	—
	0.35 R	—	$t = \sqrt{\frac{K_1 \cdot P}{K_2 \cdot Z \cdot N \cdot l_{35}}}$
	0.60 R	$t = \sqrt{\frac{K_3 \cdot P}{K_4 \cdot Z \cdot N \cdot l_{60}}}$	
P = Output of engine at maximum continuous rating (kW) Z = Number of Blades N = Number of maximum continuous revolutions per minute divided by 100 (rpm / 100) R = Radius of Propeller		l_{25} = Width of blade at radius of 0.25 R (m) l_{35} = Width of blade at radius of 0.35 R (m) l_{60} = Width of blade at radius of 0.60 R (m) K ₁ , K ₂ , K ₃ , K ₄ = Coefficient given by the following formula	
Coefficient	Solid Propeller		Controllable Pitch Propellers
K ₁	$K_1 = \frac{61}{\sqrt{1 + 1.62 \left(\frac{P_{25}}{D}\right)^2}} \times \left(0.386 \frac{D}{P_{70}} + 0.239 \frac{P_{25}}{D}\right)$		$K_1 = \frac{61}{\sqrt{1 + 0.827 \left(\frac{P_{35}}{D}\right)^2}} \times \left(0.308 \frac{D}{P_{70}} + 0.131 \frac{P_{35}}{D}\right)$
K ₂	$K_2 = K - \left(1.92 \frac{E}{t_0} + 1.71\right) \frac{D^2 N^2}{1000}$		$K_2 = K - \left(1.79 \frac{E}{t_0} + 1.56\right) \frac{D^2 N^2}{1000}$
K ₃	$K_3 = \frac{61}{\sqrt{1 + 0.281 \left(\frac{P_{60}}{D}\right)^2}} \times \left(0.113 \frac{D}{P_{70}} + 0.0223 \frac{P_{60}}{D}\right)$		
K ₄	$K_4 = K - \left(1.24 \frac{E}{t_0} + 1.093\right) \frac{D^2 N^2}{1000}$		
D = Diameter of Propeller (m) t ₀ = Thickness of blade at propeller shaft centre line (the straight line connecting the thickness at blade tip and the thickness at radius 0.25R in the maximum thickness section is to be taken as the basis) (mm)		E = Rake in tip of the blade face (mm) K = Values given by the following table P ₂₅ = Face pitch at the radius of 0.25R (m). P ₃₅ = Face pitch at radius of 0.35R (m). P ₆₀ = Face pitch at radius of 0.60R (m). P ₇₀ = Face pitch at radius of 0.70R (m).	

Table 5.3.1 (a)

Materials	K	Min. tensile strength N/mm2 [kgf/mm2]
Grey cast iron	0.6	195 [20]
Cast steel	0.9	410[46]
		450[46]
	1.0	480[49]
Copper Alloy casting	1.0	430[44]
	1.1	490[50]
	1.3	590 [60]

3.3. Blade Thickness – Highly Skewed Fixed-pitch Propellers**3.3.1 Propeller Blades with Skew Angle θ ; where $25^\circ < \theta \leq 50^\circ$**

The provisions of [3.3.1] of this section are applicable to fixed pitch propellers which are having a skew angle of over 25° but not exceeding 50° and made of Type 4 material only. For propellers of other materials, or with skew angle greater than 50° , Refer [3.3.2] below.

a) Blade thickness at 0.25 radius:

The maximum thickness at 0.25 radius should not be less than the thickness required in [3.1] above for fixed pitch – propellers multiplied by the factor m as given below:

$$m = \sqrt{1 + 0.0065 (\theta - 25)}$$

b) Blade thickness at 0.6 radius:

The maximum thickness of the blade section at 0.6 radius should not be less than that obtained from the following equations:

$$t_{0.6} = K_3 \cdot \sqrt{(1 + C_{0.9}) \left(1 + \frac{2C_{0.9}}{C_{0.6}}\right) \left(\frac{HD\Gamma}{RP_{0.6}Y}\right)^{0.5}}$$

$$\Gamma = \left(1 + \frac{\theta - 25}{\theta}\right) (\phi^2 + 0.16\phi \cdot \theta \cdot P_{0.9} + 100)$$

Where

$C_{0.6}$ = Expanded chord length at the 0.6 radius divided by propeller diameter

$C_{0.9}$ = Expanded chord length at the 0.9 radius divided by propeller diameter

K_3 = Coefficient as given below:

Table 5.3.2: Value of K_3

	SI	MKS	US
K_3	12.6	6.58	1.19

$P_{0.6}$ = Pitch at the 0.6 radius divided by propeller diameter

$P_{0.9}$ = Pitch at the 0.9 radius divided by propeller diameter

$t_{0.6}$ = Required thickness of the blade section at 0.6 radius; mm (in.)

Y = Minimum specified yield strength of type 4 propeller material; N/mm² (kgf/mm², psi). Refer Table 5.2.

θ = Skew angle in degrees (Refer 1.2.1 of this chapter)

ϕ = Rake angle in degrees [Refer 1.2.3(b) of this chapter] at 0.6 radius, positive for aft rake

H = Power at rated speed; KW (PS, hp)

D = Propeller diameter; m (ft)

R = RPM at rated speed

c) Blade thickness between 0.6 and 0.9 radii:

The maximum thickness at any radius between 0.6 and 0.9 radii should not be less than that obtained from the following equation:

$$t_x = 3.3 D + 2.5 (1 - x)(t_{0.6} - 3.3 D) \text{ mm; or}$$

$$t_x = 0.04 D + 2.5 (1 - x)(t_{0.6} - 0.04 D) \text{ inch.}$$

Where:

t_x = required minimum thickness of the thickest part of the blade section at radius ratio x .

$t_{0.6}$ = thickness of blade section at the 0.6 radius, as required by (b) above.

x = ratio of the radius under consideration to $D/2$; $0.6 < x \leq 0.9$

d) Trailing edge thickness at 0.9 radius:

The edge thickness at 0.9 radius measured at 5% of chord length from the trailing edge is to be not less than 30% of the maximum blade thickness required by (c) above at that radius.

3.3.2 Propeller made up of Other Than Type 4 Materials with Skew Angle θ ; where $25^\circ < \theta \leq 50^\circ$:

Propellers made of materials other than Type 4 and with skew angle $25^\circ < \theta \leq 50^\circ$ are subject to special consideration. Design analyses, as indicated in Sect [3.4] below, are required to be submitted.

3.3.3 Propeller Blades with Skew Angle $\theta > 50^\circ$

Propellers with the maximum skew angle exceeding 50° will be subjected to special consideration. Design analyses, as indicated in Sect [3.4] below, are required to be submitted.

3.4. Blades of Unusual Design

Propellers of unusual design, such as those indicated in Sect [3.3.2] and [3.3.3] above, controllable pitch propeller of skewed design ($\theta > 25^\circ$), skewed propeller ($\theta > 25^\circ$) with wide – tip blades, cycloidal propellers, etc., are subjected to special consideration based upon the submission of propeller load and stress analyses. The analyses are to be included, but not limited to the following:

- Description of method in order to determine blade loading
- Description of method selected for stress analysis
- Ahead condition should be based on propulsion machinery's maximum rating and full ahead speed
- Astern condition should be based on the maximum available astern power of the propulsion machinery (the astern power of the main propelling machinery should be capable of 70% of the ahead rpm corresponding to the maximum continuous ahead power, as required in Ch-1, Sec-4, [4.3]); and should include crash astern operation
- Allowable stress and fatigue criteria
- Fatigue assessment

3.5. Blade-root Fillets

Fillets at the root of the blades should not be considered in order to determine the blade thickness.

3.6. Controllable Pitch Propellers- Pitch Actuation System

3.6.1 Blade Flange and Mechanisms

The strength of the propeller blade flange and pitch changing mechanism of controllable – pitch propellers subjected to the forces from propulsion torque should be at least 1.5 times that of the blade at design pitch conditions.

3.6.2 Stud Bolt Area

The sectional area of the stud bolts at the bottom of the thread, s is to be determined by the following equations:

Table 5.3.3

	SI units	MKS units	US units
s	$\frac{0.056}{r n} \frac{W k f t_{0.35}^2}{\text{mm}^2}$		$\frac{0.0018}{r n} \frac{W k f t_{0.35}^2}{\text{in}^2}$
k	$\frac{621}{U + 207}$	$\frac{63.3}{U + 21.1}$	$\frac{90000}{U + 30000}$

Where

s = Area of one stud at bottom of thread

n = Number of studs on driving side of blade

r = Radius of pitch circle of the studs; mm (in.)

k = Material correction factor for stud materials better than INTLREG Grade 2 forged steel

U = Ultimate tensile strength of the stud material; N/mm² (kgf/mm², psi)

$t_{0.35}$ = Required minimum thickness of the thickest part of the blade section at 0.35 radius; mm (in.)

W = expanded width of a cylindrical section at 0.35 radius; mm (in.)

f = material constants from the table below:

Value of 'f'		
Material type (Refer Sec-2, [2.1])	SI and MKS units	US units
2	2.1	68
3	2.13	69
4	2.62	85
5	2.37	77
CF-3	2.1	68
Note: The 'f' values of materials not covered will be specially considered upon the submission of complete material specifications including corrosion fatigue data to 10 ⁸ cycles.		

3.6.3 Blade Pitch Control

a) Bridge control:

Where the navigation bridge is provided with direct control of propulsion machinery, it is to be fitted with means to control the pitch of the propeller.

b) Duplication of power unit:

At least two hydraulic power pump units for the pitch actuating system are required to be provided and arranged so that the transfer between pump units can be readily affected. Automatic start of the standby pump unit shall be provided for propulsion machinery spaces intended for unattended operation.

The emergency pitch actuating system [as required by (c)-(iii) below] may be accepted as one of the required hydraulic power pump units, provided it is not less effective.

c) Emergency provisions:

In order to safeguard the propulsion and maneuvering capability of the vessel in the event of any single failure in either the remote pitch control system or the pitch actuating system external to the propeller shaft and oil transfer device (also known as oil distribution box), following are to be provided:

- i) Manual control of pitch at or near the pitch – actuating control valve (usually the directional valve or similar).
- ii) The pitch is to remain in the last ordered position until the emergency pitch actuating system is brought into operation.
- iii) An emergency pitch actuating system. This system is to be independent of the normal system up to the oil transfer device, provided with its own oil reservoir and able to change the pitch from full ahead to full astern.

d) Integral oil systems:

Where the pitch actuating hydraulic system is integral with the reduction gear lubricating oil system and/or clutch hydraulic system, the piping should be arranged in such a manner so that any failure in the pitch actuating system will not leave the other system(s) non-operational.

e) Provisions for testing:

Means are required to be provided in the pitch actuating system to simulate system behavior in the event of loss of system pressure. Hydraulic pump units driven by main propulsion machinery are to be fitted with a suitable by – pass for this purpose.

f) Multiple propellers:

For vessels fitted with more than one controllable pitch propeller, each of which is independent of the other, only one emergency pitch actuating system [as required by (c)(iii) above] need to be fitted, provided it is arranged such that it can be used to provide emergency pitch – changing for all propellers.

g) Hydraulic piping:

Hydraulic piping should meet the requirements of Ch-8, Sec-6, [6.2].

3.6.4 Instrumentation

All controllable pitch propeller systems are required to be provided with instrumentation as below:

a) Pitch indicators:

A pitch indicator is required to be fitted on the navigation bridge. In addition, each station capable of controlling the propeller pitch is required to be fitted with a pitch indicator.

b) Monitoring:

Individual visual and audible alarms should be provided at the engine room control station to indicate hydraulic oil low pressure and high temperature and hydraulic tank low level. A high hydraulic oil pressure alarm is to be fitted, if required by the proposed system design and, if fitted, is to be set below the relief valve setting.

For vessels assigned with **CCS** or **UM** notations, Refer Part-6, Ch-8, Table 8.3.1 for monitoring on the navigation bridge and in the centralized control station, respectively.

3.7. Propeller Fitting**3.7.1 Keyed Fitting**

For shape of the keyway in the shaft and size of the key, Refer Ch-4, Sec-3, [3.4] & [3.6] and Ch-4, Sec-3, Figure 4.3.1.

3.7.2 Keyless Fitting**a) Design criteria:**

The factor of safety against slip of the propeller hub on the tail shaft taper at 35°C (95°F) should be at least 2.8 under the action of maximum continuous ahead rated torque plus torque due to torsional vibrations. For oil injection method of fit, the coefficient of friction is to be taken no greater than 0.13 for bronze/steel propeller hubs on steel shafts. The maximum equivalent uniaxial stress (von Mises- Hencky criteria) in the hub at 0°C (32°F) is not to exceed 70% of the minimum specified yield stress or 0.2% proof stress of the propeller material.

Stress calculations and fitting instructions are to be submitted (Refer Sect [1.3.4] of this chapter) and are to include at least the following:

- Theoretical contact surface area
- The maximum permissible pull-up length at 0°C (32°F) as limited by the maximum permissible uniaxial stress specified above
- The minimum pull – up length and contact pressure at 35°C (95°F) to attain a safety factor against slip of 2.8
- The proposed pull-up length and contact pressure at fitting temperature
- The rated propeller ahead thrust

b) Nomenclature: The symbols used are defined as follows.

A = 100% of contact surface area between propeller hub & shaft taper (i.e., $A = \pi D_s L$); mm² (in²).

Oil grooves may be ignored. The propeller hub forward and aft counter bore lengths (l_1 and l_2 in Fig. 5.3.1) and forward & aft inner edge radii (r_1 and r_2 in Figure 5.3.1), if any, are to be excluded.

B = Dimensionless constant based on μ , θ and S

c = Coefficient, dependent on the type of propulsion drive: 1.0 for drives such as turbine, geared diesel, electric, and direct diesel with elastic coupling; and 1.2 for direct diesel drive. This value may have to be increased for cases where extremely high pulsating torque is expected in service.

D_b = Mean outer diameter of propeller hub corresponding to D_s ; mm (in.) D_b is to be calculated as the mean of D_{bm} , D_{bf} and D_{ba} , outer diameters of hub corresponding to D_s , the forward point of contact and the aft point of contact, respectively, Refer Figure 5.3.1.

$$D_b = \frac{D_{bm} + D_{bf} + D_{ba}}{3}$$

D_{bm} = Mean outer diameter of propeller boss, in mm (in.), at the axial position corresponding to D_s ,

Refer: Figure 5.3.1.

D_s = diameter of shaft at mid – point of the taper in axial direction; mm (in.), taking into account the exclusion of forward and aft counter bore length and the forward and aft edge radii, Refer Figure 5.3.1.

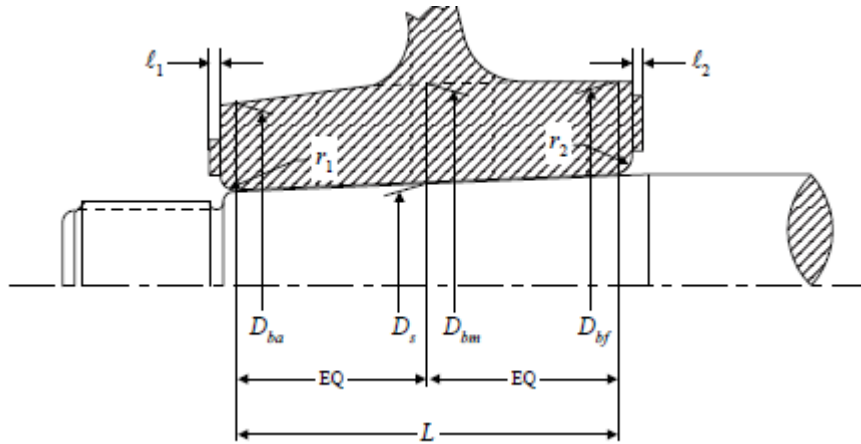


Figure- 5.3.1
Theoretical Contact Surface between Hub and Shaft

E_b = modulus of elasticity of hub material, Refer Table 5.3.4

E_s = modulus of elasticity of shaft material, Refer Table 5.3.4

F_v = shear force at propeller/shaft interface; N (kgf, lbf)

H = power at rated speed; KW (PS, hp)

K = ratio of D_b to D_s , Refer Figure 5.3.1.

L = contact length, in mm (in.), Refer Figure 5.3.1

P = mean propeller pitch; mm, (in.)

P_{min} = minimum required mating surface pressure at 35°C (95°F); N/mm² (kgf/mm², psi)

P_t = minimum required mating surface pressure at temperature t ; N/mm² (kgf/mm², psi)

P_{max} = maximum permissible mating surface pressure at 0°C; N/mm² (kgf/mm², psi)

Q = rated torque corresponding to H and R ; N-mm (kgf-mm, lbf-in)

R = rpm at rated speed

S = factor of safety against slippage at 35°C (95°F)

T = rated propeller thrust; N (kgf, lbf)

T_{ref} = 35°C (95°F)

v = vessel speed at rated power; knots (knots)

α_b = coefficient of linear expansion of propeller hub material; mm/mm°C (in / in°F); Refer Table 5.3.4

α_s = coefficient of linear expansion of shaft material; mm / mm°C (in /in °F); Refer Table 5.3.4

$\delta_{\min}$ = minimum pull – up length at 35°C (95°F); mm (in.)

δ_t = minimum pull – up length at temperature t; mm (in.)

$\delta_{\max}$ = maximum permissible pull-up length at 0°C (32°F); mm (in.)

θ = half taper of shaft; e.g. if taper = 1/15, θ = 1/30

σ_y = yield stress or 0.2% proof stress of propeller material; N/mm² (kgf/mm², psi)

μ = coefficient of friction between mating surfaces; to be taken as 0.13 for fitting methods using oil
injection and hubs of bronze of steel

ν_b = Poisson's ratio of hub material, Refer Table 5.3.4

ν_s = Poisson's ratio of shaft material, Refer Table 5.3.4

Table 5.3.4: Material Constants

Material	Modulus of Elasticity			Poisson's Ratio	Coefficient of Expansion	
	N/mm ²	kgf/mm ²	psi		mm/mm°C	in/in°F
Cast and forged steel	20.6×10^4	2.1×10^4	29.8×10^6	0.29	12.0×10^{-6}	6.67×10^{-6}
Bronzes, Types 2 & 3	10.8×10^4	1.1×10^4	15.6×10^6	0.33	17.5×10^{-6}	9.72×10^{-6}
Bronzes, Types 4 & 5	11.8×10^4	1.2×10^4	17.1×10^6	0.33	17.5×10^{-6}	9.72×10^{-6}

c) Equations:

The taper on the tail shaft cone shall not to exceed 1/15. Although the equations given below are for ahead operation, they may be considered to provide an adequate safety margin for astern operation also.

The minimum mating surface pressure at 35°C (95°F), $P_{\min}$, is to be:

$$P_{\min} = \frac{S T}{A_{cs} B} \left[-S \theta + \sqrt{\mu^2 + B \left(\frac{F_v}{T} \right)^2} \right] \dots \text{N/mm}^2 \text{ (kgf/mm}^2, \text{ psi)}$$

The rated propeller thrust, T, submitted by the designer is to be used in these calculations. In the event that this is not submitted, one of the equations in Table 5.3.5 may be used, subject to which ever yields the larger value of $P_{\min}$.

Table 5.3.5: Estimated Propeller Thrust, T

SI units (N)	MKS units (kgf)	US units (lbf)
1762 $\frac{H}{v}$ or $57.4 \times 10^6 \cdot \frac{H}{PR}$	132 $\frac{H}{v}$ or $4.3 \times 10^6 \cdot \frac{H}{PR}$	295 $\frac{H}{v}$ or $0.38 \times 10^6 \cdot \frac{H}{PR}$

The shear force at interface, F_v , is given by

$$F_v = \frac{2 c Q}{D_s} \quad \text{N (kgf, lbf);}$$

Constant B is given by:

$$B = \mu^2 - S^2 \theta^2$$

The corresponding [i.e., at 35°C (95°F)] minimum pull – up length, δ_{min} , is:

$$\delta_{min} = P_{min} \frac{D_s}{2\theta} \left[\frac{1}{E_b} \left(\frac{K^2+1}{K^2-1} + v_b \right) + \frac{1}{E_s} (1-v_s) \right] \text{ mm (in.);}$$

$$K = \frac{D_b}{D_s}$$

The minimum pull – up length, δ_t , at temperature, t , where $t < 35^\circ\text{C}$ (95°F), is:

$$\delta_t = \delta_{min} + \frac{D_s}{2\theta} (a_b - a_s) (t_{ref} - t) \text{ mm (in.);}$$

The corresponding minimum surface pressure, P_t , is:

$$P_t = P_{min} \frac{\delta_t}{\delta_{min}} \quad \text{N/mm}^2 \text{ (kgf/mm}^2, \text{ psi)}$$

The maximum permissible mating surface pressure, P_{max} , at 0°C (32°F) is:

$$P_{max} = \frac{0.7\sigma_y(K^2-1)}{\sqrt{3K^4+1}} \quad \text{N/mm}^2 \text{ (kgf/mm}^2, \text{ psi)}$$

and the corresponding maximum permissible pull – up length, δ_{max} , is:

$$\delta_{max} = \frac{P_{max}}{P_{min}} \delta_{min} \text{ mm (in.)}$$

SECTION 4 INSPECTION, TESTING AND CERTIFICATION

Contents

4.1. Material Tests	234
4.2. Hydrostatic Tests of Controllable Pitch Propellers	234
4.3. Contact Area Check and Securing for Keyed and Keyless propellers	234
4.4. Inspection and Certification	234

4.1. Material Tests

Propeller materials are required to be tested in the presence of a Surveyor. Ref: Sec-2, [2.3] of this chap

4.2. Hydrostatic Tests of Controllable Pitch Propellers

In the presence of a Surveyor, the completed piping system of the controllable pitch propeller hydraulic system is to be hydrostatically tested at a pressure equal to 1.5 times the design pressure. Relief valve operation is also to be verified.

4.3. Contact Area Check and Securing for Keyed and Keyless propellers

In the presence of a Surveyor, the propeller hub to tail shaft taper contact area is required to be checked. In general, the actual contact area shall not be less than 70% of the theoretical contact area. Non-contact bands extending circumferentially around the propeller hub or over the full length of the hub are not acceptable. Installation is to be done in accordance with the procedure referred to in Sect [3.7.2(a)] of this chapter and final pull – up travel is to be recorded. After final pull – up, propellers are to be secured by a nut on the after end of the tail shaft. The nut is to be secured to the tail shaft against loosening. Refer also Ch-4, Sec-3, [3.7].

4.4. Inspection and Certification

Finished propellers are to be inspected and certified at the manufacturer's plant by the Surveyor. The blade forms, pitch, blade thickness, diameters, etc. are required to be checked for conformance with approved plans. The entire surface of the finished propeller is to be examined visually and by liquid penetrant method (Refer Part-2, Ch-4, Sec-6, [6.2.12]). All finished propellers are to be statically balanced in the presence of the Surveyor. As far as possible, reference is to be made to the provisions of ISO 484 for these purposes.

The surfaces of stainless steel propellers are required to be suitably protected from the corrosive effect of the industrial environment until fitted on the vessel. Refer Part-2, Ch-2, Sec-8, [8.2].

SECTION 5 INSTALLATION AND TRIAL

Contents

5.1. Keyed Propellers	236
5.2. Fit of Studs and Nuts – Controllable Pitch Propellers	236
5.3. Corrosion Protection.....	236
5.4. Circulating Currents.....	236
5.5. Sea Trials	236

5.1. Keyed Propellers

The sides of the key should have a true fit in the keyways of the propeller hub and the shaft. Refer also Ch-4, Sec-3/ [3.7] for tail shaft propeller – end design.

5.2. Fit of Studs and Nuts – Controllable Pitch Propellers

Studs, nuts and bolts are to have tight – fitting threads and are also required to be provided with effective means of locking. Effective sealing arrangements are to be provided in way of the bolt or stud holes against seawater ingress or oil leakage. Bolts, studs and nuts should be made up of corrosion resistant materials or adequately protected from corrosion.

5.3. Corrosion Protection

The exposed steel of the shaft shall be protected from the action of the water by filling all spaces between cap, hub and shaft with a suitable material. The propeller assembly is to be sealed at the forward end with a well – fitted soft – rubber packing ring. When the rubber ring is fitted in an external gland, the hub counter bore is to be filled with suitable material, and clearances between shaft liner and hub counter bore are to be kept minimum. Ample clearance is required to be provided between liner and hub, when the rubber ring is fitted internally. The rubber ring is to be sufficiently oversized to squeeze into the clearance space provided; and, where necessary, a filler piece is to be fitted in way of the propeller – hub keyway to provide a flat, unbroken seating for the rubber ring. The recess formed at the small end of the taper by the overhanging propeller hub is also to be packed with rust – preventive compound. Refer Ch-4, Sec-3, [3.8] for sealing requirements and Ch-4, Figure 4.3.1 for typical arrangements.

5.4. Circulating Currents

A warning notice plate shall be provided in a visible place cautioning against the removal of such protection, where means are provided to prevent circulating currents from passing between the propeller, shaft and the hull.

5.5. Sea Trials

The designed performance of the propeller at rated speed shall be demonstrated during sea trial. The blade pitch control functions, from full ahead through full astern, are required to be demonstrated for controllable pitch propellers. The emergency provisions in Sect [3.6.3](c) of this chapter are also to be demonstrated.

CHAPTER 6 STEERING GEARS

CONTENTS

SECTION 1 GENERAL REQUIREMENTS	238
SECTION 2 MATERIALS	241
SECTION 3 SYSTEM ARRANGEMENTS	243
SECTION 4 MECHANICAL COMPONENT DESIGN	246
SECTION 5 HYDRAULIC SYSTEM	250
SECTION 6 ELECTRICAL SYSTEMS, CONTROLS, INSTRUMENTATION AND COMMUNICATIONS	254
SECTION 7 INSTALLATION, TESTS AND TRIALS	260
SECTION 8 ADDITIONAL REQUIREMENTS	263
SECTION 9 CERTIFICATION	267

SECTION 1 GENERAL REQUIREMENTS

Contents

1.1. Scope	239
1.2. Basic Principles	239
1.3. General Definitions	239
1.4. Steering Gear Compartment	240
1.5. Steering Gear Performance	240
1.6. Documents to be submitted	240

1.1. Application

This section is applicable to vessels which steering is effected by means of a rudder or rudders and an electric, hydraulic or electro – hydraulic steering gear, application of this section is done here.

Additional requirements for azimuthal thrusters are given in Ch-7, Sec-3, [3.6].

Steering gears intended for vessels strengthened for navigation in ice are to comply also with additional requirements in Part 5A.

In case of any additional requirements which are specific to passenger vessels and to vessels intended to carry oil, chemical or liquefied gases in bulk, additional requirements are provided in section 8 of this chapter for convenience.

1.2. Basic Principles

All vessels are to be provided with power – operated means of steering. As a minimum, are to be supported by duplication of power units, and by reduction in piping, electrical power supply, and control circuitry. Steering should be capable to regain in case of the failure of a power unit, a piping component, a power supply circuit or a control circuit. As per application, in addition to this, duplication of rudder actuators are required to be provided for oil and fuel oil carriers, chemical carriers and gas carriers in accordance with the requirements in Sec-4, [4.2] and Sec-8, [8.2] of this chapter.

1.3. General Definitions**1.3.1. Steering Gear**

A Steering Gear is the machinery, rudder actuators, steering gear power units and ancillary equipment. It is also the means of applying torque to the rudder stock (e.g., tiller or quadrant) necessary for affecting the movement of the rudder for the purpose of steering the vessel under normal service conditions.

1.3.2. Steering Gear Power Unit

Steering Gear Power Unit is:

- (i) In the case of electro – hydraulic steering gears, an electric motor and its associated electrical equipment and connected pump.
- (ii) In the case of other hydraulic steering gears, a driving engine and connected pump.
- (iii) In the case of electric steering gears, an electric motor and its associated electrical equipment.

1.3.3. Power Actuating System

Power Actuating System of a hydraulic and electro – hydraulic steering gears, is the hydraulic equipment which is provided for supplying power to turn the rudder stock. It comprises of a steering gear power unit or units, along with the associated pipes and fittings and a rudder actuator. Where duplicated power actuating systems are required by the Rules, they may share common mechanical components, i.e., tiller, quadrant and rudder stock, or components serving the same purpose.

1.3.4. Rudder Actuator

Rudder Actuator is the component which moves the rudder by directly converting hydraulic pressure into mechanical action to move the rudder. This may be a hydraulic cylinder or a hydraulic motor.

1.3.5. Maximum Working Pressure

Maximum Working Pressure is the pressure required to satisfy the operational conditions, as specified in [1.5] of this section.

1.3.6. Steering Gear Control System

Steering Gear Control System is the equipment with the help of which orders are transmitted from the navigation bridge to the steering gear power actuating system. Steering gear control systems comprises of transmitters, receivers, hydraulic control pumps and their associated motors; motor controllers, piping and cables required to control the steering gear power actuating system. For the purpose of the Rules, steering wheels, steering levers, and rudder angle feedback linkages are not considered to be a part of the control system.

1.3.7. Maximum Ahead Service Speed

Maximum Ahead Service Speed is the greatest speed which the vessel is designed to maintain in service at sea at the deepest sea going draft.

1.3.8. Rule Required Upper Rudder Stock Diameter

The Rule Required Upper Rudder Stock Diameter is the rudder stock diameter in way of the tiller, calculated as given in Chapter-12, Sec-1 of this Part.

1.4. Steering Gear Compartment

The steering gear should be protected from the weather. Steering gear compartments are to be readily accessible and, as far as possible, separated from the machinery spaces. Working access is to be provided to the steering gear machinery and controls with handrails, gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage. The steering gear compartment is required to be provided with visual compass readings.

1.5. Steering Gear Performance

The steering gear should be capable of:

- a) Putting the rudder from 35° on one side to 35° on the other side with the vessel running ahead at the maximum continuous rated shaft rpm and at the summer load waterline and, under the same conditions, from 35° on either side to 30° on the other side in not more than 28 seconds; and
- b) With one of the power units inoperative, putting the rudder from 15° on one side to 15° on the other side in no more than 60 seconds with the vessel running ahead at the summer load waterline at one half of the maximum ahead service speed or 7 knots, whichever is the greater.

The performance of steering gear for passenger vessels is given in Sec-8, [8.1].

1.6. Documents to be submitted

Following plans and particulars are to be submitted for review:

- Arrangement of steering gear machinery
- Hydraulic piping system diagram
- Power supply system diagrams
- Motor control system diagrams
- Steering control system diagrams
- Instrumentation and alarm system diagrams
- Drawings and details for rudder actuators
- Drawings and details for torque transmitting parts and parts subjected to internal hydraulic pressure

SECTION 2 MATERIALS

Contents

2.1. General materials 242

2.2. Material Testing 242

2.1. General materials

All parts of the steering gear transmitting forces to the rudder and pressure retaining components of hydraulic rudder actuators are to be of steel or other approved ductile material. In general materials are not to have a tensile strength in excess of 650 N/mm² (66 kgf/mm², 94,300 psi).

Gray cast iron or other material having an elongation ($L_0/d = 4$) less than 12% in 50 mm (2 in.) is not to be used for these parts.

2.2. Material Testing

Except as modified below, materials for the parts and components mentioned in Sect [2.1] above are required to be tested in the presence of the Surveyor in accordance with the requirements of Part 2, Chapter 2 or such other appropriate material specifications as may be approved in connection with a particular design.

2.2.1. Coupling Bolts and Keys

Material tests for steering gear coupling bolts and torque transmitting keys need not be witnessed by Surveyor, but manufacturer's test certificates traceable to these components are to be presented upon request

2.2.2. Small Parts of Rudder Actuators

Material tests for forged, welded or seamless steel parts (including the internal components) of rudder actuators that are under 150 mm (6 in.) in internal diameter need not be carried out in the presence of the Surveyor. Such parts may be accepted on the basis of a review of mill certificates by the Surveyor.

2.2.3. Tie Rod Nuts

Material tests for commercially supplied tie-rod nuts need not be witnessed by the Surveyor provided the nuts are in compliance with the approved steering gear drawings and are appropriately marked and identified in accordance with a recognized industry standard. Mill test reports for the tie-rod nuts shall be made available to the Surveyor upon request. The material testing is required to be performed in the presence of the Surveyor, for all non-standard tie-rod nuts.

2.2.4. Piping Material

It is not required by the Surveyor to be physically present at time of testing piping materials. The Surveyor can inspect pipes on the basis of certificates provided by the mil, and on the physical inspection and review of mill certificate.

SECTION 3 SYSTEM ARRANGEMENTS

Contents

3.1. Power Units	244
3.2. Rudder Actuators	244
3.3. Single Failure Criterion.....	244
3.4. Independent Control Systems	244
3.5. Non-duplicated Components.....	244
3.6. Power Gear Stops	244
3.7. Steering Gear Torques	244

3.1. Power Units

The steering gear should be composed of two or more identical power units and should be capable of operating the rudder as required by Sec-1, [1.5] (a) & (b) of this chapter. The power units are required to be served by at least two power circuits (Refer Sec-6, [6.1]). Power units are required to be type tested, Refer Sec-9, [9.3].

3.2. Rudder Actuators

Steering gears may be composed of a single rudder actuator for all vessels except the following:

- a) For oil carriers, fuel oil carriers, chemical carriers and gas carriers of 100,000 tones deadweight and above, the steering gear shall be comprised of two or more identical rudder actuators.
- b) For oil carriers, fuel oil carriers, chemical carriers and gas carriers of 10,000 gross tonnage and above but less than 100,000 tones deadweight, the steering gear may be comprised of a single, non – duplicated rudder actuator provided it complies with Sec-8, [8.2.3].

3.3. Single Failure Criterion

The hydraulic system is required to be designed in such a way so that after a single failure in the piping system or one of the power units, the defect can be isolated so that the integrity of the remaining part of the system will not be impaired and the steering capability can be maintained or speedily regained. Refer also section 5 of this chapter.

3.4. Independent Control Systems

Two independent steering gear control systems shall be provided, each of which can be operated from the navigation bridge. These control systems are to allow rapid transfer of steering power units and of control between the units. Refer Sec-6, [6.2] of this chapter.

3.5. Non-duplicated Components

Essential components which are not required to be duplicated are to utilize, where appropriate, anti-friction bearings, such as ball bearings, roller bearings or sleeve bearings which are to be permanently lubricated or provided with lubrication fittings.

3.6. Power Gear Stops

The steering gear is required to be fitted with arrangements, such as limit switches, for stopping the gear before the structural rudder stops (Refer Ch-12, Sec-1, [1.1.6]) or positive mechanical stops within the steering gear are reached. These arrangements are to be synchronized with the rudder stock or the position of the gear itself and maybe an integral part of the rudder actuator. Arrangements to satisfy this requirement through the steering gear control system are not permitted.

3.7. Steering Gear Torques

3.7.1 Minimum Required Rated Torque

The rated torque of the steering gear shall not be less than the expected torque, as defined in Ch-12, Sec-1/ [1.1.5].

3.7.2 Maximum Allowable Torque

The transmitted torque, T_{max} , of the steering gear shall not be greater than the maximum allowable torque, T_{ar} , based on the actual rudder stock diameter.

- a) Transmitted torque.

The transmitted torque, T_{max} , is to be based on the relief valve setting and is required to be determined accordingly with the help of the following equations:

- For ram type actuator:

$$T_{\max} = \frac{P \cdot N \cdot A_p \cdot L_2}{C \cdot \cos^2 \theta} \quad \text{kN-m (tf-m, Ltf-ft)}$$

- For rotary vane type actuator:

$$T_{\max} = \frac{P \cdot N \cdot A_p \cdot L_2}{C} \quad \text{kN-m (tf-m, Ltf-ft)}$$

- For linked cylinder type actuator:

$$T_{\max} = \frac{P \cdot N \cdot A_p \cdot L_2 \cdot \cos \theta}{C} \quad \text{kN-m (tf-m, Ltf-ft)}$$

Where,

P = steering gear relief valve setting pressure, bar (kgf/cm², psi)

N = number of active pistons or vanes

A_p = area of piston or vane, mm² (cm², in²)

C = factor = 10000 (1000 for kgf/cm², 2240 for psi)

L

₂ = torque arm, equal the distance from the point of application of the force on the arm to the center of the rudder stock at zero (0) degrees of rudder angle, m (ft)

θ = maximum permissible rudder angle (normally 35 degrees)

b) Maximum allowable torque for rudder stock.

In accordance with the following equation, the maximum allowable torque, T_{ar}, for the actual rudder stock diameter is to be determined:

$$T_{ar} = \frac{2.0 (D_r / N_u)^3}{K_s} \quad \text{kN-m (tf-m, Ltf-ft)}$$

Where;

D_r = actual rudder stock diameter at minimum point below the tiller or the rotor, mm (in.)

N_u = factor = 42.0 (89.9 for kgf/cm², 2.39 for psi)

K_s = material factor for rudder stock.

SECTION 4 MECHANICAL COMPONENT DESIGN

Contents

4.1. Mechanical Strength.....	247
4.2. Rudder Actuators.....	247
4.3. Tillers, Quadrants and Other Mechanical Parts	247
4.4. Rudder Stock to Tiller/Quadrant Connection	248
4.5. Welding.....	249

4.1. Mechanical Strength

All mechanical components which transmit force to or from the rudder are required to have strength equivalent to that of the Rule required upper rudder stock (refer to Sec-1/ [1.3.8]).

4.2. Rudder Actuators**4.2.1. Design**

Rudder actuators should be designed accordingly to the requirements of pressure vessels in Chapter 10, Sec-1, except that the maximum allowable stress S is not allowed to exceed the lower of the following:

$$\frac{U}{A} \text{ or } \frac{Y}{B}$$

where;

Y = minimum specified yield point or yield strength

U = minimum specified tensile strength of material at room temperature

Values of the factor A and B are given below:

	Rolled or forged steel	Cast steel	Nodular cast iron
A	3.5	4	5
B	1.7	2	3

For requirements relative to vessels intended to carry oil, chemicals, or liquefied gases in bulk of 10,000 gross tonnage and over, but less than 100,000 tonnes deadweight, fitted with non-duplicated rudder actuators, refer Sec-8, [8.2.3].

4.2.2. Oil Seals

Oil seals between non-moving parts which forms the part of the exterior pressure boundary should be made up of the metal upon metal type or of an equivalent type. Oil seals between moving parts which forms the part of the external pressure boundary are required to be fitted in duplicate so that the failure of one seal does not render the actuator inoperative. Alternative seal arrangements may be acceptable provided equivalent protection against leakage can be ensured.

4.3. Tillers, Quadrants and Other Mechanical Parts**4.3.1 General**

All the steering gear parts, such as tillers, quadrants, pins, rams, keys and tie rods, which transmit force to or from the rudder, are required to be proportioned so as to have strength equivalent to that of the Rule required upper rudder stock, taking into consideration the difference in materials between the rudder stock and the component.

4.3.2 Tillers and Quadrants**a) Tiller or quadrant hub.**

Dimensions of the hub are to be as follows (use consistent system of units):

- i. Depth of the hub is not to be less than S .
- ii. Mean thickness of the hub is not to be less than $S/3$.
- iii. Notwithstanding (ii) above, the polar section modulus of the hub should be not less than that given below:

$$0.196 \times S^3 \times \frac{K_h}{K_s}$$

Where;

S = Rule-required upper rudder stock diameter

K_h = Material factor of hub

K_s = Material factor of rudder stock

b) Tiller or quadrant arm.

The section modulus of the tiller or quadrant arm anywhere along its length shall not be less than that given below (use consistent system of units):

$$\frac{0.167 S^3 (L_2 - L_1)}{L_2} \times \frac{K_t}{K_s}$$

where;

L₁ = Distance between the section of the arm under consideration & the center of the rudder stock

L₂ = distance from point of application of the force on the arm to the center of the rudder stock

K_t = material factor of tiller or quadrant arm

Other symbols are as defined above.

c) Bolted hub.

Split or semi-circular tiller or quadrant hubs assembled by bolting shall have bolts on any side having a total cross-sectional area not less than that given below (use a consistent system of units):

$$\frac{0.196 S^3}{L_3} \times \frac{K_b}{K_s}$$

where;

K_b = material factor of bolt

L₃ = distance between the center of the bolts and the center of the rudder stock

Other symbols are as defined above.

Thickness of the bolting flange is not to be less than the minimum required diameter of the bolt.

d) Tiller pin.

The total effective shear area of the tiller pin shall not be less than that given below. (Use consistent system of units):

$$\frac{0.196 S^3}{L_2} \times \frac{K_p}{K_s}$$

where;

K_p = material factor of the pin

Other symbols are defined above.

4.3.3 Tie Rod

For multiple rudder installations or similar, where tie rod (or jockey bar) is fitted between tillers to synchronize them, the buckling strength of the tie rod is required to be not less than that given below (use a consistent system of units):

$$\frac{0.113 S^3 U_R}{L_2}$$

Where; U_R = ultimate tensile strength of the rudder stock

Other symbols are defined above

4.4. Rudder Stock to Tiller/Quadrant Connection**4.4.1 Key**

The effective area of the key in shear is not to be less than that given below (use a consistent system of units):

$$\frac{0.196 S^3}{r} \times \frac{K_t}{K_s}$$

where;

- S = Rule – required upper rudder stock diameter
r = actual rudder stock radius at mid length of key
K_k = material factor of key
K_s = material factor of rudder stock

The bearing stresses of the tiller and rudder stock keyways are not required to be more than 90% of the applicable material yield stress.

4.4.2 Keyless Coupling

Hydraulic or shrink fitted keyless coupling is to be based on preload stress calculations and fitting procedures. The calculated torsional holding capacity is to be at least 2.0 times the transmitted torque based on the steering gear relief valve setting. The coefficient of friction for the oil injection method of fit is to be taken as no greater than 0.14 and that for dry method is to be taken as no greater than 0.17. Preload stress is not to exceed 90% of the minimum yield strength. Maximum equivalent Von-Mises Stress is not to exceed minimum yield strength considering all loads including preload stress and two times transmitted torque.

4.5. Welding

All the welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads are required to be full penetration type or to be of other approved design.

SECTION 5 HYDRAULIC SYSTEM

Contents

5.1. System Design 251

5.2. Hydraulic Oil Reservoir and Storage Tank 252

5.3. Piping Design 252

5.4. Piping Components 252

5.1. System Design

5.1.1 General

The hydraulic system is required to be fitted with two or more power units, Refer Section 3/[3.1]. It may be fitted with a single hydraulic rudder actuator unless required otherwise by Section 3/[3.2].

5.1.2 Piping Arrangements

Piping is to be arranged such that:

- Single failure criteria in Section 3/[3.3] are met.
- Transfer between power units can be readily affected.
- Air may be bled from the system.

5.1.3 Hydraulic Lock

Hydraulic lock may occur where a piping system is arranged such that malfunctions (for example, in directional valves or in the valve control) can cause power units to work in a closed circuit against each other rather than in parallel, delivering fluid to the rudder actuator, thus resulting in loss of steering. An audible and visual hydraulic lock alarm, which identifies the failed system, should be provided on the navigation bridge, where a single failure can lead to hydraulic lock and loss of steering. Also refer Table 6.6.1- Note 4 of this chapter.

Alternatively, an independent steering failure alarm for follow-up control systems complying with the following requirements may be provided in lieu of a hydraulic lock alarm.

Where an independent steering failure alarm is installed for follow-up control systems, it is required to comply with the following:

- a) The steering failure alarm system is required to actuate an audible and visible alarm in the wheelhouse when the actual position of the rudder differs by more than 5 degrees from the rudder position ordered by the follow-up control systems for more than:
 - 30 seconds for ordered rudder position changes of 70°;
 - 6.5 seconds for ordered rudder position changes of 5°; and

The time period calculated by the following formula for ordered rudder positions changes between 5° and 70°:

$$t = \frac{R}{2.76} + 4.64$$

Where;

t = maximum time delay in seconds

R = ordered rudder change in (°) degrees

- b) The steering failure alarm system must be separate from, and independent of, each steering gear control system, except for input received from the steering wheel shaft.
- c) Each steering failure alarm system should be supplied by a circuit that:
 - i) Is independent of other steering gear system and steering alarm circuits.
 - ii) Is fed from the emergency power source through the emergency distribution panel in the wheelhouse, if installed; and
 - iii) Has no overcurrent protection except short circuit protection

5.1.4 Isolation Valves

Isolating valves are required to be fitted on the pipe connections to the rudder actuators. For vessels with non - duplicated rudder actuators, the isolating valves are to be directly mounted on the actuator.

5.1.5 Filtration

A means should be provided to maintain the cleanliness of the hydraulic fluid.

5.1.6 System Overpressure Protection

Relief valves should be provided for the protection of the hydraulic system at any part which can be isolated and in which pressure can be generated from the power source or from external forces. Each relief valve is to be capable of relieving not less than 110% of the full flow of the pump(s) which can discharge through it. With this flow condition, the maximum pressure rise shall not exceed 10% of the relief valve setting, taking into consideration increase in oil viscosity for extreme ambient conditions.

The relief valve setting shall be at least 1.25 times the maximum working pressure (Refer Sec-1, [1.3.5] of this chapter), but is not to exceed the maximum design pressure (Refer [5.3.1] of this section).

5.1.7 Fire Precautions

The provisions of Chapter 8, Sec-6/[6.2.4.1] are required to be met wherever applicable.

5.2. Hydraulic Oil Reservoir and Storage Tank

A fixed hydraulic oil storage tank independent of the reservoir is required to be provided in addition to the power unit reservoir. The storage tank should have sufficient capacity to recharge at least one power actuating system, including the power unit reservoir. The tank is to be permanently connected by piping in such a manner so that the system can be readily recharged from a position within the steering gear compartment. An approved level indicating system is to be provided for the storage tank.

Also refer Chapter 8, Sec-6/ [6.2.2] for arrangements of the power unit reservoir and the storage tank.

5.3. Piping Design

5.3.1 System Pressure

Hydraulic system piping should be designed to at least 1.25 times the maximum working pressure (Sect [1.3.5] of this chapter), taking into account any pressure which may exist in the low – pressure side of the system.

5.3.2 Pipes and Pipe Fittings

Pipes and pipe branches are required to meet the design requirements of Ch-8, Sec-2/ [2.3.1] & [2.3.2]. Pipe joints are to be done in accordance with Ch-8, Sec-2/[2.3.3] in general, and Ch-8, Sec-6/[6.2.3.1] in particular. Particular attention should be paid to the Notes 1 & 2 in Table 8.6.1 of Chapter-8 where additional limitations on pipe joints are specified for steering gear hydraulic piping. Refer also Sect [5.4.3] below.

5.4. Piping Components

5.4.1 Power Units

Power units are to be certified by INTLREG. Refer Sec-3/ [3.1] and Sec-9/[9.3].

5.4.2 Rudder Actuators

Rudder actuators should be design approved and should be certified by INTLREG. Refer Sect [3.2], [4.2] and [9.4] of this chapter.

5.4.3 Pipes and Pipe Fittings

For pipes and pipe fittings, refer to Sect [5.3.2] above. Piping materials for hydraulic service are required to be traceable to manufacturers' certificates, but need not be certified by INTLREG. Refer also Ch-8, Sec-1/[1.4] for certification of piping system components.

5.4.4 Other Piping Components

Refer to Ch-8, Sec-6/6.2.3], for valves, hoses and accumulators. For relief valve, Refer also [5.1.6] of this section.

5.4.5 Relief Valves

In addition to [5.4.4] above, discharge capacity test reports verifying the capacity required in [5.1.6] of this section for all relief valves are required to be submitted for review.

**SECTION 6 ELECTRICAL SYSTEMS, CONTROLS,
INSTRUMENTATION AND COMMUNICATIONS**

Contents

6.1. Electrical Systems 254

6.2. Control Systems 256

6.3. Instrumentation 258

6.4. Communications 259

6.1 Electrical Systems**6.1.1. Power Supply Feeders**

Each electric or electro-hydraulic steering gear is required to be served by at least two exclusive circuits, fed directly from the main switchboard; however, one of the circuits may be supplied through the emergency switchboard. Each of duplicated power units required by [3.1] of this chapter is to be served by one of these circuits. The circuits supplying an electric or electro – hydraulic steering gear are to have adequate rating for supplying all motors, control systems and instrumentation which are normally connected to them and operated simultaneously. The circuits are to be separated throughout their length as widely as is practicable. Refer also Part-6, Ch-5, Sec-3/ [3.2] for the steering gear power supply. In ships of less than 1600 gross tonnage, if an auxiliary steering gear is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering gear may be fed by one circuit from the main switchboard.

6.1.2. Electrical Protection**6.1.2.1. General**

Each steering gear feeder should be provided with short – circuit protection which is to be located at the main or the emergency switchboard, as applicable. Power unit motor overload protection normally should not be provided, except as indicated in [6.1.2.3] below. Other means of protection like motor overload alarm and motor phase failure alarm, as applicable, are required to be provided as indicated in item-(d) of Table 6.6.1. Also refer Part-6, Ch-5, Sec-3/[3.5] for protection of the steering gear feeder circuit.

6.1.2.2. Direct Current Motors

The feeder circuit breaker is required to be set to trip instantaneously at not less than 300% and not more than 375% of the rated full – load current of the steering gear motor, except that the feeder circuit breaker on the emergency switchboard may be set to trip at not less than 200%.

6.1.2.3. Alternating Current Motors

In addition to short circuit protection, overload protection may be permitted if it is set at a value not less than 200% of the full load current of the motor (or of all the loads on the feeder), and is required to be arranged to permit the passage of the starting current.

6.1.2.4. Fuses

The use of fuses instead of circuit breakers is not permitted for steering gear motor feeder short circuit protection.

6.1.3. Under voltage Release

Power unit motor controllers and other automatic motor controllers are required to be fitted with under voltage release (capable of restarting automatically when power is restored after a power failure).

6.1.4. Motor Rating**6.1.4.1 Steering Gears with Intermittent Working Duty**

Electric motors of and converters associated with electro – hydraulic steering gears with intermittent working duty should be at least of 25% non-periodic duty rating (corresponding to S6 of IEC Publication 60034-1), as per Part-6, Ch-4, Sec-1/ [1.1.2.3] and Part-6, Ch-4, Table 4.3.1. Electric motors of electro-mechanical steering gears are, however, to be at least of 40% non-periodic duty rating (corresponding to S3 of IEC Publication 60034-1).

6.1.4.2 Steering Gears with Continuous Working Duty

Electric motors of and converters associated with steering gears with continuous working duty are to be of continuous rating (corresponding to S1 of IEC Publication 60034-1), as per Part-6, Ch-4, Sec-1/ [1.1.2.4] and Part-5, Ch-4, Table 4.3.1.

6.1.5. Emergency Power Supply

An alternative power supply, sufficient at least to supply one steering gear power unit and its associated control system and the rudder angle indicator, is to be provided automatically within 45 seconds either from the emergency source of electrical power or from an independent source of power located in the steering gear compartment, where the required rudder stock diameter (Refer Sec-1/[1.3.8]) is over 230 mm (9 inches). This independent source of power is required to be used only for this purpose.

The steering gear power unit under alternative power supply is required to be capable of moving the rudder from 15° on one side to 15° on the other side in not more than 60 seconds with the vessel at the summer draft while running at one half the maximum ahead service speed or 7 knots, whichever is the greater (Refer Sec-1, [1.5] (b)).

In every vessel of 10,000 gross tonnage and upwards, the alternative power supply shall have a capacity for at least 30 minutes of continuous operation and in any other vessel for at least 10 minutes.

6.2 Control Systems

6.2.1. General

6.2.1.1. Redundancy

There should be two independent control systems (Refer definition in Sec-1/[1.3.6]) provided, each of which can be operated from the navigation bridge. These control systems should be independent in all respects and should provide on the navigation bridge all necessary apparatus and arrangements to start and stop the steering gear motors and the rapid transfer of steering power and control between units.

Control cables and piping for the independent control systems are required to be separated throughout their length, as widely as is practicable.

Wires, terminals and the components for duplicated steering gear control systems installed in units, control boxes, switchboards or bridge consoles are required to be separated throughout their length as widely as is practicable. The separation may be achieved by means of a fire retardant plate, where physical separation is not possible.

6.2.1.2. Local Steering Gear Control

Steering gear compartment should be provided with local steering gear control.

6.2.1.3. Duplication

All electric components of the steering gear control system are required to be duplicated. This does not require duplicating a steering wheel or steering lever.

6.2.1.4. Steering Mode Selector Switch

If a joint steering mode selector switch (uniaxial switch) is employed for both steering gear control systems, then an isolating plate or an air gap is used to separate and divide the connections for the circuits of the control systems.

6.2.1.5. Follow-up Amplifier

In the case of double follow-up control, the amplifiers are required to be designed and fed so as to be electrically and mechanically separated. The follow-up amplifiers are to be protected selectively, in the case of non-follow-up control and follow-up control.

6.2.1.6. Additional Control Systems

Control circuits for additional control systems (e.g., steering lever or autopilot) are required to be designed for all pole disconnection.

6.2.1.7. Feed-back Units and Limit Switches

The feed-back units and limit switches, if any, for the steering gear control systems are to be separated electrically and mechanically connected to the rudder stock or actuator separately.

6.2.1.8. Hydraulic Control Components

Hydraulic system components in the power actuating or hydraulic servo systems controlling the power systems of the steering gear (e.g., solenoid valves, magnetic valves) are required to be considered as part of the steering gear control system and shall be duplicated and separated.

Hydraulic system components in the steering gear control system that are part of a power unit maybe regarded as being duplicated and separated when there are two or more separate power units provided and the piping to each power unit can be isolated.

6.2.2. Power Supply

If the control systems operable from the navigation bridge are electric, then each system is required to be served by its own separate circuits supplied from a steering gear power circuit in the steering gear compartment, or directly from the switchboard bus bars supplying that steering gear power circuit at a point on the switchboard adjacent to the supply to the steering gear power circuit.

Circuits supplying power to steering gear controls are to be provided with short-circuit protection

6.2.3. Control System Override**6.2.3.1 Steering Gear Compartment**

Means are to be provided in the steering gear compartment to disconnect the steering gear control system from power circuit when local control is required to be used. If more than one steering station is provided, a selector switch should disconnect completely all stations, except the one in use.

6.2.3.2 Autopilot

- a) Steering gear systems which are provided with an autopilot system are required to have a device at the primary steering station to completely disconnect the autopilot control to permit change over to manual operation of the steering gear control system. A display shall be provided at the steering station to ensure that the helmsman can readily and clearly recognize which mode of steering control (autopilot or manual) is in operation.

- b) In addition to the changeover device as in (a) above, for primary steering stations, which are fitted with an automatic autopilot override to change over from autopilot control to manual operation, the following are to be provided.
- i) The automatic override of the autopilot is required to occur when the manual helm order is 5° of rudder angle or greater.
 - ii) An audible and visual alarm is required to be provided at the primary steering station in the event that the automatic autopilot override fails to respond when the manual helm order is 5° of rudder angle or greater. The alarm should be separate and distinct from other bridge alarms, and should continue to sound until it is acknowledged.
 - iii) An audible and visual alarm that is immediately activated upon automatic autopilot override actuation should be provided at the primary steering station. The alarm should be distinct from other bridge alarms, and should continue to sound until it is acknowledged.

6.2.4. Hydraulic Telemotor

A second independent system need not be fitted, except in oil or fuel oil carriers, chemical carriers, or gas carriers of 10,000 gross tonnage and above (Refer also Sec-8, [8.2], where the control system consists of a hydraulic telemotor.

6.2.5. Computer – based Systems

Steering control systems that are computer-based systems are required to comply with Part-6, Ch-8, Sec-1/[1.3.2] and are to be considered system category III.

6.3 Instrumentation

- 6.3.1 As indicated in Table 6.6.1, instruments for monitoring the steering gear system should be provided. All alarms should be audible and visual and should be of the self-monitoring type so that a circuit failure will cause an alarm condition. There are to be provisions for testing alarms.

Table 6.6.1: Steering Gear Instrumentation

Monitored Parameters		Display/Alarm	Location
a.	Rudder angle indicator (Refer note 1)	Display	• Navigation bridge • Steering gear compartment
b.	Power unit motor running	Display	• Navigation bridge • Engine room control station
c.	Power unit power supply failure	Alarm	• Navigation bridge • Engine room control station
d.	Power unit motor overload (Refer note 2)	Alarm	• Navigation bridge • Engine room control station
e.	Power unit motor phase failure (Refer note 2 & 3)	Alarm	• Navigation bridge • Engine room control station
f.	Control power failure	Alarm	• Navigation bridge • Engine room control station
g.	Hydraulic oil reservoir low level	Alarm	• Navigation bridge • Engine room control station

INTLREG Rules and Regulations for Classification of Steel Vessels

h.	Hydraulic lock (Refer note 4)	Alarm	• Navigation bridge
i.	Auto-pilot running (Refer note 5)	Display	• Navigation bridge
j.	Auto-pilot failure (Refer note 5)	Alarm	• Navigation bridge
k.	Steering mode (auto pilot/manual) indication	Display	• Navigation bridge
l.	Automatic autopilot override failure (Refer note 5)	Alarm	• Navigation bridge
m.	Automatic autopilot override activated (Refer note 5)	Alarm	• Navigation bridge
n.	Loop failures (Refer note 6)	Alarm	• Navigation bridge
o.	Computer-based system failures (Refer note 7)	Alarm	• Navigation bridge
Note: 1. The rudder angle indication is to be independent of the steering gear control system, and readily visible from the control position. 2. The operation of this alarm is not to interrupt the circuit. 3. For three phase AC supply only. 4. The alarm is to be activated when the position of the variable displacement pump control system does not correspond to the given order; or when the incorrect position of the 3-way full flow valve or similar in the constant delivery pump system is detected. Monitoring for hydraulic lock is not required, when a steering failure alarm system is provided. Refer Sec-5/ [5.1.3] (a), (b) & (c) of this chapter. 5. If provided. 6. Monitoring is to be provided for short circuit, broken connections and earth faults for command and feedback loops. Monitoring for loop failures is not required, when a steering failure alarm system is provided. Refer Sec-5/[5.1.3] (a), (b) & (c) of this chapter. 7. For steering control systems that are computer-based systems, monitoring is to be provided for data communication errors, computer hardware failures and software failure. Refer also Part 6-Ch 8/ Sect 5. Monitoring for computer-based system failures is not required, when a steering failure alarm system is provided. Refer Sec-5/ [5.1.3] (a), (b) & (c) of this chapter.			

6.4 Communications

- 6.4.1 A means of communication should be provided between the navigation bridge and the steering gear compartment. Additionally, communication should be provided between these spaces and the main propulsion control station, in accordance with Part-6, Ch-7, Sec-3/ [3.2].

SECTION 7 INSTALLATION, TESTS AND TRIALS

Contents

7.1. Foundation of Steering Gear	261
7.2. Operating Instructions	261
7.3. Installation Tests.....	261
7.4. Sea Trials	261

7.1. Foundation of Steering Gear

Steering gears should be bolted to a substantial foundation effectively attached to the hull structure. Suitable chocking arrangements should be provided to the satisfaction of the Surveyor.

7.2. Operating Instructions

Appropriate operating instructions with a block diagram showing changeover procedures for steering gear control systems and steering gear power units are required to be permanently displayed on the navigation bridge and in the steering gear compartment. The instructions shall be permanently posted on the navigation bridge and in the steering gear compartment for the operator to shut down the failed system, where failure alarms are provided to indicate hydraulic locking.

7.3. Installation Tests

After installation on board the vessel, the complete piping system, including power units, rudder actuators and piping, is required to be subjected to a hydrostatic test equal to 110% of the relief valve setting, including a check of the relief valve operation in the presence of the Surveyor.

7.4. Sea Trials

A trip for trial should be made for the steering gear in order to demonstrate to the Surveyor that the requirements of this section have been made. The trials should be done with the rudder fully submerged. Alternative procedures for trials with less than full rudder submergence are required to be submitted for consideration, (also Refer Sec.8 [8.4]) where full rudder submergence cannot be obtained in ballast conditions.

7.4.1 Full Speed Trial

Satisfactory performance is required to be demonstrated under the following conditions:

- i) Changing the rudder position from 35° on either side to 30° on the other side in not more than 28 seconds with the vessel running ahead at the maximum continuous rated shaft rpm. The propeller pitch is required to be at the maximum design pitch approved for the above maximum continuous ahead rated, for controllable pitch propellers.
- ii) Unless [7.4.2(iii)] or Sec-8, [8.3] is applicable, this test is required to be carried out with all power units intended for simultaneous operation for this condition under actual operating conditions.

7.4.2 Half Speed Trial

Satisfactory performance is required to be demonstrated under the following conditions.

- i) Changing the rudder position from 15° on either side to 15° on the other side in not more than 60 seconds while running at one-half of the maximum ahead speed or 7 knots whichever is the greater.
- ii) This test is to be conducted with either one of the power units used in [7.4.1(ii)] above in reserve.
- iii) This test may be waived where the steering gear consists of two identical power units with each capable of meeting the requirements in [7.4.1(i)] above.

7.4.3 Steering Gears with More than Two Power Units

The test procedures are required to be specially considered on the basis of the specifically approved operating arrangements of the steering gear system, where three or more power units are provided.

7.4.4 Additional Items

The trial should also include the operation and verification of the following:

- i) The power units, including transfer between power units.
- ii) The steering gear controls, including transfer of control and local control.
- iii) The emergency power supply, if applicable.
- iv) The means of communication between the navigation bridge, engine room and the steering gear compartment.
- v) The storage and recharging system in Sec-5, [5.2] of this chapter (test may be done at dockside).
- vi) The alarms and indicators required by Sec-6, [6.3] (test may be done at dockside).
- vii) Where the steering gear is designed to avoid hydraulic locking (Sec-5, [5.1.3]), this feature is to be demonstrated.
- viii) The isolation of one power actuating system and time for regaining steering capability (test may be done at dockside).
- ix) Where practicable, simulation of a single failure in the hydraulic system, and demonstration of the means provided to isolate it and the regaining of steering capability, as in Sec-3, [3.3] and Sec-5, [5.1.3].
- x) The stopping of the steering gear before the rudder stop is reached, as in Sec-3, [3.6].

SECTION 8 ADDITIONAL REQUIREMENTS

Contents

8.1. Additional Requirements for Passenger Vessels	264
8.2. Additional Requirements for Oil or Fuel Oil Carriers, Chemical Carriers and Gas Carriers	264
8.3. Additional Requirements for Sea Trials.....	266
8.4. Alternative way to demonstrate the requirements of steering gear trials.	266

8.1. Additional Requirements for Passenger Vessels

8.1.1. Performance

The steering gear shall be designed in such a manner so that it is capable of operating the rudder, as required by Sec-1, [1.5(a)] of this chapter, with any one of the power units not in operation.

8.2. Additional Requirements for Oil or Fuel Oil Carriers, Chemical Carriers and Gas Carriers

8.2.1. Vessels of 10,000 Gross Tonnage and Upwards

8.2.1.1. Single Failure Criterion

The steering gear should be arranged in such a manner that in the event of the loss of steering capability due to a single failure in any part of one of the power actuating systems (Refer Sec-1, [1.3.3] of this chapter), excluding the tiller, quadrant or components serving the same purpose, or seizure of the rudder actuators, steering capability is to be regained in not more than 45 seconds.

8.2.1.2. Power Actuating System

The steering gear is to comprise either:

- a) Two independent and separate power actuating systems, each capable of meeting the requirements of Sec-1/ [1.5(a)] of this chapter; or
- b) At least two identical power actuating systems which, acting simultaneously in normal operation, should be capable of meeting the requirements of Sec-1, [1.5(a)] of this chapter. Inter-connection of hydraulic power actuating systems may be provided, wherever complying with this requirement is necessary. In order for the other actuating system or systems to remain fully in operation, it should be capable of detecting the loss of hydraulic fluid from one system and the defective system should be automatically isolated.

8.2.1.3. Non-hydraulic Steering Gears

Equivalent standards are required to be achieved by steering gears other than of the hydraulic type.

8.2.2. Alternative for Vessels 10,000 Gross Tonnage and Upwards but Less than 100,000 Tonnes Deadweight

In lieu of completely meeting the requirements in Sect [8.2.1] above, vessels within this size range may as an alternative, exclude the application of single failure criterion to rudder actuator provided that an equivalent safety standard is achieved and that:

- a) The steering capability is required to be regained within 45 seconds following the capability loss due to a single failure of the piping system or in any one of the power units and
- b) The requirements of Sect[8.2.3] below are met by the single rudder actuator.

8.2.3. Non-duplicated Rudder Actuators for Vessels of 10,000 Gross Tonnage and Upwards but Less than 100,000 Tonnes Deadweight

A single rudder actuator may be accepted for oil or fuel oil carriers, chemical carriers or gas carriers of 10,000 gross tonnage and upwards but of less than 1,00,000 tonnes dead weight, provided the following additional requirement are complied with.

8.2.3.1. Analysis

To show the suitability of the design for the intended service, detailed calculations are required to be submitted for the rudder actuator. This is to include a stress analysis of the pressure retaining parts of the actuator to determine the stresses at the design pressure.

A fatigue analysis and fracture mechanic analysis may be required, where considered necessary due to the design complexity or manufacturing procedures. , All foreseen dynamic loads are to be taken into account, in connection with these analyses. In addition to, or in lieu of, theoretical calculations depending on the complexity of the design, experimental stress analysis may be required.

8.2.3.2. Allowable Stresses

For the purpose of determining the general scantlings of parts of rudder actuators subject to internal hydraulic pressure, the allowable stresses shall not exceed:

$$\sigma_m \leq f$$

$$\sigma_l \leq 1.5f$$

$$\sigma_b \leq 1.5f$$

$$\sigma_l + \sigma_b \leq 1.5f$$

$$\sigma_m + \sigma_b \leq 1.5f$$

Where;

σ_m = equivalent primary general membrane stress

σ_l = equivalent primary local membrane stress

σ_b = equivalent primary bending stress

σ_B = specified minimum tensile strength of material at ambient temperature

σ_Y = specified minimum yield stress or 0.2% proof stress of material at ambient temperature

f = the lesser of σ_B / A or σ_Y / B , where the values of A and B are as follows:

	Steel	Cast Steel	Nodular cast iron
A	4	4.6	5.8
B	2	2.3	3.5

8.2.3.3. Burst Test

Pressure retaining parts not requiring fatigue analysis and fracture mechanic analysis may be accepted on the basis of a certified burst test and the detailed stress analysis required by [8.2.3.1] above need not be submitted.

The minimum bursting pressure is required to be calculated as follows:

$$P_b = P \times A \times \frac{\sigma_{Ba}}{\sigma_B}$$

Where;

P_b = minimum bursting pressure

P = design pressure as defined in [5.3.1] of this chapter

A = from table in [8.2.3.2] above

σ_{Ba} = actual tensile strength

σ_B = tensile strength as defined in [8.2.3.2] above

8.2.3.4. Non-destructive Testing

The rudder actuator is required to be subjected to complete non-destructive testing to detect both surface flaws and volumetric flaws. The procedure and acceptance criteria should be in accordance with the requirements of recognized standards or as may be determined by approved fracture mechanic analysis.

8.3. Additional Requirements for Sea Trials

8.3.1. The performance test criteria in Sec-7/[7.4.1(a)] should be demonstrated during sea trial with any one of the power units in reserve.

8.3.2. For vessels having two independent and separate power actuating systems as per [8.2.1.2(b)] above. The capabilities of the steering gear to function as required in [8.2.1.1] & [8.2.2] of this section, as applicable, are also to be demonstrated; this may be conducted at dock side.

8.4. Alternative way to demonstrate the requirements of steering gear trials.

(SOLAS II-1/29 effective 1 January 2016)

Where it is impracticable to demonstrate the requirement for steering gear with the ship at its deepest seagoing draught, ships may demonstrate compliance with the requirement by one of the following methods:

8.4.1 The ship is at even keel and the rudder fully submerged whilst running ahead at the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch; or

8.4.2 Where full rudder immersion during sea trials cannot be achieved, an appropriate ahead speed shall be calculated using the submerged rudder blade area in the proposed sea trial loading condition. The calculated ahead speed shall result in a force and torque applied to the main steering gear which is at least as great as if it was being tested with the ship at its deepest seagoing draught and running ahead at the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch; or

8.4.3 The rudder force and torque at the sea trial loading condition have been reliably predicted and extrapolated to the full load condition. The speed of the ship shall correspond to the number of maximum continuous revolutions of the main engine and maximum design pitch and propeller.

SECTION 9 CERTIFICATION

Contents

9.1. General..... 268

9.2. Material Testing..... 268

9.3. Prototype Tests of Power Units..... 268

9.4. Components Shop Tests..... 268

9.1. General

A Surveyor should inspect, test and certify steering gear components at the plant of manufacture in accordance with the following requirements. Hydraulic oil pumps are required to be certified, Refer Chapter-8, Sec-1/[1.4.2.1(i)].

9.2. Material Testing

Refer Sec-2/[2.2] of this chapter, for testing of steering gear component materials.

9.3. Prototype Tests of Power Units

Shop testing of the prototype of each new design power unit pump should be done for not less than 100 hours. The testing should be carried out in accordance with an approved program and is to include the following as a minimum:

- a) The pump and stroke control (or directional control valve) is required to be operated continuously from full flow and relief valve pressure in one direction through idle to full flow and relief valve pressure in the opposite direction.
- b) Pump suction conditions are to simulate lowest anticipated suction head. The power unit is required to be checked for abnormal heating, excessive vibration or other irregularities. Following the test, the power unit pump should be disassembled and inspected in the presence of a Surveyor.

9.4. Components Shop Tests

Each component of the steering gear piping system, including the power units, rudder actuators and piping, should be inspected by a Surveyor during fabrication, and hydrostatically tested to 1.5 times the relief valve setting (or system design pressure) in the presence of a Surveyor.

CHAPTER 7 THRUSTERS, WATERJETS AND DYNAMIC POSITIONING SYSTEMS

CONTENTS

SECTION 1 GENERAL REQUIREMENTS	270
SECTION 2 THRUSTER MATERIALS	274
SECTION 3 DESIGN OF TRUSTERS	276
SECTION 4 CONTROLS, INSTRUMENTATION AND COMMUNICATIONS	283
SECTION 5 MISCELLANEOUS REQUIREMENTS FOR THRUSTER ROOMS	285
SECTION 6 CERTIFICATION AND TRIAL	287
SECTION 7 WATERJETS	289
SECTION 8 DYNAMIC POSITIONING SYSTEMS	298

SECTION 1 GENERAL REQUIREMENTS

Contents

1.1. Scope 271

1.2. Class Notations 271

1.3. General Definitions 271

1.4. Documents to be Submitted 272

1.1. Scope

This Chapter applies to azimuth or rotatable thruster units, for propulsion or D.P. duty which transmit a power greater than 220 kW used as the sole means of steering and are in addition to the relevant requirements. However requirements of control/ monitoring would apply for all types of Thrusters.

In general, for a vessel to be assigned an unrestricted service notation a minimum of two azimuth thruster units are to be provided where these form the sole means of propulsion. Where a single thruster installation is proposed, it will be subject to special consideration.

Maneuvering thrusters intended to help in maneuvering and dynamic positioning thrusters, where fitted, may, upon owner's request, be certified as per the provisions of this section. In such cases, appropriate class notations, as indicated in [1.2] of this section, will be assigned upon verification of conformation to relevant provisions of this section.

Thrusters intended for being used in propulsion with or without combined duties for helping in maneuvering or dynamic positioning are to conform to apt provisions of this chapter along with other relevant provisions of Part 5A.

Types of thruster not mentioned in this chapter, like cycloidal propellers, pump or water-jet type thrusters, will be considered only on the basis of manufacturer's submittal of design and engineering analyses.

Thrusters are to be constructed with sufficient strength, capacity and the necessary supporting systems to provide reliable propulsion and steering to the vessel in all operating conditions. Special consideration will be given to the suitability of any essential component which is not duplicated.

1.2. Class Notations

1.2.1 APS Notation

Self-propelled vessels, where fitted with thrusters capable of producing thrusts primarily in athwartship direction and intended to help in maneuvering the vessel, at owner's discretion, may conform to the provisions of section 1 through section 8 of this chapter. After compliance is verified, the class notation **APS** (athwartship thruster) may be assigned.

1.2.2 PAS Notation

Non-self-propelled vessels, where fitted with thrusters to help in the maneuvering or propelling while under tow, upon owner's discretion, may conform to the provisions of section 1 through section 8 of this chapter; and after compliance is verified, the class notation **PAS** (propulsion assist) may be assigned.

1.2.3 DP -0, -1, -2 & -3 Notations

Non-self-propelled vessels or self-propelled ones, where fitted with a system of positioning instruments, thrusters and control systems to enable them to maintain position at sea without external aid, upon owner's discretion, may conform to section 1 through section 7 of this chapter. Upon owner's request and after verification of compliance with the applicable requirements, the class notation **DP** (dynamic positioning system) followed by a numeral of 0, 1, 2 or 3, to indicate the degree of redundancy of the system, will be assigned.

1.3. General Definitions

1.3.1 Thruster

a) General

Thrusters are the devices which are capable of delivering side thrust or thrusts through 360° to improve vessel's maneuverability, specifically in confined waters. Three generic types of such thrust-producing devices are: the lateral or tunnel thruster, commonly known as 'bow thruster', which comprises of a propeller installed in a athwartship tunnel;

jet type thruster, which comprises of a pump taking suction from the keel and discharge to either side; and azimuthal thruster, which can be rotated through 360° so that thrust can be developed in any direction. Cycloidal propellers can be considered as a type of azimuthal thruster.

b) Propeller-type thruster

Irrespective of the fact that whether they normally are used for propulsion, propellers which are to be operated for an extended time period during service in a condition where the vessel is not free running approximately along the direction of the thrust, are to be considered thrusters for this section.

1.3.2 Continuous Duty Thruster

A continuous duty thruster is a type of thruster designed for continuous operation, such as propulsion assist, dynamic positioning thrusters or main propulsion units.

1.3.3 Intermittent Duty Thruster

a).An intermittent duty thruster is a type of thruster designed for operation at peak power or rpm levels, or both, for maximum periods of one (1) hour followed by periods at the continuous rating or less, with total running time not going beyond eight (8) hours in twenty (20) hours. Commonly, such thrusters are not intended to operate for more than 1000 hours per year.

(b) Declared Operational Limits

Declared steering angle limits and maximum rotational speed are operational limits in terms of maximum steering angle, and rotational speed, or equivalent, according declared guidelines for safe operation, also taking into account the vessel's speed or propeller torque/speed or other limitation. The "declared steering angle limits" and "maximum rotational speed" are to be established by the vessel's designer and shipbuilder based on the vessel specific non-traditional steering means. Vessels' maneuverability tests, such as IMO Standards for Ship Maneuverability, Resolution MSC.137(76) are to be carried out not exceeding the declared operational limits.

1.3.4 Steering Gear Power Unit

For purposes of alternative propulsion and steering arrangements, the steering gear power units are to be considered as defined in Part 5A-6-1/[1.3.2] For electric steering gears, the electric steering motor is to be considered as part of power unit and actuator.

1.4. Documents to be Submitted

The following plans and information are to be submitted.

1.4.1. Fixed/azimuth propulsion thrusters

- a) A general arrangement sectional assembly plan showing all the connections of the torque transmitting components from the prime mover to the propeller, together with the azimuthing mechanism and if a nozzle is provided, the nozzle ring structure and nozzle support struts.
- b) Detailed and dimensional plans of the individual torque transmitting components.
- c) Schematic plans for lubricating and hydraulic systems, together with pipe material, relief valves and working pressures.

1.4.2. Tunnel thrusters

In addition to applicable requirements of Sect [1.4.1] above, structural assembly plan including connections to tunnel.

1.4.3. Calculations and specifications

- a) Thruster prime mover type and operational power/speed envelop.
- b) Rating and type of motor for the azimuthing mechanism (e.g. type hydraulic or electric).
- c) Gearing calculations for the azimuthing and propulsion mechanism which is to be designed in accordance with classification notes on the design of gearing. Calculation for bevel gears is to be on the basis of a conversion to equivalent helical gear.
- d) Bearing specifications.
- e) Details of control engineering aspects in accordance with Chapter 7.
- f) Calculations indicating suitability of components for short term high power operation, where applicable.
- g) Where design is carried out using fatigue analysis, a fatigue strength analysis of components indicating a factor of safety of 1.5 at the design loads based on a suitable fatigue failure criteria is required to be submitted for review.

1.4.4. Additionally, plans of each component and of the systems associated with the thruster are to be submitted as detailed in the applicable sections of these Rules. Characteristically, following are applicable:

Supporting structures:	Part-3
Diesel engine prime mover:	Chapter 2, Sec-1, [1.1.5]
Gearing:	Chapter 3, Sec-1, [1.3]
Shafting:	Chapter 4, Sec-1, [1.3]
Propellers:	Chapter 5, Sec-1, [1.3]
Machinery piping system:	Chapter 8, Sec-1, [1.5]
Electric motor and controller:	Part-6, Ch-1, Sect 3/ [3.1.1.6]
Electrical Installation and Control Systems:	Part-6, Ch-1, Sec-3

SECTION 2 THRUSTER MATERIALS

Contents

2.1. General	275
2.2. Material Testing	275

2.1. General

All materials used in the construction of torque-transmitting components of the thruster are to be as per applicable requirements of Part 5A of the Rules. For instance, material requirements for propellers are to be as specified in Chapter 5, Sec-2 of this part; materials for gears, Chapter 3, Sec-2 of this part; materials for shafting, Chapter 4, Sec-2 of this part; materials for steering systems, Chapter 6, Sec-2, [2.1] of this part, etc. All material specifications are given in Part 2, Chapter 2.

Where alternative material specifications are proposed, details of chemical composition and mechanical properties similar to those required by these Rules are to be submitted for approval.

2.2. Material Testing**2.2.1 Testing by a Surveyor**

The testing of materials of the following components are to be done in the presence of a Surveyor for verification of their compliance with the applicable requirements of Part 2, Chapter 2, or other appropriate material specifications as may be approved with respect to a particular design.

- Gears (propulsion and steering)
- Shafts, shaft flanges, keys
- Coupling bolts
- Impellers
- Propellers
- Couplings

Bolts made to meet a recognized standard and used as coupling bolts need not be tested in Surveyor's presence. However Specification for materials for the stock, struts, etc, is to be submitted for approval.

Materials for thrusters of 375 kW (500 hp) or less, including shafting, gears, pinions, couplings and coupling bolts may be accepted on the basis of the manufacturer's certified mill test reports and a satisfactory surface inspection and hardness test witnessed by a INTLREG Surveyor.

SECTION 3 DESIGN OF THRUSTERS

Contents

3.1. Prime Movers	277
3.2. Propellers	277
3.3. Gears	280
3.4. Shafts	280
3.5. Anti-friction Bearings	280
3.6. Steering Systems	280
3.7. Access for Inspection	282

3.1. Prime Movers**3.1.1 Internal Combustion Engines**

Internal combustion engines used for driving thrusters are to conform to the design, construction, testing and certification requirements of Part 5A, Chapter 2. Engine support systems are to be as specified in Part 5A, Chapter 8 section 4; except for standby pumps and similar redundancy criteria specified for propulsion engines which are not required for thruster engines.

3.1.2 Electric Motors

Electric motors driving thrusters are to conform to the design, construction, testing and certification requirements of Part-6, Ch-3. Power for thruster motors may be derived from ship service generators; except that precautions, such as interlock arrangements, are to be fitted to prevent starting except when there are enough generators on-line to support starting and running of the thruster motor. All ship service generators may be put on line for this purpose, Refer Part-6, Ch-2, Sect 2/[2.1].

3.2. Propellers**3.2.1 General**

The thruster propellers are to conform to the requirements of Chapter 5 of this part, except as modified hereunder.

3.2.2 Propeller Blades of Conventional Design

Where the propeller blades are of conventional design with skew angle not exceeding 25°, the thickness of the propeller blade is not to be less than determined using following equations. Fillets at the root of the blades are not to be considered in the determination of the blade thickness.

(a) Fixed pitch propellers

The minimum required blade thickness at 0.25 radius, $t_{0.25}$, is to be determined using following equations:

$$t_{0.25} = \sqrt[k_1]{\frac{AH}{C_n CRN}} \pm \left(\frac{C_s}{C_n}\right) \left(\frac{BK}{4C}\right) \text{ mm (in.)}$$

$$A = 1.0 + \frac{6.0}{P_{0.70}} + 4.3 P_{0.25} \quad \text{for free running propellers}$$

$$A = 7.2 + \frac{2.0}{P_{0.70}} + 4.3 P_{0.25} \quad \text{For propellers performing bollard pull, athwartship thrusting, dynamic positioning and similar duties;}$$

$$B = \frac{4300 w a}{N} \left(\frac{R}{100}\right)^2 \left(\frac{D}{20}\right)^3$$

$$C = (1.0 + 1.5 P_{0.25})(W f - B)$$

Other symbols are defined in [3.2.2(d)] of this section.

(b) Controllable pitch propellers

The minimum required blade thickness at 0.35 radius, $t_{0.35}$, is to be determined using following equations:

$$t_{0.35} = \sqrt[k_2]{\frac{AH}{C_n CRN}} \pm \left(\frac{C_s}{C_n}\right) \left(\frac{BK}{6.3C}\right) \quad \text{mm (in.)}$$

$$A = 1.0 + \frac{6.0}{P_{0.70}} + 3P_{0.35}$$

for free running propellers

$$A = 7.2 + \frac{2.0}{P_{0.70}} + 3P_{0.35}$$

for non-free running propellers [Refer [3.2.2(a)] of this section];

$$B = \frac{4900wa}{N} \left(\frac{R}{100} \right)^2 \left(\frac{D}{20} \right)^3$$

$$C = (1.0 + 0.6 P_{0.35})(W f - B)$$

Other symbols are defined in [3.2.2(d)] of this section.

(c) Nozzle propellers (wide-tip blades)

The minimum required blade thickness at 0.35 radius, $t_{0.35}$, is to be determined using following equations:

$$t_{0.35} = \sqrt[3]{\frac{AH}{C_n CRN}} \pm \left(\frac{C_s}{C_n} \right) \left(\frac{BK}{5.6C} \right) \quad \text{mm (in.)}$$

$$A = 1.0 + \frac{6.0}{P_{0.70}} + 2.8P_{0.35}$$

for free running propellers

$$A = 7.2 + \frac{2.0}{P_{0.70}} + 2.8P_{0.35}$$

for non-free running propellers [Refer [3.2.2(a)] of this section];

$$B = \frac{4625wa}{N} \left(\frac{R}{100} \right)^2 \left(\frac{D}{20} \right)^3$$

$$C = (1.0 + 0.6 P_{0.35})(W f - B)$$

Other symbols are defined in [3.2.2(d)] of this section.

(d) Symbols

The symbols used in the above formulas are defined, in alphabetical order, as follows (the units of measure are in SI (MKS and US) systems, respectively):

a = expanded blade area divided by the disc area

a_s = area of expanded cylindrical section at 0.25 or 0.35 radius, as applicable; mm^2 (in^2)

C_n = section modulus coefficient at 0.25 or 0.35 radius, as applicable; to be determined by the following equation:

$$C_n = \frac{I_0}{U_f W T^2}$$

If the value of C_n exceeds 0.1, the required thickness is to be computed with $C_n = 0.1$.

C_s = section area coefficient at 0.25 or 0.35 radius, as applicable, to be determined using following equation:

$$C_s = \frac{a_s}{WT}$$

The values of C_s and C_n computed as stipulated above are to be indicated on the propeller drawing.

D = propeller diameter; m (ft)

f, w = material constants, Refer table below:

Material type	SI & MKS units		US units	
	f	w	f	w
2	2.1	8.3	68	0.3
3	2.13	8	69	0.29
4	2.62	7.5	85	0.27
5	2.37	7.5	77	0.27
CF-3	2.1	7.75	68	0.28

H = power at rated speed; kW (PS, hp)

I_0 = moment of inertia of the expanded cylindrical section at 0.25 or 0.35 radius about a straight line through the center of gravity parallel to the pitch line or to the nose-tail line; mm⁴ (in⁴)

K = rake of propeller blade, in mm (in.) (positive for aft rake and negative for forward rake)

K₁, K₂, and K₃ are constants and are to be of values as specified below:

	SI unit	MKS unit	US unit
K ₁	337	289	13
K ₂	271	232	10.4
K ₃	288	247	11.1

N = number of blades

P_{0.25} = pitch at 0.25 radius divided by propeller diameter

P_{0.35} = pitch at 0.35 radius divided by propeller diameter, corresponding to the design ahead condition

P_{0.7} = pitch at 0.7 radius divided by propeller diameter, corresponding to the design ahead condition

R = rpm at rated speed

T = maximum design thickness at 0.25 or 0.35 radius from propeller drawing mm (in.)

t_{0.25} = required thickness of blade section at 0.25 of propeller radius; mm (in.)

t_{0.35} = required thickness of blade section at 0.35 of propeller radius; mm (in.)

U_f = maximum normal distance from the moment of inertia axis to points in the face boundary (tension side) of the section; mm (in.)

W = expanded width of a cylindrical section at the 0.25 or 0.35 radius

3.2.3 Blades of Unusual Design

Propellers of unusual design for thruster duties, like:

- Propellers with the skew angle $\theta > 25^\circ$
- Propellers with wide-tip blades and skew angle $\theta > 25^\circ$
- Controllable pitch propellers with skew angle $\theta > 25^\circ$
- Cycloidal propellers, etc.

are subject to special consideration on the basis of submittal of propeller load and stress analyses. Refer to Part 5A, Ch-5, Sec-3, [3.4].

3.2.4 Propeller Blade Studs and Bolts

(a) Area

Studs which are used to secure propeller blades are required to have a cross-sectional area at the minor diameter of the thread of not less than that determined by the equations in Part 5A, Ch-5, Sec-3/ [3.7.2].

(b) Fit of studs and nuts

Studs are required to be fitted tightly into the hub and shall be provided with an effective means for locking. The nuts are also to have a tight-fitting thread and be secured by stop screws or other effective locking devices.

3.2.5 Blade Flange and Mechanism

The strength of the propeller blade flange and internal mechanisms of controllable-pitch propellers subjected to the forces from propulsion torque is required to be determined as follows:

- For intermittent duty thrusters, be at least equal to that of the blade design pitch condition.
- For continuous duty thrusters, be at least 1.5 times that of the blade at design pitch condition.

3.3. Gears

3.3.1 Continuous Duty Gears

Gears for continuous duty thrusters shall meet the provisions of chapter 3 of this part.

3.3.2 Intermittent Duty Gears

As described in Sect [1.3.3] of this chapter, gears for intermittent duty thrusters are required to be as per a recognized standard and are to be submitted for consideration.

3.4. Shafts

3.4.1 Gear Shafts

Gear and pinion shaft diameters are to be determined by the equations given in chapter 3 section [3.7] of this part.

3.4.2 Propeller and Line Shafts

Shafting is to be done as per the provisions of chapter 4 section [3.1] of this part through chapter 4 section [3.9] of this part, and cardan shafts, chapter 4 section [3.5] of this part.

3.4.3 Couplings and Clutches

Shaft couplings, clutches, etc. are to be done as per the provisions of chapter 4 section [3.10] of this part.

3.5. Anti-friction Bearings

Full bearing identification and life calculations are required to be submitted. Calculations shall cover all the gear forces, thrust vibratory loads at maximum continuous rating, etc. The minimum L10 life is not to be less than:

- i) Continuous duty thrusters (propulsion and DP -0, 1, 2, and 3: 20,000 hours
- ii) Intermittent duty thrusters: 5,000 hours

Shorter life may be considered along with an approved bearing inspection/replacement program that reflects calculated life.

3.6. Steering Systems

The applicable requirements of chapter 6 of this part and the following requirements are to be met by the steering systems for azimuthal thrusters.

3.6.1 Vessels with Only One Azimuthal Thruster

Vessels equipped with one azimuthal thruster for propulsion and steering, thruster is to have steering systems of redundant design such that a single failure in one system does not affect the other.

3.6.2 Cargo Vessels with Two Azimuthal Thrusters

In cargo vessels equipped with two azimuthal thrusters for propulsion and steering, each thruster is to have at least one steering system. The steering system for each thruster is to be independent of the steering system for the other.

3.6.3 Passenger Vessels with Two Azimuthal Thrusters

For passenger vessels equipped with two azimuthal thrusters for propulsion and steering, each thruster is to have steering systems of a redundant design such that a single failure in one system does not affect any other.

3.6.4 Performance

Each azimuthal thruster shall be capable of rotating at a speed of not less than 0.4 rpm (from 35° on either side to 30° on the other side in not more than 28 s) while steering the vessel running ahead at the maximum continuous rated shaft rpm and at the summer load waterline. Where the azimuthal thruster is arranged to rotate for the crash stop or astern maneuver, it is to be capable of rotating at the speed of not less than 2.0 rpm (180° in not more than 15 s) to account for the crash stop or astern maneuver.

3.6.5 Arrangements

The main steering gear arrangements for vessel's directional control is to:

- i) Of adequate strength and capable of steering the vessel at maximum ahead service speed.
- ii) Capable of changing direction of the vessel's directional control system from one side to the other at declared steering gear angle limits at an average rotational speed of not less than 2.3°/s with vessel running ahead at maximum ahead service speed.
- iii) Operated by power
- iv) Reverse direction of thrust in sufficient time, and so to bring the vessel to rest within a reasonable distance from maximum ahead service speed, shall be demonstrated and recorded

3.6.6 Auxiliary Steering Gear Arrangements

3.6.6(a) The auxiliary steering arrangements for vessel's directional control is to be:

- i) Of adequate strength and capable of steering the vessel at navigable speed and of being brought quickly into action in an emergency;
- ii) Capable of changing direction of the vessel's directional control system from one side to the other at declared steering angle limits at an average rotational speed, of not less than 0.5°/s; with the vessel running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater; and;
- iii) For all vessels, operated by power where necessary to meet the requirements of [3.6.6](a) and in any vessel having power of more than 2,500 kW propulsion power per thruster unit.

3.6.6(b) In a vessel fitted with multiple steering systems, such as but not limited to azimuthing thrusters or water jet propulsion systems, an auxiliary steering gear need not be fitted, provided that:

- i) For a passenger vessel, each of the steering systems, capable of satisfying the requirements in [3.6.6](a)ii) while any one of the power units is out of operation;
- ii) For a cargo vessel, each of the steering systems, capable of satisfying the requirements in Sect [3.6.6](a)ii) while operating with all power units;

iii) The steering systems is arranged so that after a single failure in its piping or in one of the power units, vessel's steering capability (but not individual steering system operation) can be maintained or speedily regained (e.g., by the possibility of positioning the failed steering system in a neutral position in an emergency, if needed).

3.6.6(c) Independent Source of Power.

Where the propulsion power exceeds 2,500 kW per thruster unit, an alternative power supply, sufficient at least to supply the steering arrangements which complies with the requirements of Sect [3.6.6](a)ii) and also its associated control system and the steering system response indicator, is to be provided automatically, within 45 seconds, 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 is to be used only for this purpose. In every vessel of 10,000 gross tonnage and upwards, the alternative power supply is to have a capacity for at least 30 minutes of continuous operation and in any other vessel for at least 10 minutes.

3.7. Access for Inspection

Adequate access covers are to be provided to permit inspection of gear train in absence of disassembling thruster units.

SECTION 4 CONTROLS, INSTRUMENTATION AND
COMMUNICATIONS

Contents

4.1. Control System	284
4.2. Instrumentation	284
4.3. Communications	284

4.1. Control System

Effective means of controlling the thruster from the navigation bridge is required to be provided. Control power is to be provided from thruster motor controller or directly from the main switchboard. Using local means of control, propulsion thrusters are also to be fitted.

For specific requirements related to class notation DP -0, 1, 2 or 3, Refer [8.5] of this chapter.

4.2. Instrumentation

Alarms and monitoring requirements are indicated here below.

An indication of the angular position of the azimuth thruster(s) and the propeller pitch position for azimuth and/or tunnel thruster(s) are to be provided at each location from which it is possible to control the direction of thrust or the pitch.

All alarms associated with thruster unit faults are to be indicated individually on the navigating bridge and in accordance with the alarm system specified.

Instrumentation and alarms are to be provided as specified in Table 7.4.1, as applicable.

Table 7.4.1: Instrumentation for Thrusters

Monitored Parameter	Navigation Bridge	Main Control Station (Refer note 1, 2)
Engine low lubricating oil pressure alarm	X (Refer note 1)	X
Engine coolant high temperature alarm	X (Refer note 1)	X
Motor overload alarm	X (Refer note 1)	X
Thruster RPM	X	X
Thrust direction (azimuthing type)	X	X
Thruster power supply failure alarm	X	X
Controllable pitch propellers hydraulic oil low pressure alarm	X (Refer note 1)	X
Controllable pitch propellers hydraulic oil high pressure alarm	X (Refer note 1)	X
Controllable pitch propellers hydraulic oil high temperature alarm	X (Refer note 1)	X
Fire detection	X	X
Notes 1. Either an individual indication or a common trouble alarm may be fitted at this location, provided individual indication is installed at the equipment (or main control station) 2. For vessels not fitted with a main control station, the indication is to be installed at the equipment or other suitable location		

4.3. Communications

Some means for voice communication is required to be provided between the navigation bridge, main propulsion control station and the thruster room.

For specific requirements related to class notation DP -0, 1, 2 or 3, Refer [8.6] of this chapter.

SECTION 5 MISCELLANEOUS REQUIREMENTS FOR THRUSTER
ROOMS

Contents

5.1. Ventilation.....	286
5.2. Bilge System for Thruster Compartments	286
5.3. Fire Fighting Systems.....	286

5.1. Ventilation

Suitable ventilation of thruster rooms is required to simultaneously allow the crew attendance and for thruster machinery to operate at rated power in all weather conditions.

5.2. Bilge System for Thruster Compartments

Thrusters installed in unattended spaces are, normally, to be arranged such that bilge pumping can be effected from outside the space while where bilge pumping can be effected only from within the space, a bilge alarm to warn of high bilge water level is to be fitted in a centralized control station, the navigation bridge or other normally manned control station. For bilge systems, refer to Chapter 9 section 3 of this part.

Thrusters in enclosed modules (capsules) are to have a high water level alarm. Minimum one pump is able to bilge the module is to be operable from outside the module.

5.3. Fire Fighting Systems

In general, spaces where thrusters are located, including enclosed modules, are to be protected with firefighting system as specified in latest IMO Requirements

SECTION 6 CERTIFICATION AND TRIAL

Contents

6.1. Certification 288

6.2. Trials..... 288

6.1. Certification

In accordance with the following requirements, thrusters and associated equipment are to be inspected, tested and certified by INTLREG, as applicable:

Diesel engines:	Chapter 2, Sec-1
Gas turbines:	Chapter 2, Sec-3
Electric motors:	Part-6, Chapter-4
Gears:	Chapter 3, Sec-1
Shafting:	Chapter 4, Sec-1
Propellers:	Chapter 5, Sec-1

6.2. Sea Trials

The performance tests are required to be carried out in the presence of a Surveyor in a sea trial, upon completion of the installation. This is to include but not limited to running tests at intermittent or continuous rating, variation through design range of the magnitude and/or direction of thrust, vessel turning tests and vessel maneuvering tests not to exceed the declared limits

In general, for Azimuth & Tunnel Thrusters the following are to be tried out:-

6.2.1 Azimuth Thruster:

The performance specified for the craft is to be demonstrated.

The actual values of steering torque are to be verified during sea trials to confirm that the design maximum dynamic duty torque has not been exceeded.

6.2.2 Tunnel thrusters

It is to be demonstrated that the thruster unit meets the specified performance.

6.2.3 Sea Trial Results

The stopping times, vessel headings and distances recorded on trials, together with the results of trials to determine the ability of vessel's having multiple propulsion/steering arrangements to navigate and maneuver with one or more of these devices inoperative, are to be available on board for the use of the Master or designated personnel.

6.2.4 Notification of Declared Operational Limits

At each position where the directional control system can be operated, the declared operational limits are to be permanently indicated by a placard.

SECTION 7 WATERJETS

Contents

7.1. General.....	290
7.2. Design	291
7.3. Material and testing specifications	292
7.4. Design of components.....	293
7.5. Inspection and Testing	294
7.6. Control, Alarm, Safety Functions and Indications	295
7.7. General Arrangement.....	297
7.8. Vibration	297
7.9. Installation Survey	297
7.10 Shipboard Testing	297

7.1. General

7.1.1. Application

Application of the rules to axial water jets are intended for main propulsion and steering for all types of vessel. Certificate shall be delivered along with the water jet unit.

Water jet units with main steering function are also regarded as steering gear for the vessel.

After classification, water jet units for auxiliary steering purposes (i.e. not for propulsion) are only subject to classification.

7.1.2. Documentation Requirements

According to Table 7.7.1, plans, particulars and calculations shall be submitted.

7.1.3. General Definitions

As defined below the rules use the nomenclature:

a) Ducting

Streaming along the vessel bottom, water flows into a duct, leading the water to the water jet. The duct forms an integral part of the vessel hull. Normally, it is manufactured at the yard.

b) 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.

c) Stator Housing

Reduction of the swirl added to the water by the impeller is done, and the longitudinal speed of the water flow is increased by leading the water flow through a row of stationary vanes downstream of the impeller. The vanes are usually formed as an integral part of the water jet housing.

d) Impeller Housing

Impeller Housing is the water jet casing which surrounds the impeller.

e) Steering nozzle

The direction of the water jet flow changes as the water flow is lead through a passage way that can be tilted horizontally in relation to the vessel's longitudinal axis. This creates a turning moment used for steering the vessel.

f) 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.

g) Hydraulic actuators

Hydraulic actuators are used for either steering or reversing as the driving force that impose the reversing bucket or acts on the steering nozzle in order to create a change in the water flow direction.

Table 7.7.1: Documentation Requirements

Waterjet arrangement	I
Cross section drawing of unit	I
Structural drawings(housing,mountingflangesetc.)and connections to the water inlet including NDT specification	I
Impeller including NDT specification	I
Shafting parts to be documented according to Part 5A, Ch.4	A
Stator housing(with guide vanes)	I
Steering arrangement	A
Reversing arrangement	A
Hydraulic actuators for steering and reversing.	A
Bearing arrangement with particulars	A
Seal box*	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 and monitoring system including set points and time delays,	A
Waterjet pump characteristic,with operation limits including cavitation limits,refer limit as forTable7.7.3	I
Impeller thrust,vessel thrust and maximum reversing forces at crash stop	I
Normal operating parameters that define the permissible operating conditions,such as thrust,impellerr.p.m., vessel speed,impeller r.p.m.versus vessel speed,Refer limit as forTable7.7.3	I
Calculated lifetime of roller bearings	A
Impeller blade strength calculations	R(I)
Strength calculation of the stern flange connection	R(A)
Strength calculation of the steering and reversing mechanism	R(A)
Housing strength calculation	R(I)
* Type approval is required for oil lubricated standard design.	
A = For approval I = For information R(A)= Upon request; for approval R(I) = Upon request; for information	

7.2. Design

7.2.1. It is important to design all machinery so that expected deviations of influence parameters do not result in unacceptable reduction of the reliability or safety. Influence parameters can be for example:

- power and speed
- number of passing through a barred speed range
- machining notches in inaccessible areas
- diesel engine misfiring
- variation of elastic coupling characteristics
- variation of damper characteristics
- normal tear and wear
- deviation between actual material properties of the component and the minimum specified properties

- 7.2.2. Due to accumulated fatigue, the scantling criteria may have to be based on the overload for plants where overload is frequently used (intermittent load).
- 7.2.3. Whenever failures occur to products certified by the Society and addressed in these rules, including parts for which documents are submitted for information, the manufacturer (and designer, if producing under license) is committed to involve the Society in corrective actions. The corrective actions include changes to design and or quality control. Withdrawal of the type approval as well as restrictions of future approvals and or certification may occur if failure occurs while involving the Society, or to carry out proper corrective actions.
- 7.2.4. Equivalent or better rules may be used in order to replace when the rules refer to or contain certain calculation methods. The objective is to document equivalent reliability. Rule methods normally aim at certain minimum safety factors. It might be necessary to reconsider the required safety factors when such methods are replaced by more refined methods.
- 7.2.5. When the rules require calculations and or analyses, this is to contain objectives, premises, assumptions and the conclusions.
- 7.2.6. By means of approved tests or service experience, the reliability and safety of components and complete units may also be documented. The later will only be considered if a relevant load history can be documented. The society will decide the acceptance of load history from case-to-case. Relevant load history means a suitable operation period (e.g. more than 2 500 hours for propulsion) under running conditions similar to the expected running conditions for the product to be approved.
- 7.2.7. The society will follow up and verify the basic requirements for design, manufacturing, testing and documentation during design approval or survey, while others are given mainly as general information for the designer, manufacturer or yard, and as basis for their own construction and follow-up. It is to be noted, however, that the absence of verification by the Society for such requirements during approval or survey phases will not relieve the designer, manufacturer or yard from their obligation to fulfill the said rule requirements.

7.3. Material and testing specifications

- 7.3.1. As a minimum a material specification is to contain the following:
 - a) type of material
 - b) chemical composition
 - c) production method (cast, hot rolled, separately forged, blank cut out of a forged bar of specified size, etc.)
 - d) type of heat treatment
 - e) minimum mechanical properties (which normally includes impact energy Charpy-V for quenched and tempered steels)
 - f) An NDT specification containing:
 - method of NDT
 - extent
 - acceptance criteria
- 7.3.2. The water jet unit shall be capable of withstanding the loads imposed by all permissible operating modes, including the condition when the inlet of the suction is blocked.

- 7.3.3. The stresses in water jet components shall be considered based on loads due to the worst permissible operating conditions, taking into account:
- a) Hydrodynamic loads, including varying hydrodynamic loads due to water flow disturbances introduced e.g. by the ducting or hull.
 - b) Vessel accelerations versus water jet r.p.m.

Note:

At full design speed on a straight course and with the vessel designated trim, giving the designed water head above the water intake, harmful impeller cavitation will normally not occur. In this context by introducing vibration or impeller erosion, harmful cavitation is that cavitation which will reduce shafting system and water jet component lifetime.

However, the water jet 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. Harmful impeller cavitation may occur as a consequence of abnormal water jet flow conditions in situations where operation exceeds the design premises. With increasing water jet size this phenomenon has showed to be of increasing importance.

To combat this, the water jet 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. This advice becomes important when the bigger the water jets become bigger in size.

- 7.3.4. Inspection facilities shall be provided to the water jet units for inspection of the shaft and impeller.

7.4. Design of components

- 7.4.1. The dimensions of the shafts and the shafting components, including bearings, shall comply with the requirements in Chapter-4.
- 7.4.2. Designing of the impeller housing and stator housing shall be done against fatigue considering impeller pulses and other flow pulses.
- 7.4.3. In consideration of the worst permissible operational conditions, steering and reversing mechanisms shall be designed .
- 7.4.4. The materials used in the hydraulic actuators shall be suitable for the expected environmental conditions.
- 7.4.5. As given in the Chapter-8, hydraulic actuators for steering shall comply with the requirements.
- 7.4.6. As given in the Chapter-8, the hydraulic actuators for reversing shall comply with the requirements . However, the design and test pressure for the reversing actuators shall be the same as for the steering actuators if the hydraulic system for the reversing actuators is the same as for the steering system. Acceptance of the higher nominal stresses may be done for the reversing actuator.
- 7.4.7. The critical details of the duct and connections to the hull structure shall be designed against extreme loads occurring during crash stop and fatigue considerations related to reversing, steering and impeller pulses.

7.5. Inspection and Testing

7.5.1. General

The certification principles and the principles of Manufacturing Survey Arrangements are described in Part-1. Regarding material and testing specifications, refer Part-2.

According to a recognized standard or Part-2, Ch-3, welding procedures shall be qualified.

7.5.2. Certification of parts

Water jet parts, semi-products or materials shall be tested and certified according to Table 7.7.2 and 7.5.3 below if not otherwise agreed in Manufacturing Survey Arrangements, described in Part-1, Ch-3.

According to Part-5, Ch-8, the control and monitoring systems for water jets shall be certified

7.5.3. Testing and inspection of parts

In addition to the main overall dimensions, the visual inspections by the Society shall include random dimensional check of vital areas such as flange transition radius, bolt holes etc.

Particulars concerning ducting inspections

The impeller shall be statically balanced.

7.5.4. Assembling

For fitting of the impeller to the shaft, Refer Chapter-4.

Table 7.7.2: Requirements for certification of parts

	Product certificate, only when sub-contracted	Documentation by certificates						
		Material certificate	Ultra-sonic X-ray testing	or Surface crack detection (Refer note 2)	Pressure testing	Dimensional inspection	Visual inspection	Other
Impeller	AA	W		W		W	AA	W (Refer note 1)
Stator housing		W	W (Refer note 3)	W		W	AA	
Impeller housing		W	W (Refer note 3)	W		W	AA	
Shafting	According to Chapter-6							
Hydraulic actuators for reversing and steering (Refer note 4)	AA	AA or W (Refer note 2)	U-S or surface crack detection (W) (Refer note 3)		NV or W (Refer note 3)			
Other steering and reversing components		W		(W) (Refer note 3)			W	
Bolts		TR						
Ducting when delivered integral with the water jet		W	W			W	AA	
NOTE 1) AA for steering hydraulic actuators, W for reversing hydraulic actuators. 2) Crack detection in final condition. 3) NDT of welds upon request. 4) Hydraulic actuator includes cylinder, rod, cylinder end eye and rod end eye. 5) TR Test Report								

7.6. Control, Alarm, Safety Functions and Indications**7.6.1. General**

The systems shall comply with the requirements in Part-5A

7.6.2. Monitoring and bridge control

In accordance with Table 7.7.3, the monitoring of water jets (for propulsion) shall be done regarding to: Indications, alarms and requests for slowdown.

7.6.3. Monitoring and bridge control shall also be in compliance with Part-6**7.6.4. Frequent corrections in the steering control system, when the vessel is on straight course, shall be avoided if practicable.****7.6.5. Monitoring and bridge control shall also be in compliance with Part-6.****7.6.6. Frequent corrections in the steering control system, when the vessel is on straight course, shall be avoided if practicable.**

Note: By monitoring the control signal the actual corrections should be preferably read. Alternatively, direct measurements on mechanical feedback device from the water jet can be used.

Table 7.7.3: Control and monitoring of water jets

System / Item	Gr 1 Indication alarm load reduction	Gr 2 Automatic start of stand- by pump with alarm	Gr 3 with alarm	Comment
1.0 Steering				
Loss of steering and reversing signal	A, LR			Request for slow down
2.0 Hydraulic oil				
Pressure	IR, LA, LR			Request for slow down
Level in supply tank	IL, LA			
3.0 Lubricating oil				
Temperature	IR, HA			
Pressure (if forced lubrication)	IR, LA, LR			Request for slow down
Level in oil tank (if provided)	IL, LA			
4.0 Operational limitations (Refer note 1)				
The ratio impeller r.p.m versus vessel speed	IR, HA, LR			Request for slow down
Maximum permissible vessel acceleration exceeded				Indication on bridge
Gr 1 Sensor(s) for indication, alarm, load reduction (common sensor permitted but with different set points and alarm shall be activated before any load reduction) Gr 2 Sensor for automatic start of standby pump Gr 3 Sensor for shutdown				
IL = Local indication (presentation of values), in vicinity of the monitored component IR = Remote indication (presentation of values), in engine control room or another centralized control station such as the local platform/maneuvering console A = Alarm activated for logical value LA = Alarm for low value HA = Alarm for high value AS = Automatic start of standby pump with corresponding alarm LR = Load reduction, either manual or automatic, with corresponding alarm, either slow down (r.p.m. reduction) or alternative means of load reduction (e. g. pitch reduction), whichever is relevant SH = Shut down with corresponding alarm. May be manually (request for shut down) or automatically executed if not explicitly stated above.				
NOTES				
1. Load reduction, implies that a unit is brought to a safe state under the prevailing conditions, but the reduction is limited to a degree where the function the unit serves is not lost, only degraded. 2. Shut down, implies that a unit is brought to a safe state. The safe state may be stop of a unit or decelerate. 3. The requirements above are only valid for water jets with inlet diameter in excess of 1000mm.				

7.7. General Arrangement

- 7.7.1. Complying with the manufacturer's specification, the installation and arrangement of the water jet unit with auxiliaries shall be done.
- 7.7.2. Protection shall be provided to the ship external parts of the water jet by guard rails or other suitable means.

7.8. Vibration

- 7.8.1. Refer Chapter-4, for requirements concerning whirling calculations and shaft alignment specification.
- 7.8.2. Refer Chapter-2, for requirements concerning torsional vibration calculations for diesel driven water jets.

7.9. Installation Survey

- 7.9.1. 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.
- 7.9.2. Impeller clearances shall be checked after installation and shaft alignment and shall be in accordance with the manufacturer's specification.
- 7.9.3. Normal procedures for shafting apply, Refer Chapter-4.
- 7.9.4. To be in accordance with the manufacturer specification, thrust bearing axial clearances after installation shall be verified, unless verified during assembly of the water jet.
- 7.9.5. In accordance with drawings and specifications from the water jet designer, the ducting shall be manufactured. The surfaces shall be smooth and free from sharp edges or buckling that could give rise to turbulence in the water flow and thereby adversely affect water jet operating conditions.
Note: In assuring that the ducting dimensions agree with the water jet designer's drawings great care should be taken. The ducting designer should be consulted for use of possible dimensional checking equipment, such as templates especially made for that purpose.
- 7.9.6. In accordance with the manufacturer's specification, all piping systems shall be properly flushed. This shall be documented by a work certificate.
- 7.9.7. Pressure testing of piping shall be done according to Chapter-9.

7.10. Shipboard Testing

- 7.10.1. For general requirements related to the testing of control and monitoring, Refer Part 6, Ch-8, Sec-3.
- 7.10.2. As specified in [7.10.3], [7.10.4] and [7.10.5], final acceptance of the control system is dependent upon satisfactory results of the harbour testing and the final sea trial.
- 7.10.3. Attention shall be paid to combinations of operational functions. Testing of all combinations of functions shall be carried out.
- 7.10.4. Checking of indication and alarm (if applicable) of operation outside the specified operation limits shall be done. This applies to acceleration as well as impeller r.p.m. versus vessel speed.
- 7.10.5. The water jet r.p.m. versus vessel speed shall be noted and plotted against the manufacturers operational curves when inlet diameter exceeds 1 000 mm. The surveyor shall verify the correct reading of values, and after completion of the test the results shall be submitted to the approval.

SECTION 8 DYNAMIC POSITIONING SYSTEMS

Contents

8.1. General	299
8.2. Thruster System	301
8.3. Power Generation and Distribution System	301
8.4. Environment Sensor and Position Reference System	302
8.5. Control System	303
8.6. Communications for Vessels with Dynamic Positioning.....	304
8.7. Certification and Trials.....	305

8.1. General**8.1.1 Class Notations and Degree of Redundancy**

The requirements of this Chapter apply to ships with installed dynamic positioning systems and are additional to those applicable in other Parts of these Rules.

A ship provided with a dynamic positioning system in accordance with these Rules will be eligible for an appropriate class notation which will be recorded in the Register Book.

Requirements, additional to these Rules, may be imposed by the National Administration with whom the ship is registered and/or by the administration within whose territorial jurisdiction it is intended to operate. Where national legislative requirements exist, compliance with such regulations shall also be necessary.

For the purpose of these Rules, the area of operation is the specified allowable position deviation from a set point.

Special consideration will be given where the dynamic positioning system is used primarily for purposes other than position keeping, e.g. track following. A descriptive note may be entered in the Register Book to this effect.

As described below, dynamic positioning systems may be assigned with different class notations depending on the degree of redundancy built into the system. These notations are not class requirements and are assigned only upon specific requests.

DP-0 For vessels fitted with a dynamic positioning system with centralized manual position control and automatic heading control to maintain the position and heading under the specified maximum environmental conditions.

DP-1 For vessels fitted with a dynamic positioning system capable of automatically maintaining the position and heading of the vessel under specified maximum environmental conditions having an independent centralized manual position control with automatic heading control.

DP-2 For vessels fitted with a dynamic positioning system which automatically maintains the position and heading of the vessel within a specified operating envelope under specified maximum environmental conditions during and after any single fault, excluding a loss of compartments or compartment.

DP-3 For vessels fitted with a dynamic positioning system capable of automatically maintaining the position and heading of the vessel within a specified operating envelope under specified maximum environmental conditions during and after any single fault, including complete loss of a compartment because of flood or fire.

8.1.2 General Definitions**(a) Dynamic positioning (DP) system**

It is a hydro-dynamic system to control or maintain the position and heading of the vessel by centralized manual control or with help of an automatic response to the variations in the environmental conditions within the specified limits.

(b) Specified maximum environmental conditions

The specified maximum environmental conditions are the current, specified wind speed and wave height under which the vessel is to do its intended operations.

(c) Specified operating envelope

It is the area in which vessel shall stay to satisfactorily perform the intended operations under the specified maximum environmental conditions.

(d) Single fault

The single fault refers to inability of a component or a subsystem in any part of the DP system to perform its duties. For vessels with DP-3 notation, loss of any single compartment is also considered a single fault.

8.1.3 Plans and Data to be Submitted

Where one of the class notations mentioned in [8.1.1] of this section is requested, following plans and data are to be submitted for review, as applicable.

- Location of thrusters and control system components
- System description with a block diagram illustrating the functional relationship between various components
- Details of the position reference system, environmental monitoring systems, DP alarm system and any interconnection within the main alarm system
- Electrical power generation and distribution system with its interconnections to control system
- Details of the consequence analyzer .Refer [8.5.6] of this section
- Thruster remote control system
- Automatic DP control and monitoring system
- Certification of suitability of control equipment for the marine atmosphere
- Environmental force calculations and design safe operating envelope
- Thruster design
- Thruster force calculations and predicted polar plots
- Failure modes and effects analysis (FMEA) (Refer [8.1.4] below) (DP-2 and DP-3)
- DP operations manual (Refer [8.1.5] below)
- Test schedule

8.1.4 Failure Modes and Effect Analysis

A failure modes and effect analysis (FMEA) is to be done and also sufficiently detailed to cover the systems related to the dynamic positioning of the vessel but not remain limited to the following information:

- All the systems associated with the dynamic positioning of the vessel are to be described in detail along with a functional block diagram showing their mutual interaction. Such systems would include the DP electrical or computer control systems, electrical power distribution system, power generation, fuel systems, lubricating oil systems, cooling systems, backup control systems, etc.
- All substantial failure modes
- Most predictable cause related to each failure mode
- The transient effect of each failure on vessel position
- The failure detecting method
- Analysis of all possible failure modes
- Effect of such failures upon rest of the system's ability to maintain station

Where parts of the system are identified as non-redundant and where redundancy isn't feasible, these parts are to be studied further with special consideration of their reliability and mechanical protection. The study results are to be submitted for review.

8.1.5 DP Operations Manual

A dynamic positioning operations manual is to be prepared for each vessel, and i.e. to be submitted solely for verification of that information in the manual, relative to the dynamic positioning system, is to be consistent with the design and information considered in the review of the system. One copy of the operations manual is required to be kept onboard.

This manual provides guidance to the DP operator about the specific dynamic positioning installations and arrangements of a particular vessel. The DP operations manual cover the following information but are not restricted to it.

- A description of all the systems including backup systems and communication systems which are associated with the dynamic positioning of the vessel.
- Block diagram showing the functional relationship between components, as described in [8.1.3] of this section
- Definition of terms, symbols as well as abbreviations
- Description of the different operational modes and transition between them.
- A functional description of each system, including backup and communication systems
- Operating instructions for normal operational mode (and operational modes after a failure) of the DP electrical or computer control systems, manual position control system, manual thruster control system, DP equipment (thrusters, electric motors, electric drives or converters, electric generators, etc.)
- Operating instructions for systems and equipment's, indicated above, during failure conditions
- References to where more detailed information can be found onboard the vessel, such as the detailed specific operation instructions furnished by the manufacturer of the DP electrical or computer control systems, manufacturer's troubleshooting procedures in case of vendor-supplied equipment, etc.

8.2. Thruster System

8.2.1 General

The thrusters, in general, are to conform to requirements of section 2 through section 7 of this chapter, as applicable.

8.2.2 Thruster Capacity

(a) Vessels with **DP-0 or DP-1** notation

These vessels shall have thrusters in number and of capacity adequate to maintain position and heading under the specified maximum environmental conditions.

(b) Vessels with **DP-2 or DP-3** notation.

These vessels shall have thrusters in number and of capacity adequate to maintain position and heading, in case of any single fault, under the specified maximum environmental conditions. This includes the failure of any one thruster.

8.2.3 Thruster Configuration

The effects due to the interference with other thrusters, hull or other surfaces are to be considered while determining location of thrusters.

8.3. Power Generation and Distribution System

8.3.1 General

Apart from applicable requirements in Part-5A, following are the additional requirements.

8.3.2 Power Generation System

(a) Vessels with **DP-2** notation.

Generators and their distribution systems are to be sized and arranged such that, in the event of any section of bus bar being lost for any reason, adequate power is still available to supply the vital ship service loads, critical operational loads and to maintain the vessel position within the specified operating envelope under the specified maximum environmental conditions. Vital services for generators and their prime movers, like cooling water and fuel oil systems, are to be arranged such that, with any single fault, adequate power is still available to supply the vital loads and maintain position within the specified operating envelope under the specified maximum environmental conditions.

(b) Vessels with **DP-3** notation

Generators and their distribution systems are to be sized and arranged in at least two compartments so that, if any compartment is lost due to fire or flood, adequate power is available for maintenance of position within the specified operating envelope, and starting any non-running load without the associated voltage dip that cause running motor to stall or control equipment to drop out.

Vital services for generators and their prime movers, like cooling water and fuel oil systems, are to be arranged so that, with any single fault in the systems or the loss of any single compartment, adequate power is still available for supplying the essential loads, the critical operational loads and also maintain position within the specified operating envelope under the specified maximum environmental conditions.

8.3.3 Power Management System

In case of **DP-2 and DP-3** notations, power management systems are to be rendered to ascertain that adequate power is available for vital operations, and prevent loads from starting while the generator capacity is inadequate. At least two power management systems are to be provided, to cater to the possible failure of either of the power management system. Techniques such as shedding of non-essential loads or interfacing with control system are considered to provide temporary thrust reduction to ascertain availability of power.

Each power management system is to be supplied with power from an uninterruptible power system (UPS) and there shall be such arranged that a loss of power to one such system will not result in the loss of power to the other.

In case of **DP-3** notation, power management systems are to be so located and arranged such that no single fault, including fire or flood in one compartment, will render all the power management systems inoperable.

8.3.4 Uninterruptible Power Systems (UPS)

In case of **DP-1, DP-2 and DP-3** notations, an independent uninterruptible power system is to be there for each independent control system and its associated monitoring and reference system. Each such system shall be able to supply power for minimum 30 minutes after main power supply fails.

In case of **DP-3** notation, back-up control system required by Sect [8.5.3(c)] and its associated reference system is to have a dedicated independent UPS. The uninterruptible power systems are to be so located and arranged that no single fault, like fire or flood in one compartment, interrupts the power supply to back up control system i.e. required by Sect [8.5.3(c)] and its associated reference system.

8.4. Environment Sensor and Position Reference System

8.4.1 Vessels with **DP-0 or DP-1** Notation

For **DP-0** notation, a position reference system, a wind sensor and a gyro-compass are required to be fitted. For **DPS-1** notation, they are to be provided in duplicate.

8.4.2 Vessels with **DP-2** Notation

In addition to the systems in Sect[8.4.1] for **DP-1** notation, a third independent position reference system, a third wind sensor and a third gyro-compass are to be provided. Two of the position reference systems may operate on the same principle. A single failure shall not to affect more than one position reference system (i.e., no common mode failures) simultaneously.

8.4.3 Vessels with **DP-3** Notation

In addition to the requirements in Sect [8.4.2] above for **DP-2** notation, the third wind sensor, third gyro-compass and the third independent position reference system are to be directly connected to the back-up control station with their signals repeated to main control station.

8.4.4 Signal Processing

Where three position reference systems are required, control computers are to use signal processing techniques to authenticate the received data. When data is out of range, an alarm is to ring.

8.5. Control System

8.5.1 Control and Monitoring System Components

Generally, control and monitoring (alarms and instrumentation) system components for dynamic positioning systems of vessels which are intended to be assigned with **DP** notations are to conform to the provisions of Part 6, Ch-8, Sec-3.

8.5.2 Control Stations

(a) Control station arrangement

The mains of dynamic positioning control station are to be so arranged that operator is aware of the external environmental conditions and activities relevant to **DP** operation.

(b) Emergency shutdown

An emergency shutdown facility for each thruster is stationed at the main dynamic positioning control station. The emergency shutdown facility is to be independent of the automatic control systems ([8.5.3] of this section), manual position control system ([8.5.4] of this section) and manual thruster control system ([8.5.5] of this section) and is so arranged that it shuts down each thruster individually.

(c) Vessels with **DP-3** notation

For **DP-3** notation, an emergency back-up control station is to be stationed in a separate compartment that is located and so arranged that no single fault, in event of a fire or flood in one compartment, will make both the main and back-up control system inoperative.

8.5.3 Position Keeping Control System Redundancy

(a) Vessels with **DP-1** notation

An automatic control system and a manual position control system with automatic heading control are to be fitted. Controls may be transferred between the two systems manually.

(b) Vessels with **DP-2** notation

Two automatic control systems and a manual position control system with automatic heading control are to be fitted. Both are to be independent, self-monitoring and arranged in such a way that, in case one fails, control is automatically shifted to the other. The cabling for the control systems and thrusters is to be arranged in such a manner that under single fault conditions, it will still be possible to adequately control enough thrusters to stay in the specified operating envelope.

(c) Vessels with **DP-3** notation

Three automatic control systems and a manual position control system with automatic heading control are to be fitted. The two of them are to be so located at the dynamic positioning control station that they are independent, self-monitoring and arranged in such a way that, in case one fails, control is automatically shifted to the other. The third automatic control system is to be present in the emergency back-up control station and transfer of control to it is to be manually initiated. The cabling for the control systems and thrusters is to be arranged in a manner that under single fault conditions, including loss of a compartment in event of fire or flood; it will be possible to control enough thrusters to enable staying within specified operating envelope.

8.5.4 Manual Position Control System

The manual position control system described above in Sect [8.5.3] is to be independent of automatic control systems so that it operates even when that system fails. This system serves as one joystick for manual control of the vessel position and is to be supplemented with arrangements for automatic heading control.

8.5.5 Manual Thruster Control System

In addition to Sect [8.5.3] and [8.5.4], a manual thruster control system is required as per [4.1] of this chapter. The manual thruster control system is to be independent of the automatic control systems so that it will be operational even upon its failure. The system is to serve as an effective mean of individually controlling each thruster from the navigation bridge. The system provides an individual joystick for each thruster.

Any failure in the manual position control system shall not affect the working of manual thruster control system that individually controls each thruster.

8.5.6 Consequence Analysis and DP Alert System – Vessels with **DP-2 or DP-3 Only**

For vessels with **DP-2 or DP-3** notation, the **DP** control system is to incorporate a consequence analyzer that monitors vectorial thrust that is vital to maintain position under prevailing environmental conditions and do the calculations to verify that during a single failure, there will be adequate thrust to maintain position in steady state and during transient.

8.5.7 Alarms and Instrumentation

As mentioned in Table 7.8.1, the alarms, displays and indicators are required to be present at each control station, or as applicable.

8.6. Communications for Vessels with Dynamic Positioning

Some voice communication means are to be provided in between each **DP** control position and Navigation Bridge, engine control position, and other relevant operation control centers allied with **DP** and any location i.e. required by section 5 of this chapter.

Table 7.8.1: Instrumentation at DP Control Station

System	Monitored Parameters	Alarm	Display
Thruster Power System	Engine lubricating oil pressure – low	x	
	Engine coolant temperature – high	x	
	CPP hydraulic oil pressure – low and high	x	
	CPP hydraulic oil temperature – high	x	
	CPP pitch		x
	Thruster RPM		x
	Thrust direction		x
	Thruster motor/semiconductor converter coolant leakage	x	
	Thruster motor semiconductor converter temperature		x
	Thruster motor short circuit		x
	Thruster motor exciter power available		x
	Thruster motor supply power available		x
	Thruster motor overload	x	
	Thruster motor high temperature	x	
Power Distribution System	Status of automatically controlled circuit breakers		x
	Bus bar current and power levels		x
	High power consumers – current levels		x
System Performance	Excursion outside operating envelope	x	
	Control system fault	x	
	Position sensor fault	x	
	Vessels target and present position and heading		x
	Wind speed and direction		x
	Selected reference system		x
Specific Requirements for DP-2 & DP-3	Thruster location (pictorial)		x
	Percentage thrust		x
	Available thrusters on stand-by		x
	DP alert through consequence analyzer	x	
	Position information of individual position reference systems connected		x

8.7. Certification and Trials

8.7.1 Control and Monitoring System Equipment

Control & monitoring (alarms and instrumentation) system equipment's used in dynamic positioning system to be assigned with a **DP** notation are required to be certified for suitability in marine conditions.

Hydraulic and pneumatic piping systems associated with the dynamic positioning system shall be subjected to pressure tests at 1.5 times the relief-device setting using the service fluid in the hydraulic system and dry air or inert gas for pneumatic systems as testing media. The tests are to be done in the presence of a Surveyor.

8.7.2 Trials

After installation of the dynamic positioning system is done, all the performance tests are to be done to the Surveyor's satisfaction, at sea trials. The test schedule is to be designed to demonstrate the redundancy level established in FMEA (Failure Modes and Effects Analysis, Refer [8.1.4] of this section). Where feasible, the test environment shall reflect the limiting design operating conditions.

Control units are to be surveyed at the manufacturer's works and are to be tested in accordance with the approved test schedule to the Surveyor's satisfaction.

Before a new installation (or any existing installation, which has been subject to alteration or addition which may affect the performance characteristics of the system) is put into service, sea trials are to be carried out to the approved

The suitability of the dynamic positioning system is to be demonstrated during sea trials, observing the following:

- a) Response of the system to simulated failures of major items of control and mechanical equipment, including loss of electrical power, verifying the findings of the FMEA where required.
- b) Response of the system under a set of predetermined maneuvers for changing:
 - i) Location of area of operation.
 - ii) Heading of the ship.
- c) Continuous operation of the system over a period of four to six hours.

Two copies of the dynamic positioning system sea trial test schedules, each signed by the Surveyor and Builder, are to be provided on completion of the survey. One copy is to be placed and retained on board the ship and the other submitted to INTLREG.

Records and data regarding the performance capability of the dynamic positioning system are to be maintained on board the ship and are to be made available at the time of the Annual Survey.

CHAPTER 8 MACHINERY PIPING SYSTEM

CONTENTS

SECTION 1 GENERAL REQUIREMENTS	308
SECTION 2 METALLIC PIPING	319
SECTION 3 PLASTIC PIPING.....	359
SECTION 4 PIPING SYSTEMS FOR INTERNAL COMBUSTION ENGINES	378
SECTION 5 PIPING SYSTEMS FOR STEAM PLANTS	395
SECTION 6 OTHER PIPING SYSTEMS.....	412

SECTION 1 GENERAL REQUIREMENTS

Contents

1.1. General	309
1.2. General Definitions	310
1.3. Classes of Piping Systems	311
1.4. Certification	313
1.5. Documents to be submitted:	317

1.1. General**1.1.1. Application**

Applications of the provisions of this chapter are made to all the piping systems. These include piping systems covered in Section 2 through Section 6, as well as to ship piping systems in Chapter 13, "Fire Safety" in Part 5A, and to piping systems of specialized types of vessels in the applicable sections of Part 6.

1.1.2. Organization of Piping Systems Requirements

The organizations of the provisions for piping systems are shown in the Figure 8.1.1. These requirements are divided into the following flow chart:

Figure 8.1.1: Organization

PART 5A, Chapter 8: MACHINERY PIPING SYSTEM			
GENERAL		SPECIFIC SYSTEM REQUIREMENTS	
Section 1	GENERAL REQUIREMENTS	Section 4	PIPING SYSTEMS FOR INTERNAL COMBUSTION ENGINES
Section 2	METALLIC PIPING	Section 5	PIPING SYSTEMS FOR STEAM PLANTS
Section 3	PLASTIC PIPING	Section 6	OTHER PIPING SYSTEMS
		Chapter 9	SHIP PIPING SYSTEMS
		PART 7B	SPECIAL SERVICE VESSELS
		Chapter 13	FIRE SAFETY

i. General requirements, which include:

- Definitions of terms used throughout these sections, certification requirements of system components and plans to be submitted for review;
- Metallic piping design, pipe components, piping fabrication and testing and general shipboard installation details;
- Plastic piping design, plastic pipe components, plastic piping fabrication and testing.

ii. Specific systems requirements, which include:

- Bilges and gravity drains piping systems, and piping systems serving tanks (other than cargo tanks); piping systems for storage, transfer and processing of fuel oil and lubricating oil;
- Piping systems relating to the operation of steam turbine and steam generating plants;
- Piping systems relating to the operation of internal combustion engines;
- Other piping systems, such as hydraulic piping system, oxygen-acetylene piping system, etc.;
- Fire extinguishing systems, which are provided in Part 5A/Ch 13
- Cargo piping systems and other piping systems specific to specialized vessel types, which are provided in various chapters in Part 5A.

1.2. General Definitions

1.2.1. Piping

Piping is referred to as the assemblies of piping components and pipe supports.

1.2.2. Piping System

Piping System is a network of piping and any associated pumps, which are designed and assembled in order to serve a specific purpose. Piping systems interface with, but exclude, major equipment, such as boilers, pressure vessels, tanks, diesel engines, turbines, etc.

1.2.3. Piping Components

Piping Components include pipes, valves, tubes, flanges, fittings, gaskets, bolting, hoses, expansion joints, filters, strainers, sight flow glasses, accumulators, instruments connected to pipes, etc.

1.2.4. Pipes

Pipes are the pressure-tight cylinders that are used to contain and convey fluids. Where the word 'pipe' is used in this section, it means pipes conforming to materials and dimensions as specified in Part 2, Chapter 5, or equivalent national standards such as ASTM, BS, DIN, JIS, etc.

1.2.5. Pipe Schedule

Pipe Schedules are designations of pipe wall thicknesses as given in American National Standard Institute, ANSI B36.10. Standard and extra heavy (extra strong) pipes, where used in these sections, refer to Schedule 40 and Schedule 80, up to maximum wall thicknesses of 9.5 mm (0.375 in.) and 12.5 mm (0.5 in.), respectively. Refer Sec 2, Table 8.2.10, for a listing of commercial pipe sizes and wall thicknesses. Pipe schedule/ thicknesses may be defined/ designated by other national or internal standards.

1.2.6. Tubes

Tubes are generally small-diameter thin-wall pipes conforming to an appropriate national/ international standard. General requirements are to be met by the tube same as that of pipes.

1.2.7. Pipe Fittings

Pipe Fittings refer to piping components such as sleeves, bends, tees, elbows, flanges, etc., which are used to join together the sections of the pipe.

1.2.8. Valves

In order to control the flow of fluids in a piping system, valves i.e., for example gate valves, globe valves; butterfly valves etc. are used. Components like test cocks, drain cocks and other similar components which perform the same function as valves are considered valves in order to serve the purpose of these Rules.

1.2.9. Design Pressure (in bar [kgf/cm², psi])

Design Pressure is the pressure to which each piping component of a piping system is designed. It is not to be less than the pressure at the most severe condition of coincidental internal or external pressure and temperature (maximum or minimum) expected during service. However, in some instances the Rules do impose a specific minimum design pressure that exceeds the maximum expected service pressure; Refer for example Ch-9, Sec-7, [7.4] for heated fuel oil systems.

1.2.10. Maximum Allowable Working Pressure (in bar [kgf/cm², psi])

In general, the Maximum Allowable Working Pressure is the maximum pressure of a piping system determined by the weakest piping component in the system or by the relief valve setting. The maximum allowable working pressure is not to exceed the design pressure.

1.2.11. Design Temperature

Maximum temperature at which each piping component is designed to operate is defined as the design temperature. It shall not be less than the temperature of the piping component material at the most severe condition of temperature and coincidental pressure expected during service. Maximum fluid temperature may be taken in order to serve the purpose of the Rules.

For piping used in a low-temperature application, the design temperature should also include the minimum temperature at which each piping component is designed to operate. It shall not be higher than the temperature of the piping component material at the most severe condition of temperature and coincidental pressure expected during service. Minimum fluid temperature may be taken in order to serve the purpose of the Rules.

The design temperature is required to be used to determine allowable stresses and material testing requirements for all piping.

1.2.12. Flammable Fluids

Any fluid, regardless of its flash point, liable to support a flame should be treated as a flammable fluid for serving the purposes of Section 1 through Section 6. Aviation fuels, diesel fuels, heavy fuel oil, lubricating oil and hydraulic oil (unless the hydraulic oil is specifically specified as non-flammable) are all can be considered flammable fluids.

1.2.13. Toxic Fluids

Fluids that can cause death, severe injury or any kind of harm to human health, if swallowed or inhaled or by coming in contact with the skin are termed as toxic.

1.2.14. Corrosive Fluids

Corrosive fluids, excluding seawater, are those that possesses in their original state the property of being able to cause damage by coming into contact with living tissues, the vessel or its cargoes, by chemically reacting when escaped from their containment.

1.3. Classes of Piping Systems

According to service, design pressure and temperature, the piping systems are divided into three classes, as indicated in Table 8.1.1. Each class has specific requirements for joint design, fabrication and testing. The requirements in this regard are given in Section 2 for metallic piping. Refer Section 3, for plastic piping.

Table 8.1.1: Classes of Piping Systems

Piping Class →	Class I $P > P_2$ OR $T > T_2$	Class II Bounded by Class I and Class III - Refer chart above	Class III $P \leq P_1$ and $T \leq T_1$
Piping System ↓	bar, °C (kgf/cm ² , psi) (°F)	bar, °C (kgf/cm ² , psi) (°F)	bar, °C (kgf/cm ² , psi) (°F)
Corrosive fluids	Without special safeguards	With special safeguard	Not Applicable
Toxic fluids	All	Not applicable	Not Applicable
Flammable liquids heated above flash point or having flash point 60°C or less	Without special safeguards	With special safeguards	Open-Ended Piping
Liquefied gas	Without special safeguards	With special safeguards	Open-Ended Piping
Steam	16 300 (16.3, 232) (572)	Refer Chart	7 170 (7.1, 101,5) (338)
Thermal oil	16 300 (16.3, 232) (572)	Refer Chart	7 150 (7.1, 101.5) (302)
Fuel Oil Lubricating Oil Flammable Hydraulic Oil	16 150 (16.3, 232) (302)	Refer Chart	7 60 (7.1, 101.5) (140)
Cargo Oil Piping in Cargo Area	Not applicable	Not applicable	All
Other Fluids (including water, air, gases, non - flammable hydraulic oil)	40 300 (40.8, 580) (572)	Refer Chart	16 200 (16.3, 23.2) (392)
Open Ended Pipes (drains, over flow, vents, exhaust gas lines, boilers escapes pipes)	Not applicable	Not applicable	All
Fixed Oxygen-acetylene System	High pressure side	Not applicable	Low pressure side
NOTES: 1. The above requirements are not applicable to piping systems intended for liquefied gases in cargo and process areas 2. The above requirements are also not applicable to cargo piping systems of vessels carrying chemicals in bulk. 3. Safeguards are measures undertaken to reduce leakage possibility and limiting its consequences, (e.g., double wall piping or equivalent, or protective location of piping etc.)			

1.4. Certification**1.4.1. Certification of Piping Components**

In accordance with Table 8.1.2 and the following, piping components are required to be certified.

1.4.1.1. INTLREG Certification

The piping components should be certified by INTLREG wherever it is indicated as 'required' in Table 8.1.2. This involves design approval of the component, as applicable, and testing in accordance with the standard of compliance at the manufacturer's plant. Such components may also be accepted under the Type Approval Program, Refer Section [1.4.3].

1.4.1.2. Design Approval

Design approval is a part of the INTLREG certification process and the piping components are required to meet an applicable recognized standard, or should be design-approved by INTLREG, wherever it is indicated as 'required' in Table 8.1.2. For latter purposes, pipe fittings and valves are to be evaluated for their adequacy for the rated pressures and temperatures, and, as applicable, type inspection and testing are to be conducted as part of the design evaluation process. Refer also Section [1.4.3], Sec-2/ [2.3] and Sec-3/ [3.3] of this chapter.

1.4.1.3. Manufacturer's Certification

Wherever it is indicated as 'required' in Table 8.1.2, the manufacturer should certify that the piping component complies with the standard to which the component is designed, fabricated and tested, and to report the results of tests so conducted. For Class III components, manufacturer's trademark, pressure/temperature rating and material identification, as applicable, stamped or cast on the component and verifiable against the manufacturer's catalog or similar documentation will suffice

1.4.1.4. Identification

Where indicated as 'permanent' in Table 8.1.2, the piping component should bear permanent identification, such as manufacturer's name or trademark, pressure rating, material identity, standard of compliance, etc., as required by the standard of compliance or the manufacturer's specification. Such markings may be cast or forged integral with, stamped on, or securely affixed by nameplate on the component, and are required to serve as a permanent means of identification of the component throughout its service life.

Where indicated as 'temporary', the pipe is required to have identification for traceability during fabrication.

Table 8.1.2 Piping Classes and Certification

Piping Component	Class	INTLREG Certification (Refer note 1)	Design Approval (Refer note 1)	Manufacturer's Certification (Refer note 1)	Identification (Refer note 1)
Pipes	I, II	Required (Refer note 2)	Not applicable (Refer note 3)	Required	Temporary (Refer note 3)
	III	Not required (Refer note 3)	Not applicable (Refer note 3)	Required	Temporary (Refer note 3)
Pipe fittings	I, II	Not required	Required (Refer note 4, 6)	Required	Permanent
	III	Not required	Not required (Refer note 5, 6)	Required	Permanent
Valves	I, II	Not required	Required (Refer note 4)	Required	Permanent
	III	Not required	Not required (Refer note 5)	Required	Permanent

Notes:

1. Refer Sections [1.4.1.1], [1.4.1.2], [1.4.1.3] & [1.4.1.4].
2. Except hydraulic piping.
3. Except for plastic piping. Refer Section 3.
4. Where not in compliance with a recognized standard.
5. Documentary proof of pressure/temperature rating is required. Refer Sec-2, [2.3.9].
6. Design of flexible hoses and mechanical pipe joints is to be approved in each case. Refer Sec-2, [2.3.4] & [2.3.6] respectively.

1.4.2. Certification of Pumps

1.4.2.1. Pumps Requiring Certification

The pumps which are listed below are required to be certified by a Surveyor at the manufacturers' plants:

- i). Pumps for all vessels (500 gross tonnage and over):
 - Fuel oil transfer pumps
 - Hydraulic pumps for steering gears (Refer also Ch-6, Sect 9 [9.3] anchor windlasses, controllable pitch propellers
 - Fire pumps, including emergency fire pumps

- Other firefighting service pumps, such as, pumps for fixed water-based systems, or equivalent, local application fire-fighting systems (Refer , Ch-13, Sec-1/[1.1.3], sprinkler systems, deck foam systems, etc.
 - Ballast pumps (Refer Chapter 9)
 - Bilge pumps (Refer Chapter 9)
- ii). Pumps associated with propulsion diesel engine and reduction gears (for engines with bores > 300 mm only):
- Fuel oil service pumps, booster pumps, etc.
 - Lubricating oil pumps
 - Sea water and freshwater cooling pumps
- iii). Pumps associated with steam propulsion and reduction gears:
- Fuel oil service pumps
 - Main feed pumps
 - Main condensate pumps
 - Main circulating pumps
 - Lubricating oil pumps
 - Vacuum pumps for main condenser
- iv). Pumps associated with propulsion gas turbine and reduction gears:
- Lubricating oil pumps
 - Fuel oil service pumps
- v). Cargo pumps associated with oil carriers, liquefied gas carriers and chemical carriers.
- vi). Cargo vapor compressors associated with liquefied gas carriers (high and low duty gas compressors).
- vii). Pumps associated with inert gas systems:
- Fuel oil pumps for boilers/inert gas generators
 - Cooling water pumps for flue gas scrubber

1.4.2.2. Required Tests

The following tests are required to be carried out at the manufacturer's plant in the presence of the Surveyor.

- a) Hydrostatic tests: The pumps are required to be hydrostatically tested to a pressure of at least $1.5P$, where P is the maximum working pressure of the pump. If it is preferred to conduct the hydrostatic test on the suction side of the pump independently from the test on the discharge side, the test pressure on the suction side is required to be at least $1.5P_s$, where P_s is the maximum pressure available from the system at the suction inlet. In all cases, the test pressure for both the suction and the discharge side should not be less than 4 bar.
- b) Capacity tests: Pump capacities are required to be checked with the pump operating at design conditions (rated speed and pressure head). For centrifugal pumps, the pump characteristic (head capacity) design curve should be verified to satisfy the Surveyor. If previous satisfactory tests have been carried out on similar pumps then capacity tests might be waived.

- c) Relief valve capacity test: The valve's setting and full flow capacity corresponding to the pump maximum rating is required to be verified for positive displacement pumps with an integrated relief valve. If previous satisfactory tests have been carried out on similar pumps then the operational test for relief valve capacity might be waived.

1.4.3. Certification Based on the Type Approval Program

1.4.3.1. Pipes

For pipes which are required to be INTLREG certified in accordance with Table 8.1.2, the manufacturer may request that approval of INTLREG and list them under the Type Approval Program described in Part 1, Ch-1, Sec-11. Upon approval under Part 1, Ch-1, Sec-11 (PQA) and listing under this program, the pipes will not be required to be surveyed and certified each time they are manufactured for use onboard a vessel.

To be considered for approval under this program, the manufacturer is required to operate a quality assurance system that is certified for compliance with a recognized quality standard. In addition, quality control of the manufacturing processes should cover all of the provisions of inspection and tests required by the Rules and applicable pipe standard, in accordance with Part 1, Ch-1, Sec 11.

1.4.3.2. Pipe Fittings and Valves

For pipe fittings and valves which are not required to be certified but are required to be design approved in accordance with Table 8.1.2, the manufacturer may request that approval of INTLREG and list the component as a Design Approved Product described in Part 1, Ch-1, Sect 11. The design is required to be evaluated in accordance with Section [1.4.1.2]. As required by Part 1, Ch-1, Sec-11 upon the approval, listing, and subject to renewal and updating of the certificates it will not be necessary to submit the design of the component for approval each time it is proposed for use onboard a vessel.

The manufacturer might also request for the approval of the product and list it under the Type Approval Program. In this case, in addition to the design approval indicated above, the manufacturer is required to provide documented attestation that the product will be manufactured to consistent quality and to the design and specifications to which it is approved. Refer Part 1, Ch-1, Sec-11 (AQS)/(RQS) or Part 1, Ch-1, Sec-11(PQA).

1.4.3.3. Pumps

As an alternative to certification specified in Section [1.4.2.2] for mass-produced pumps, the manufacturer might request for the approval of INTLREG and list the pump under the Type Approval Program. For approval under this program:

- i). A sample of the pump type is required to be subjected to hydrostatic and capacity tests specified in Section [1.4.2.2]; and
- ii). The manufacturer is required to operate a quality assurance system which is to be certified for compliance with a quality standard in accordance with Part 1, Ch-1, Sec-11 (AQS)/(RQS) or Part 1, Ch-1, Sec-11 (PQA). The quality control plan is required to have provision to subject each production unit of the pump to a hydrostatic test specified in Section[1.4.2.2](a) and the manufacturer is to maintain record of such tests.

The manufacturer has the option to request approval for the pump design in accordance with (i) above only, in which case the pump type may be listed as an approved product as described in Part 1, Ch-1, Sec-11 Certification of a production

unit will be based on its being subjected to the hydrostatic test specified in Section [1.4.2.2 (a)] in the presence of a Surveyor.

1.5. Documents to be submitted:

1.5.1. System Plans

The following plans are to be submitted for review:

- Propulsion machinery space arrangement, including locations of fuel oil tanks
- Booklet of standard details (Refer Section [1.5.3])
- Bilge and drainage systems
- Boiler feed water and condensate systems
- Ballast system
- Compressed air system
- Cooling water systems
- Exhaust piping (for boilers, incinerators and engines)
- Fixed oxygen-acetylene system
- Fuel oil systems, including storage tanks, drip trays and drains
- Hydraulic and pneumatic systems
- Helicopter refueling system, fuel storage tank and its securing and bonding arrangements
- Lubricating oil systems
- Sea water systems
- Sanitary system
- Steam systems
- Steam piping analyses (as applicable)
- Tank venting and overflow systems
- Vent, overflow and sounding arrangements
- All Class I and Class II piping systems not covered above

1.5.2. Contents of System Plans

Piping system plans are required to be prepared in diagrams and should include the following information:

- Types, sizes, materials, construction standards, and pressure and temperature ratings of piping components other than pipes
- Materials, outside diameter or nominal pipe size, and wall thickness or schedule of pipes
- Maximum pump pressures and/or relief valve settings
- Design pressure and design temperature, test pressure
- Flash point of flammable liquids
- Legend for symbols used
- Instrumentation and control

1.5.3. Booklet of Standard Details

The booklet of standard details, as indicated in Sect [1.5.1] above, is required to contain standard practices that will be used in the construction of the vessel, typical details of such items as bulkhead, deck and shell penetrations, welding details, pipe joint details, etc. If desired, this information might be included in the system plans.

SECTION 2 METALLIC PIPING

Contents

2.1. Scope 320

2.2. Materials 320

2.3. Design 322

2.4. Fabrication and Tests 340

2.5. Installation Details 341

2.1. Scope

The provisions of this chapter cover metallic piping. They include requirements for piping materials, design, fabrication, inspection and testing. They also include general requirements for shipboard installation practices. Requirements for plastic piping are provided in Section 3.

2.2. Materials

2.2.1. Equivalent materials complying with the national or international standard will be considered for acceptance, while references are made to material specifications in Part-2, Ch-2, Sec-17 & Sec-18 and Part-2, Ch-4, Sec-2 & Sec-5.

2.2.2. Ferrous

2.2.2.1. Steel Pipes

- a) Material specifications: Material specifications are given in Part-2, Ch-2, Sec-17, for steel pipes that are acceptable. Materials can be considered if the properties are equivalent to these specifications.
- b) Application of seamless and welded pipes: The application of seamless and welded pipes should be done in accordance with the following Table 8.2.1:

Table 8.2.1

	Seamless Pipes	Electric Resistance Welded Pipes	Furnace Butt Welded Pipes
Class I	permitted	permitted	not permitted
Class II	permitted	permitted	not permitted
Class III	permitted	permitted	permitted (Refer note 1)
Note: 1. Except for flammable fluids.			

2.2.2.2. Forged and Cast Steels

Material specifications for steel forgings and steel castings are given in Part-2, Ch-2, Sec-6 & Sec-7, respectively. There is no service limitation except as indicated in Sect [2.2.2.5] and [2.2.2.6] below.

2.2.2.3. Gray Cast Iron

Material specifications for gray cast iron (also called ordinary cast iron) are given in Part-2, Ch-2, Sec-9. Systems that are exposed to pressure shock, vibration or excessive strain; cast iron components should not be used. In general, gray cast iron pipes, valves and fittings may be used only in Class III piping systems. Specifically, gray cast iron should not be used for the following applications:

- Valves and fittings for temperatures above 220°C (428°F)
- Valves connected to the collision bulkhead (Refer Section [2.5.5.3])
- Valves connected to the shell of the vessel (Refer Section [2.5.8.2])

- Valves fitted on the outside of fuel oil, lubricating oil, cargo oil and hydraulic oil tanks were subjected to a static head of oil [Refer, for example, Ch-9, Sec-7/[7.3.3] (a)]
- Valves mounted on boilers except as permitted for heating boilers (Refer Ch-10, Sec-5/ [5.2.])
- Pipes, valves and fittings in cargo oil piping on weather decks for pressures exceeding 16 bar (16.3 kgf/cm², 232 psi)
- Pipes, valves and fittings in cargo oil manifolds for connection to cargo handling hoses
- Fixed gas fire extinguishing systems

2.2.2.4. Nodular (Ductile) Iron

In Part-2, Ch-2, Sec-10, material specifications for nodular iron are given. For the construction of valves and fittings for temperatures of 350°C (662°F) and above, nodular iron is not permitted. Nodular iron may be used for Classes I and II piping systems and for valves listed in Sect [2.2.2.3] above provided it has an elongation of not less than 12% in 50 mm (2 in.).

2.2.2.5. Elevated Temperature Applications

In general, carbon and carbon-manganese steel pipes, valves and fittings for pressure service should not be used for temperatures above 400°C (752°F) unless their metallurgical behavior and time dependent strengths are in accordance with national or international codes or standards and that such behavior and strengths are guaranteed by the steel manufacturers.

Consideration can be given to the possibility of graphite formation in the following steels:

- Carbon steel above 425°C (797°F)
- Carbon-molybdenum steel above 470°C (878°F)
- Chrome-molybdenum steel (with chromium under 0.60%) above 525°C (977°F)

2.2.2.6. Low Temperature Applications

Ferrous materials used in piping systems operating at lower than -18°C (0°F) are required to have adequate notch toughness properties. Specifications of acceptable materials are given in Part-2, Ch-2, Sec-18. Materials for piping systems of liquefied gas carriers shall comply with Part 6, Ch-3, Sec-2.

2.2.3. Copper and Copper Alloys

Material specifications for copper and copper alloy pipes and castings are given in Part-2, Ch-4, Sec-2, Sec-5, & Sec-6. Copper and copper alloys should not be used for fluids having a temperature greater than the following:

Copper-nickel:	300°C (572°F)
High temperature bronze:	260°C (500°F)
All other copper and copper alloys:	200°C (392°F)

Copper and copper alloy pipes may be used for Classes I and II systems, provided they are of the seamless drawn type. Seamless drawn and welded copper pipes can be accepted for Class III systems.

2.2.4. Aluminium

Piping containing flammable fluids should be constructed of steel or other materials approved by INTLREG. Other equivalent material with a melting point above 930°C (1706°F) and with an elongation above 12% may be accepted. Aluminum and aluminum alloys which are characterized by low melting points, below 930°C (1706°F), are considered heat sensitive materials and are not to be used to convey flammable fluids, except for such piping as arranged inside cargo tanks or heat exchangers or otherwise permitted for engine attached filters.

On oil tankers and chemical tankers aluminized pipes are prohibited in cargo tanks, cargo deck tank area, pump rooms, cofferdams, or other areas where cargo vapor may accumulate. Aluminized pipes may be permitted in ballast tanks, in inerted cargo tanks, and, provided the pipes are protected from accidental impact, in hazardous areas on open deck.

2.3. Design

2.3.1. Pipes

The wall thickness of a pipe shall not be less than the greater of the value obtained by Sect [2.3.1.1] or [2.3.1.3] below. However, Sect [2.3.1.2] may be used as an alternative to Sect [2.3.1.1].

2.3.1.1. Pipes Subject to Internal Pressure

The minimum wall thickness should not be less than that calculated by the following equations or that specified in Sect [2.3.1.3] below, whichever is greater. Units of measure are given in the order of SI (MKS, US) units, respectively. The use of these equations is subjected to the following conditions:

- The following requirements apply for pipes where the outside to inside diameter ratio does not exceed a value of 1.7.
- Ferrous materials are required to be those that have specified elevated temperature tensile properties required below.

$$t = (t_0 + b + c)m$$
$$t_0 = \frac{PD}{KSe + P}$$

Where;

t = minimum required pipe wall thickness (nominal wall thickness less manufacturing tolerance); mm (in.)

t₀ = minimum required pipe wall thickness due to internal pressure only; mm (in.)

P = design pressure; bar (kgf/cm², psi)

D = outside diameter of pipe; mm (in.)

K = 20 (200, 2) for SI (MKS, US) units of measure, respectively

S = permissible stress; N/mm² (kgf/mm², psi); to be determined by (a) or (b) below:

- a) Carbon steel and alloy steel pipes with a specified minimum elevated temperature yield stress or 0.2% proof stress: S is to be the lowest of the following three values:

$$\frac{\sigma_T}{2.7} \frac{\sigma_Y}{1.8} \frac{\sigma_R}{1.8}$$

Where;

σ_T =Specified minimum tensile strength at room temperature, i.e., 20°C (68°F)

σ_Y =Specified minimum yield strength at the design temperature

σ_R =Average stress to produce rupture in 100,000 hours at the design temperature

- b) Copper and Copper alloys: S is to be in accordance with Table 8.2.3.

e = efficiency factor, to be equated to:

1.0:for seamless pipe

1.0:for electric-resistance welded pipes manufactured to a recognized standard

0.6:for furnace butt-welded pipes

For other welded pipes, the joint efficiency is to be determined based on the welding procedure and the manufacturing and inspection processes.

- b = allowance for bending; mm (in.). The value for b is to be chosen in such a way that the calculated stress in the bend, due to the internal pressure only, does not exceed the permissible stress. When the bending allowance is not determined by a more accurate method, it is to be taken as:

$$b = \frac{0.4 D t_0}{R}$$

R= mean radius of the bend

c = Corrosion Allowance; mm (in.); to be determined as follows;

- For steel pipes, the value for c is to be in accordance with Table 8.2.4.
- For non-ferrous metal pipes (excluding copper-nickel alloys containing 10% or more nickel), c = 0.8 mm (0.03 in.).
- For copper-nickel alloys containing 10% or more nickel, c = 0.5 mm (0.02 in.).
- Where the pipe material is corrosion resistant with respect to the media, e.g., special alloy steel, c = 0.

m = coefficient to account for negative manufacturing tolerance when pipe is ordered by its nominal wall thickness, calculated as follows:

$$= \frac{100}{100 - a}$$

a = percentage negative manufacturing tolerance, or 12.5% where a is not available

2.3.1.2. Pipes Subject to Internal Pressure – Alternative Equation

As an alternative to Sect [2.3.1.1] above, for steel pipe specifications in Part-2, Ch-2, Sec-17, the minimum wall thickness may be determined by the following equations or that specified in Sect [2.3.1.3] below, whichever is greater. Units of measure are given in the order of SI (MKS, US) units, respectively.

$$t = \frac{PD}{KS + MP} + c$$

Where;

P, D, K, t are defined in [2.3.1.1] above; and

P = for calculation purpose, not to be taken as less than 8.6 bar, 8.8 kgf/cm² (125 psi)

S = allowable stress from Table 8.2.2; N/mm² (kgf/mm², psi).

M = factor, from Table 8.2.2.

c = allowance for threading grooving or mechanical strength, and is to be as given below:

- Plain end pipe ≤ 100 mm (4 in.) NB: 1.65 mm (0.065 in.)
- Plain end pipe ≤ 100 mm (4 in.) NB for hydraulic oil service: 0
- Plain end pipe > 100 mm (4 in.) NB: 0
- Threaded pipe ≤ 9.5 mm (3/8 in.) NB: 1.27 mm (0.05 in.)
- Threaded pipe > 9.5 mm (3/8 in.) NB: [0.8 X (mm per thread)] or [0.8 ÷ (threads per in.)]
- Grooved pipe: depth of groove

The above method of calculation may also be used for determining required wall thickness for pipes of other materials. In such cases, the value of S can be obtained from ANSI B31.1 Code for Power Piping.

2.3.1.3. Minimum Pipe Wall Thickness and Bending

Notwithstanding Sections [2.3.1.1] or [2.3.1.2] above, the minimum wall thickness of pipes should not be less than that indicated in Table 8.2.5 for steel pipes, and Table 8.2.6 & Table 8.2.7 for other metal pipes. The wall thicknesses listed in these tables are nominal wall thicknesses. No allowances need to be made to account for negative tolerance or reduction in thickness due to bending, when using the tables.

Pipe bending is to be done in accordance with Part-2, Ch-2, Sec-17/ [17.13]. Alternatively, bending in accordance with a recognized standard (e.g., ASME B31.1 – Section 129.1 and 129.3) or other approved specifications to a radius that will result in a surface free of cracks and substantially free of buckles may be acceptable.

2.3.2. Pipe Branches

Pipe branches may be made by the use of standard branch fittings or by welded fabrication. The main pipe is weakened by the hole that must be made in it to accommodate the branch pipe in case of welded fabrication. The opening is required to be compensated as follows:

- Excess wall thickness, over and above the minimum required wall thickness of the main pipe and the branch required for pressure service (disregarding corrosion allowance and manufacturing tolerances) determined by the equation in Sections [2.3.1.1] or [2.3.1.2] above may be considered for this purpose.
- Reinforcement pads might be used to compensate the opening.

In accordance with the criteria of opening reinforcement of a pressure vessel, the opening and its compensation may be designed. Refer, for example, Ch-10, Sec-3/ [3.4].

2.3.3. Pipe Joints

2.3.3.1. Butt Welded Joints

Butt welded joints may be used for all classes of piping, where complete penetration at the root is achieved. Degree of verification of sound root penetration is required to be done in accordance with Part-2, Ch-3, Sec-4/ [4.3] & [4.6].

2.3.3.2. Socket Welded Joints

Socket welded joints using standard fittings may be used for Classes I and II piping up to and including 80 mm (3 in) nominal diameter, except in toxic and corrosive fluid services (Refer Sec-1, [1.2.13] & [1.2.14]) or services where fatigue, severe erosion or crevice corrosion is expected to occur. Socket welded joints using standard fittings may be used for Class III piping without limitation. The fillet weld leg size is required to be at least 1.1 times the nominal thickness of the pipe. Refer Figure 8.2.1.

2.3.3.3. Slip-on Welded Sleeve Joints

Slip-on welded sleeve joints may be used for Classes I and II piping up to and including 80 mm (3 in.) nominal diameter except in toxic and corrosive fluid services (Refer Sec-1, [1.2.13] & [1.2.14]) or services where fatigue, severe erosion or crevice corrosion is expected to occur, provided that:

- The inner diameter of the sleeve shall not exceed the outer diameter of the pipe by more than 2mm (0.08 in.)
- The depth of insertion of the pipe into the sleeve is required to be at least 9.5 mm (0.375 in.)
- The gap between the two pipes is required to be at least 2 mm (0.08 in.)
- The fillet weld leg size is as per Section [2.3.3.2], Refer Figure 8.2.2.

Slip-on welded sleeve joints may be used for Class III piping without size limitation. In such cases, joint design and attachment weld sizes may be done in accordance with a recognized alternative standard.

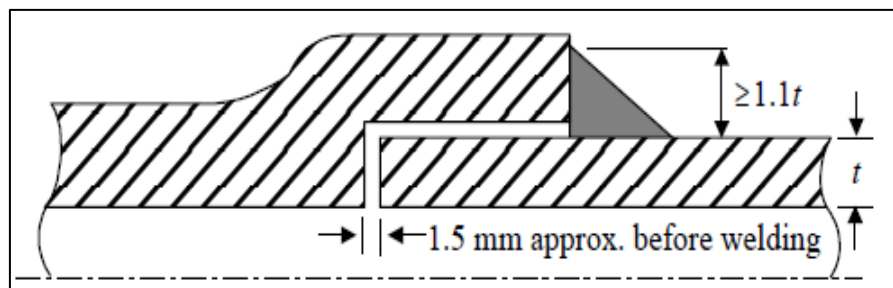


Figure 8.2.1: Typical Socket Weld Joint

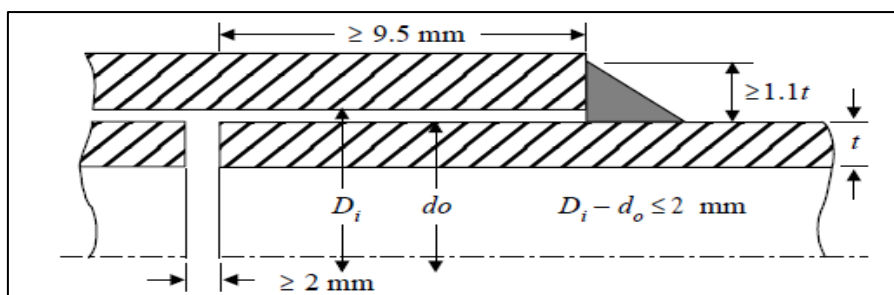


Figure 8.2.2: Typical Slip-on Welded Sleeve Joint

2.3.3.4. Flanged Joints

Flanges of all types (Refer Table 8.2.8 for typical types) conforming to and marked in accordance with a recognized national standard may be used within the pressure-temperature ratings of the standard, subject to limitations indicated in Table 8.2.9. The calculations made to a recognized method are to be submitted for review, for flanges not conforming to a recognized standard. Non-standard flanges are to be subjected to the same limitations as indicated in Table 8.2.9. Flanges conforming to a standard are required to be attached to pipes by welding or other acceptable means as specified in the standard. For example, slip-on flanges conforming to ASME B16.5 are to be attached to pipes by a double fillet weld having throat size of not less than 0.7 times the wall thickness of the pipe. Non-standard flanges are to be attached to pipes by a method approved with the design.

2.3.3.5. Threaded Joints

a) Taper-thread joints

Threaded joints having tapered pipe threads complying with a recognized standard shall not be used for toxic and corrosive fluid services and for all services of temperatures exceeding 495°C (923°F). They may be used for Classes I and II piping subject to limitations indicated in the table below. They may be used for Class III piping without limitation. For hydraulic oil system, Refer Table 8.6.1.

Pipe Nominal Diameter, d		Maximum Pressure Permitted		
mm	in.	Bar	kgf/cm ²	psi
d > 80	d > 3	Not permitted for Classes I & II		
80 ≥ d > 50	3 ≥ d > 2	27.6	28.1	400
50 ≥ d > 25	2 ≥ d > 1	41.4	42.2	600
25 ≥ d > 20	1 ≥ d > 0.75	82.8	84.4	1200
d ≤ 20	d ≤ 0.75	103	105.5	1500

b) Taper-thread joints for hydraulic oil system

Taper-thread joints up to 80 mm (3 in.) nominal diameter may be used without pressure limitation for connection to equipment only, such as pumps, cylinders,

accumulators, valves, gauges and hoses. When such fittings are used solely to join sections of pipe, they are to be done in accordance with Section [2.3.3.5] (a). However, hydraulic systems for the following services are to comply with Section [2.3.3.5] (a) in all respects:

- Steering gear hydraulic systems
- Controllable pitch propeller hydraulic systems
- Hydraulic systems associated with propulsion or propulsion control

c) Straight-thread 'O'-ring joints.

For hydraulic oil piping, straight thread 'O'-ring type fittings (Refer Figure 8.2.3) may also be used for connections to equipment, without pressure and service limitation, but shall not be used for joining sections of pipe.

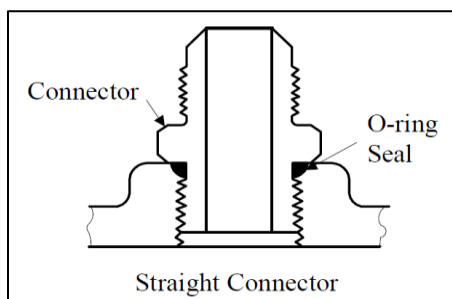


Figure 8.2.3: Straight-thread 'O'-Ring Joints

2.3.4. Flexible Hoses

2.3.4.1. Definition

A flexible hose assembly is a short length of metallic or non-metallic hose normally with prefabricated with end fittings or without with clamping arrangement ready for installation.

2.3.4.2. Scope

The application of the requirements of Section [2.3.4.3] to [2.3.4.6] are to be done to flexible hoses of metallic or non-metallic material intended for a permanent connection between a fixed piping system and items of machinery. The requirements also apply to temporary connected flexible hoses or hoses of portable equipment.

As defined in Section [2.3.4.1], flexible hose assemblies are acceptable for use in oil fuel, lubricating, hydraulic and thermal oil systems, fresh water and sea water cooling systems, compressed air systems, bilge and ballast systems, and Class III steam systems where they comply with Section [2.3.4.3] to [2.3.4.6].

In high pressure fuel oil injection systems, flexible hoses are not acceptable.

For flexible hose assemblies, these requirements are not applicable to hoses intended to be used in fixed fire extinguishing systems.

2.3.4.3. Design and Construction

a) Hose material

In accordance with recognized National or International Standards, flexible hoses are required to be designed and constructed. Flexible hoses which are

constructed of rubber or plastics materials and intended for use in bilge, ballast, compressed air, oil fuel, lubricating, hydraulic and thermal oil systems are to incorporate a single double or more closely woven integral wire braid or other suitable material for reinforcement.

Flexible hoses of plastics materials such as Teflon or Nylon, (which are used for the purposes mentioned above), where reinforcement is not possible by incorporating closely woven integral wire braid are to have suitable reinforcing material as far as practicable.

Where rubber or plastic material hoses 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 which is provided during manufacturing. Flexible hoses for use in steam systems are to be of metallic construction.

Flexible hose assemblies intended for installation in piping systems where pressure pulses and/or high levels of vibration are expected to occur in service, are to be designed for the maximum expected impulse peak pressure and forces due to vibration. The tests required by [2.3.4.5] below are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.

b) Hose end fittings.

Flexible hoses are to be complete with approved end fittings in accordance with manufacturer's specification. Flanged end connections shall comply with Section [2.3.3.4] and threaded end connections with Section [2.3.3.5], as applicable and each type of hose/fitting combination is required to be subject to prototype testing to the same standard as that required by the hose with particular reference to pressure and impulse tests.

The use of hose clamps and similar types of end attachments is not acceptable for flexible hoses in piping systems for steam, starting air, flammable media, or for sea water where failure may result in flooding. The use of hose clamps may be accepted in other piping systems, where the working pressure is less than 5 bar (5.1 kgf/cm², 72.5 psi) and provided there are at least two stainless steel hose clamps at each end connection. The hose clamps are required to be at least 12 mm (0.5 in.) wide and should not be dependent upon spring tension to remain fastened.

c) Fire resistance.

Flexible hose assemblies constructed of non-metallic materials intended for installation in piping systems for flammable media and sea water systems where failure may result in flooding, are required to be of a fire-resistant type*. Fire resistance shall be demonstrated by testing to ISO 15540 and ISO 15541

* **Note:** The installation of a shutoff valve immediately upstream of a sea water hose does not satisfy the requirement for fire-resistant type hose.

d) Hose application.

Flexible hose assemblies are required 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 other relevant requirements of this Section.

Flexible hose assemblies intended for installation in piping systems are required to be designed for the maximum expected impulse peak pressure and forces

due to vibration, where pressure pulses and/or high levels of vibration are expected to occur in service. The tests required by Section [2.3.4.5] are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.

2.3.4.4. Installation

In general, flexible hoses are required to be limited to a length necessary to provide for relative movement between fixed and flexibly mounted items of machinery, equipment or systems.

Flexible hose assemblies shall not be installed where they may be subjected to torsion deformation (twisting) under normal operating conditions.

In piping systems, the number of flexible hose is required to be kept to minimum and is to be limited for the purpose stated in Sect[2.3.4.2] above.

Where flexible hoses are intended to be used in piping systems conveying flammable fluids that are in close proximity of heated surfaces, the risk of ignition due to failure of the hose assembly and subsequent release of fluids is required to be mitigated as far as possible by the use of screens or other similar protection.

Flexible hoses are required to be installed in clearly visible and readily accessible locations.

The installation of flexible hose assemblies is required to be done in accordance with the manufacturer's instructions and use limitations with particular attention to the following:

- Orientation
- End connection support (where necessary)
- Avoidance of hose contact that could cause rubbing and abrasion
- Minimum bend radii

2.3.4.5. Tests

i). Test procedures.

The acceptance of flexible hose assemblies is subjected to satisfactory type testing. Type test programs for flexible hose assemblies are required to be submitted by the manufacturer and should be sufficiently detailed to demonstrate performance in accordance with the specified standards.

In accordance with the requirements of the relevant standard, the tests are, as applicable, required to be carried out on different nominal diameters of hose type complete with end fittings for pressure, burst, impulse resistance and fire resistance. The following standards are to be used as applicable.

- ISO 6802 – Rubber and plastics hoses and hose assemblies with wire reinforcement – Hydraulic impulse test with flexing.
- ISO 6803 – Rubber and plastics hoses and hose assemblies – Hydraulic-pressure impulse test without flexing.
- ISO 15540 – Ships and marine technology – Fire resistance of hose assemblies – Test methods.
- ISO 15541 – Ships and marine technology – Fire resistance of hose assemblies – Requirements for test bench.
- ISO 10380 – Pipework – Corrugated metal hoses and hose assemblies.

Other standards may be accepted where agreed.

ii). Burst test.

All flexible hose assemblies are required to be satisfactorily Prototype burst tested to an international standard to demonstrate they are able to withstand a pressure not less than four (4) times its design pressure without indication of failure or leakage.

Note: The international standards, e.g. EN or SAE for burst testing of non-metallic hoses, require the pressure to be increased until burst without any holding period at $4 \times \text{MWP}$.

2.3.4.6. Marking

Flexible hoses should be permanently marked by the manufacturer with the following details:

- Hose manufacturer's name or trademark.
- Date of manufacture (month/year)
- Designation type reference.
- Nominal diameter.
- Pressure rating
- Temperature rating.

Where a flexible hose assembly is made up of items from different manufacturers, the components are required to be clearly identified and traceable to evidence of prototype testing.

2.3.5. Expansion Joints

2.3.5.1. Molded Expansion Joints

a) Molded Nonmetallic Expansion Joints.

The following requirements can be applied where molded expansion joints made of reinforced rubber or other suitable nonmetallic materials are proposed for use in Class III circulating water systems in machinery spaces:

- The expansion joint is required to be oil resistant.
- The maximum allowable working pressure shall not be greater than 25% of the hydrostatic bursting pressure determined by a burst test of a prototype expansion joint. Results of the burst test are required to be submitted.
- Plans of molded or built-up expansion joints over 150 mm (6 in.), including internal reinforcement arrangements, are required to be submitted for approval. Such joints should be permanently marked with the manufacturer's name and the month and year of manufacture.

b) Molded Expansion Joints of Composite Construction

The following requirements applies, where molded expansion joints of composite construction utilizing metallic material, such as steel or stainless steel or equivalent material, with rubberized coatings inside and/or outside or similar arrangements are proposed for use in oil piping systems (fuel, lubricating or hydraulic oil):

- Expansion joint ratings for temperature, pressure, movements and selection of materials are to be suitable for the intended service.

- The maximum allowable working pressure of the system shall not be greater than 25% of the hydrostatic bursting pressure determined by a burst test of a prototype expansion joints. Results of the burst test are required to be submitted.
- The expansion joints are required to pass the fire resistant test specified in Section [2.3.4.3 (c)].
- The expansion joints are required to be permanently marked with the manufacturer's name and the month and year of manufacture.

Molded expansion joints may be Type Approved; Refer Part-1, Ch-1.Sect 11

2.3.5.2. Metallic Bellow Type Expansion Joints

Metallic bellow type expansion joints may be used in all classes of piping, except that were used in Classes I and II piping, they will be considered based upon satisfactory review of the design. Submission of the detailed plans of the joint along with calculations and/or test results verifying the pressure and temperature rating and fatigue life are required to be done.

2.3.6. Mechanical Joints

2.3.6.1. Design

The application of these requirements shall be done to pipe unions, compression couplings and slip-on joints, as shown in Table 8.2.11. The approval is to be done based upon the results of testing of the actual joints in association with the following requirements. Mechanical joints similar to those indicated in Table 8.2.11 and complying with these requirements will be specially considered.

- a) General
INTLREG should approve the application and pressure ratings of mechanical joints. The approval is required to be based upon the testing specified in Section [2.3.6.2], as required for the service conditions and intended application.
- b) Impact on Wall Thickness.
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.
- c) Operational Conditions
Construction of mechanical joints is required to prevent the possibility of tightness failure affected by pressure pulsation, piping vibration, temperature variation and other similar adverse effects occurring during operation onboard.
- d) Materials
Material of mechanical joints is required to be compatible with the piping material and internal and external media.
- e) Burst Testing
Mechanical joints are required to be tested to a burst pressure of four (4) times the design pressure. The required burst pressure will be specially considered by INTLREG for design pressures above 200 bar (204 kgf/cm², 2900 psi).
- f) Fire Testing
Mechanical joints are required to be of fire resistant type, as required by Table 8.2.12.
- g) Locations
Mechanical joints should not be used in piping sections directly connected to the sea openings or tanks containing flammable fluids, which in the event of damage could cause fire or flooding.

- h) Application
The mechanical joints should be designed to withstand internal and external pressure, as applicable, and where used in suction lines, are required to be capable of operating under vacuum.
- i) Joints
The number of mechanical joints in oil systems is required to be kept to a minimum. In general, flanged joints conforming to recognized standards are to be used.
- j) Support and Alignment
Piping in which a mechanical joint is fitted is required 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.
- k) Slip-on Joints
Slip-on joints are required to be accessible for inspection. Unless INTLREG approves, the slip-on joints are not to be used in pipelines in cargo holds, tanks and other spaces that are not easily accessible. Application of these joints inside tanks may be permitted only for the same media that is in the tanks.

In cases where compensation of lateral pipe deformation is necessary, unrestrained slip-on joints are to be used only. Usage of these joints as the main means of pipe connection is not permitted.
- l) Application
Application of mechanical joints and their acceptable use for each service is specified in Table 8.2.12. Dependence upon the Class of piping, pipe dimensions, working pressure and temperature is specified in Table 8.2.13.

In particular cases, INTLREG might accept sizes in excess of those mentioned above, if in compliance with a recognized national or international standard.
- m) Testing
Mechanical joints are required to be tested in accordance with a program approved by INTLREG, which is to include at least the following:
 - i) Tightness test
 - ii) Burst pressure test
 - iii) Vibration (fatigue) test (where necessary)
 - iv) Pull out test (where necessary)
 - v) Pressure pulsation test (where necessary)
 - vi) Vacuum test (where necessary)
 - vii) Fire endurance test (where necessary)
 - viii) Repeated assembly test (where necessary)
- n) Joints Assembly
In accordance with the manufacturer's assembly instructions, the installation of mechanical joints is required to be done. These are to be supplied by the manufacturer, where special tools and gauges are required for installation of the joints.

2.3.6.2. Testing of Mechanical Joints

a) General

These requirements describe the type testing for the approval of mechanical joints intended for use in marine piping systems. INTLREG may specify more

severe testing conditions and additional tests if considered necessary to ensure the intended reliability and also accept alternative testing in accordance with national or international standards where applicable to the intended use and application. Refer Part-1, Ch-1, Sec-11 for general requirements for Type Approval Certification.

b) Scope

The application of this specification shall be done to mechanical joints defined in Section [2.3.6.1] including compression couplings and slip-on joints of different types for marine use.

c) Documentation

The Manufacturer is required to submit following documents and information for assessment and/or approval:

- i) Product quality assurance system implemented.
- ii) Complete description of the product.
- iii) Complete specification of materials used for all components of the assembly.
- iv) Typical sectional drawings with all dimensions necessary for evaluation of joint design.
- v) Proposed test procedure as required in Section [2.3.6.2](e) and corresponding test reports or other previous relevant tests.
- vi) Initial information:
 - Maximum design pressures (pressure and vacuum)
 - Maximum and minimum design temperatures
 - Intended services
 - Conveyed media
 - Installation details
 - Maximum axial, lateral and angular deviation, allowed by manufacturer.

d) Materials

The materials used for mechanical joints are required to comply with the requirements of Section [2.3.6.1] (d). The manufacturer is required to submit evidence to substantiate that all components are adequately resistant to working the media at design pressure and temperature specified.

e) Testing, procedures and requirements

The aim of these tests is to demonstrate the ability of the pipe joints to operate satisfactory under intended service conditions. The scope and type of tests to be conducted e.g. applicable tests, sequence of testing, and the number of specimen, is subjected to approval and will depend on joint design and its intended service in accordance with the requirements of Section [2.3.6.1] & [2.3.6.2], unless otherwise specified, water or oil is required to be used as the test fluid.

i) Test program

Testing requirements for mechanical joints are as specified in Table 8.2.14.

ii) Selection of Test Specimen

Test specimens are required to be selected from the production line or at random from stock. Where there are various sizes from the type of joints requiring approval, a minimum of three separate sizes representative of the range, from each type of joints are to be subject to the tests listed in Table 8.2.14.

iii) **Mechanical Joint Assembly**

Assembly of mechanical joints should consist of components selected in accordance with Section [2.3.6.2] (e) ii) and the pipe sizes appropriate to the design of the joints. The selection of joints for testing is to take the pipe material into consideration where pipe material would affect the performance of mechanical joints. Where not specified, the length of pipes to be connected by means of the joint to be tested is to be at least five times the pipe diameter. Verification is required to be done for the conformity of components to the design requirements before assembling the joint. In all cases the assembly of the joint shall be carried out only according to the manufacturer's instructions. No adjustment operations on the joint assembly, other than that specified by the manufacturer, are permitted during the test.

iv) **Test Results Acceptance Criteria**

Two assemblies of the same size and type that failed is required to be tested and only those tests which the mechanical joint assembly failed in the first instance are to be repeated, where a mechanical joint assembly does not pass all or any part of the tests in Table 8.2.14. In the event where one of the assemblies fails the second test, that size and type of assembly cannot be considered as acceptable. The methods and results of each test are required to be recorded and reproduced as and when required.

2.3.6.3. Method of Tests for Mechanical Joints

a) **Tightness Test**

All mechanical joints are required to be subjected to a tightness test, in order to ensure correct assembly and tightness of the joints, as follows.

- i) In accordance with the requirements of Section [2.3.6.2 (e) iii)] and the manufacturer's instructions, mechanical joint assembly test specimen is required to be connected to the pipe or tubing, filled with test fluid and de-aerated. Mechanical joints assemblies intended for use in rigid connections of pipe lengths, shall not be longitudinally restrained. Pressure inside the joint assembly is to be slowly increased to 1.5 times of design pressure. This test pressure is required to be retained for a minimum period of 5 minutes. The test (including fire test) is to be repeated for two test pieces, in the event where there is a drop in pressure or there is visual indication of leakage. If during the repeat test, one test piece fails, the testing is regarded as having failed. Other alternative tightness test procedures, such as a pneumatic test, may be accepted.
- ii) A static gas pressure test is required to be carried out for compression couplings to demonstrate the integrity of the mechanical joints assembly for tightness under the influence of gaseous media. The pressure is to be raised to maximum pressure or 70 bar (71.4 kg/cm², 1,015 psi) whichever is less.
- iii) Where the tightness test is carried out using gaseous media as permitted in the above first point, then the static pressure test mentioned in (ii) above need not be carried out.

b) **Vibration (Fatigue) Test**

The mechanical joints assembly is required to be subject to the following vibration test, in order to establish the capability of the mechanical joint assembly to withstand fatigue, which is likely to occur due to vibrations under service conditions.

Conclusions of the vibration tests should not show leakage or damage, which could subsequently lead to a failure.

- i) *Testing of compression couplings and pipe unions:* In accordance with the method described below, compression couplings, pipe unions or other similar joints intended for use in rigid connections of pipe are required to be tested. Rigid connections are joints, connecting pipe length without free angular or axial movement. Two lengths of pipe are required to be connected by means of the joint that is to be tested. One end of the pipe is required to be rigidly fixed while the other end is to be fitted to the vibration rig. Such arrangement is shown in Figure 8.2.4.

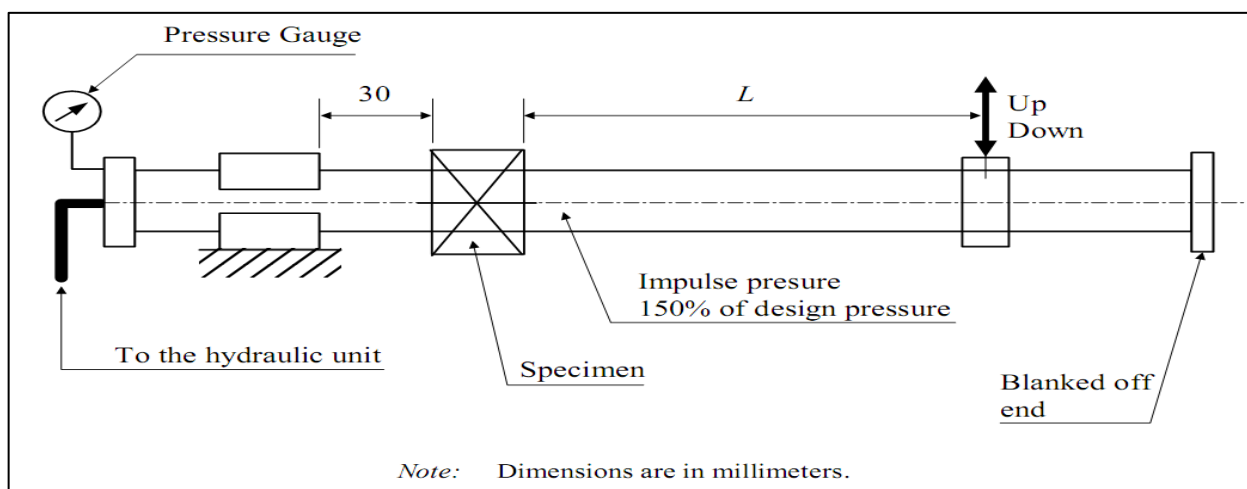


Figure 8.2.4: Arrangement for the Test Rig and the Joint Assembly Specimen Being Tested

The joint assembly is required to be filled with test fluid, de-aerated and pressurized to the design pressure of the joint. Pressure during the test is to be monitored. In the event of drop in the pressure and visual signs of leakage the test shall be repeated as described in Section [2.3.6.2 (e) iv)]. For signs of damage which may eventually lead to joint leakage, visual examination of the joint assembly is to be carried out. Re-tightening may be accepted once during the first 1000 cycles. Vibration amplitude is to be within 5% of the value calculated from the following formula:

$$A = \frac{2 S L^2}{3 E D}$$

Where;

A = single amplitude, mm (cm, in)

L = length of the pipe, mm (cm, in)

S = allowable bending stress, in N/mm² (kgf/cm², psi) based on 0.25 of the yield stress

E = modulus of elasticity of tube material
(for mild steel, E = 210 kN/mm², 214 × 10⁴ kgf/cm², 30 × 10⁶ psi)

D = outside diameter of tube, mm (cm, in)

Test specimen is to withstand not less than 10⁷ cycles with frequency 20-50 Hz without leakage or damage.

- ii) *Grip type and Machine grooved type joints*: In accordance with the following method, grip type joints and other similar joints containing elastic elements are required to be tested. A test rig of cantilever type used for testing fatigue strength of components may be used. Such arrangement is shown in Figure 8.2.5.

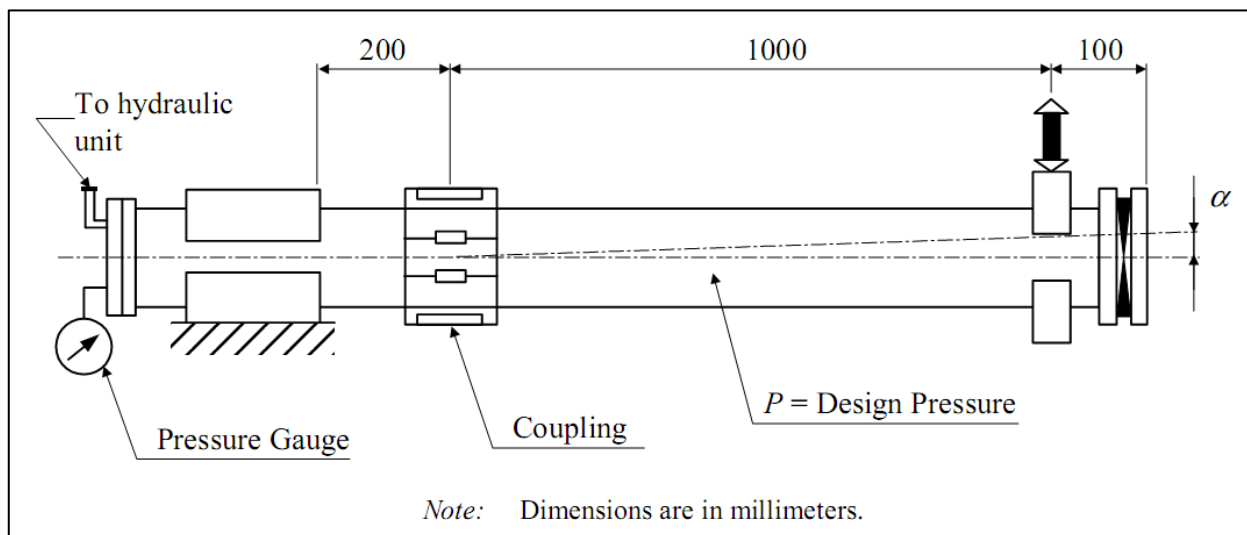


Figure 8.2.5: Arrangement for the Test Specimen Being Tested in the Test Rig

Two lengths of pipes are required to be connected by means of joint assembly specimen to be tested. One end of the pipe is to be rigidly fixed while the other end is required to be fitted to the vibrating element on the rig. The length of pipe connected to the fixed end should be kept as short as possible and in no case exceeds 200 mm (20 cm, 7.9 inch). Mechanical joint assemblies are not to be longitudinally restrained. The assembly is to be filled with test fluid, de-aerated and pressurized to the design pressure of the joint. Preliminary angle of deflection of pipe axis is required to be equal to the maximum angle of deflection, recommended by the manufacturer. The amplitude is to be measured at 1 m (3.3 ft) distance from the centerline of the joint assembly at free pipe end connected to the rotating element of the rig. (Refer Figure 8.2.4) Parameters of testing are to be as indicated below and to be carried out on the same assembly:

Number of cycles	Amplitude, mm	Frequency, Hz
3×10^6	± 0.06	100
3×10^6	± 0.5	45
3×10^6	± 1.5	10

Pressure during the test is required to be monitored. The test is to be repeated as described in Section [2.3.6.2 (e) iv)], in the event of a drop in the pressure and visual signs of leakage. Visual examination of the joint assembly is to be carried out for signs of damage which may eventually cause leakage.

c) Pressure Pulsation Test:

In accordance with the following method, joint assemblies intended for use in rigid connections of pipe lengths are to be tested, in order to determine the capability of a mechanical joint assembly to withstand pressure pulsation likely

to occur during working conditions. The mechanical joint test specimen for carrying out this test may be the same as that used in the test in Section [2.3.6.3 (a) i)] provided it passed that test. The vibration test in Section [2.3.6.3 (b)] and the pressure pulsation test are required to be carried out simultaneously for compression couplings and pipe unions. The mechanical joint test specimen is to be connected to a pressure source capable of generating pressure pulses of magnitude as shown in Figure 8.2.6.

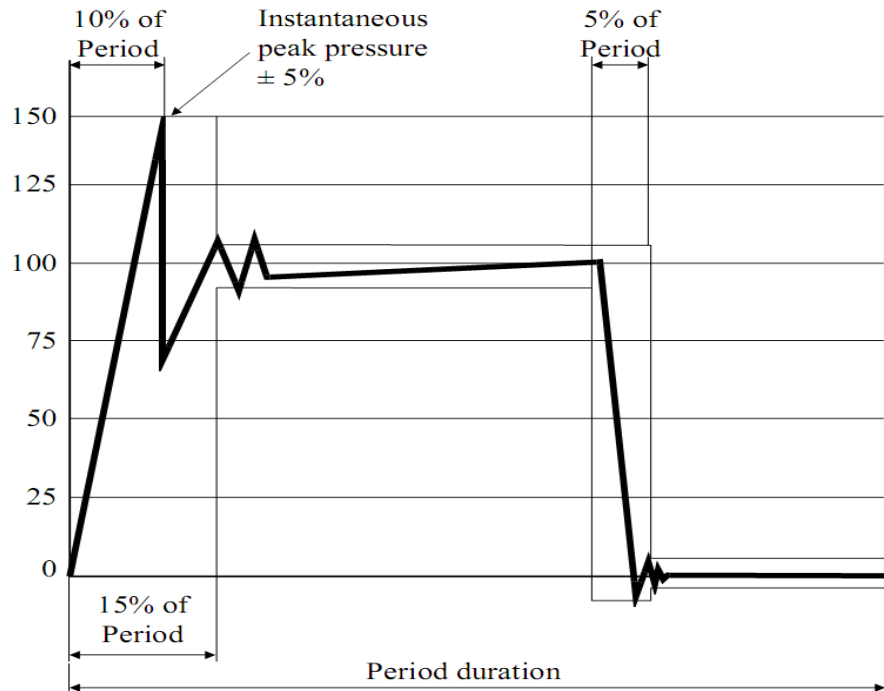


Figure: 8.2.6: Distribution of the Pressure Pulses Magnitude % Design Pressure vs. Period Duration

Impulse pressure is to be raised from 0 to 1.5 times the design pressure of the joint with a frequency equal to 30-100 cycles per minute. The number of cycles shall not be less than 5×10^5 cycles. During the test, the mechanical joint is to be examined visually for sign of leakage or damage.

d) Burst Pressure Test:

The following burst test is required to be carried out, in order to determine the capability of the mechanical joint assembly to withstand a pressure as stated by Section [2.3.6.1 (e)]. In accordance with the requirements of Section [2.3.6.2 (e) iii)], mechanical joint test specimen is to be connected to the pipe or tubing, filled with test fluid, de-aerated and pressurized to test pressure with an increasing rate of 10% per minute of test pressure. The mechanical joint assembly intended for use in rigid connections of pipe lengths shall not be longitudinally restrained. Duration of this test is not to be less than 5 minutes at the maximum pressure. This pressure value will be annotated. Where consider convenient, the mechanical joint test specimen used in tightness test in Section [2.3.6.3 (a)], same specimen may be used for the burst test provided it passed the tightness test. The specimen may have small deformation whilst under test pressure, but no leakage or visible cracks are permitted.

e) Pull-Out Test:

The following pull-out test is required to be carried out, in order to determine the ability of a mechanical joint assembly to withstand axial load that is likely to be encountered in service without the connecting pipe from getting detached. Pipe length of suitable size is required to be fitted to each end of the mechanical joints assembly test specimen. The test specimen is required to be pressurized to design pressure such that the axial loads imposed are of a value calculated by the following formula:

$$L = \left(\frac{\pi D^2}{4} \right) p$$

Where;

D = pipe outside diameter, mm (in.)

p = design pressure, N/mm² (kgf/mm², psi)

L = applied axial load, N (kgf, lbf)

This axial load is required to be maintained for a period of 5 minutes. The pressure is to be monitored and relative movement between the joint assembly and the pipe are to be measured during the test. The mechanical joint assembly is required to be visually examined, in order to detect the drop in pressure and signs of leakage or damage. There should be no movement between the mechanical joint assembly and the connecting pipes.

f) **Fire Endurance Test:**

The mechanical joints are required to be subjected to a fire endurance test, in order to establish the capability of the mechanical joints to withstand the effects of fire which may be encountered in service. The fire endurance test is to be conducted on the selected test specimens as per the following international standards.

- ISO 19921:2005(E) Ship and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Test methods.
- ISO 19922:2005(E) Ship and marine technology – Fire resistance of metallic pipe components with resilient and elastomeric seals – Requirements imposed on the test bench.

Clarification to the standard requirements:

- If the fire test is conducted with circulating water at a pressure different from the design pressure of the joint [however of at least 5 bar (5.1 kgf/cm², 72.5 psi)] the subsequent pressure test is to be carried out to twice the design pressure.
- In order to evaluate the fire resistance of a series or range of mechanical joints of the same design, a selection of representative nominal bores may be tested. When a mechanical joint of a given nominal bore (D_n) is so tested, then other mechanical joints falling in the range D_n to 2 × D_n (both inclusive) are considered accepted.

g) **Vacuum Test:**

The following vacuum test is required to be carried out, in order to establish capability of mechanical joint assembly to withstand internal pressures below atmosphere, similar to the conditions likely to be encountered under service conditions. Mechanical joint assembly is to be connected to a vacuum pump and subjected to a pressure 170 mbar (173 mkgf/cm², 2.47 psi) absolute. Once this pressure is stabilized the mechanical joint assembly test specimen under test

are to be isolated from the vacuum pump and this pressure is to be retained for a period of 5 minutes. Pressure is to be monitored during the test. No internal pressure rise is permitted.

h) **Repeated Assembly Test:**

As per manufacturer's instructions, Mechanical joint test specimen are required to be dismantled and reassembled 10 times and then subjected to a tightness test as defined in Section [2.3.6.2 (e) i)].

2.3.7. Valves

2.3.7.1. Standard

In general, valves are to comply with a recognized national standard and are to be permanently marked in accordance with the requirements of the standard (Refer Sec-1/ [1.4.1.4]). Refer Section [2.3.9], for valves not complying with a recognized national standard.

2.3.7.2. Design Pressure

The design pressure of valves intended for use onboard a vessel is to be at least the maximum pressure to which they will be subjected but at least 3.5 bar (3.6 kgf/cm², 50 lb/in²). Valves used in open-ended systems, except those attached to side shell (Refer Section [2.5.8]), may be designed for pressure below 3.5 bar. Such valves may include those in vent and drain lines, and those mounted on atmospheric tanks which are not part of the pump suction or discharge piping (e.g., level gauges, drain cocks, and valves in inert gas and vapor emission control system).

2.3.7.3. Construction Details

i) *Hand wheel:* All valves are to close with a right hand (clockwise) motion of the hand wheel when facing the end of the stem. Valves are to be either of the rising stem type or fitted with an indicator to show whether the valve is open or closed.

ii) *Bonnet:* All valves of Classes I and II piping systems having nominal diameters exceeding 50 mm (2 in.) are required to have bolted, pressure seal or breech lock bonnets. All valves for Classes I and II piping systems and valves intended for use in steam or oil services are to be constructed so that the stem is positively restrained from being screwed out of the body.

All cast iron valves are required to have bolted bonnets or are to be of the union bonnet type. For cast iron valves of the union bonnet type, the bonnet ring should be of steel, bronze or malleable iron.

iii) *Valve trim:* Stems, discs or disc faces, seats and other wearing parts of valves are required to be of corrosion resistant materials suitable for intended service. Resilient materials, where used, are subject to service limitations as specified by the manufacturers. The use of resilient materials in valves intended for fire mains (Refer , Ch-13, Sec-3/ [3.4.3.1] is required to be specifically approved based on submittal of certified fire endurance tests conforming to a recognized standard

iv) *Valve ends:* All valves of Classes I and II piping systems having nominal diameters exceeding 50 mm (2 in.) are required to have flanged or welded ends. Welded ends are to be butt welding type, except that socket welding ends may be used for valves having nominal diameters of 80 mm (3 in.) or less (refer Section [2.3.3.2]).

2.3.7.4. Manufacturer's Guarantee

The manufacturer of a valve is to guarantee that the valve is constructed to the standard and conforming to the identifications to which it is marked. The manufacturer

is to guarantee also that the valve has been tested before shipment to the pressure required by the pressure rating of the valve. The certificate of test is required to be submitted upon request.

2.3.8. Safety Relief Valves

Safety relief valves shall be treated as valves for the purposes of these Rules and should be constructed of materials permitted for the piping system classes and services in which they are installed. In general, they are also to comply with a recognized standard for relieving capacity.

2.3.9. Nonstandard Components

The components which are not manufactured to a recognized national standard are preferably to be Type Approved (Refer Part-1, Ch-1, Sect-11. They may be considered for acceptance based on manufacturers' specified pressure and temperature ratings and on presenting evidence, such as design calculations or type test data, that they are suitable for the intended purpose. For Classes I and II piping applications, drawings showing details of construction, welding procedures, materials, etc., as applicable, are to be submitted for such components, along with the basis for the pressure and temperature ratings.

2.3.10. Type Approval Program

The Type Approval Program (as described in Ch-1, Section 2/[2.2]) may be applied to design evaluation and approval of piping components in Section [2.3.3] through [2.3.9] of this chapter. Each product which are approved under this program need not be subjected to further design review or a prototype test, or both, each time the product is proposed for use. The list of approved products will be posted on the INTLREG website, <http://www.INTLREG.org/>.

2.4. Fabrication and Tests

2.4.1. Welded Fabrication

Requirements for welding of pipes and fittings, heat treatment and nondestructive testing are given in Part-2, Ch-3, Sec-4. For the purpose of radiography, refer Part-2, Ch-3, Sec-4/[4.5.2.1]

2.4.2. Hydrostatic Tests

2.4.2.1. Hydrostatic Test of Pipes Before Installation Onboard

All Classes I and II pipes and integral fittings after completion of shop fabrication, but before insulation and coating they are to be hydrostatically tested in the presence of a Surveyor, preferably before installation, at the following pressure.

$$P_H = 1.5 P$$

Where;

P_H = test pressure, and

P = design pressure.

Class III steam, compressed air, boiler feed and fuel oil pipes and their integral fittings, where the design pressure is greater than 3.5 bar (3.6 kgf/cm², 50 psi), are required to be hydrostatically tested to the test pressure P_H , as defined above.

Depending on the intended application, small bore pipes and tubes of less than 15 mm outside diameter may be exempted from the required hydrostatic test.

The test pressure is required to be determined by the following formula for steel pipes and integral fittings where the design temperature is above 300°C (572°F), but need not exceed 2P. The test pressure may be reduced to avoid excessive stress in way of bends to 1.5 P. In no case is the membrane stress to exceed 90% of the yield stress at the test temperature.

$$P_H = 1.5 \times P \times \frac{S_{100}}{S_T}$$

where;

S_{100} = permissible stress at 100°C (212°F), and

S_T = permissible stress at design temperature.

Where it is not possible to carry out the required hydrostatic tests for all segments of pipes and integral fittings before installation, the remaining segments, including the closing seams, may be so tested after installation. Or, where it is intended to carry out all of the required hydrostatic tests after installation, such tests may be conducted in conjunction with those required in Section [2.4.2.3]. In both of these cases, testing procedures are to be submitted to the Surveyor for acceptance.

2.4.2.2. Hydrostatic Tests of Shell Valves

All valves intended for installation on the side shell at or below the deepest load waterline, including those at the sea chests, are required to be hydrostatically tested before installation, to a pressure of at least 5 bar (5.1 kgf/cm², 72.5 psi) in the presence of the Surveyor.

2.4.2.3. Tests After Installation

a) General.

In the presence of the Surveyor, all piping systems are required to be tested under working conditions after installation and checked for leakage. Other techniques of tightness test in lieu of a working pressure test may be considered, wherever necessary.

b) Specific Systems

The following piping systems are required to be hydrostatically tested in the presence of the Surveyor after installation to $1.5P$, but not less than 4 bar (4.1 kgf/cm², 58 psi).

- Gas and liquid fuel systems
- Heating coils in tanks

For cargo oil tanker, liquefied gas carrier, and chemical carrier and associated piping, Refer relevant section in specialized ships Part 7B .

2.4.2.4. Pneumatic Tests in Lieu of Hydrostatic Tests

In general, pneumatic tests in lieu of hydrostatic test are not permitted. The pneumatic tests may be considered, where it is impracticable to carry out the required hydrostatic tests. In such cases, the procedure for carrying out the pneumatic test, having regard to safety of personnel, is to be submitted to the INTLREG Surveyor for review.

2.4.3. Resistance Testing

In the presence of the Surveyor, piping required by Section [2.5.9] to be electrically earthed (grounded) to the hull are required to be checked to ensure that the resistance from any point along the piping to the hull does not exceed 1 MΩ. Where bonding straps are used, they are to be located in visible locations.

2.5. Installation Details

2.5.1. Protection from Mechanical Damage

Protection should be given to all piping located in a position where it is liable to mechanical damage. The protective arrangements are required to be capable of being removed to enable inspection

2.5.2. Protection of Electrical Equipment

The routing of pipes in the vicinity of switchboards and other electrical equipment is required to be avoided as far as possible. Care should be taken when such a routing is necessary to ensure that no flanges or joints are installed over or near the equipment unless provisions are made to prevent any leakage from damaging the equipment or creating a hazard for personnel.

2.5.3. Provisions for Expansion and Contraction of Piping

Provisions are required to be made to take care of expansion and contraction of piping due to temperature and pressure variations as well as working of the hull. Suitable provisions include, but are not limited to, piping bends, offsets, elbows and changes in direction of the pipe routing or expansion joints.

Where expansion joints are used, the following requirements apply:

- i. *Pipe support*: Adjoining pipes are required to be suitably supported so that the expansion joints do not carry any significant pipe weight.
- ii. *Alignment*: Expansion joints shall not be used to make up for piping misalignment errors. Misalignment of an expansion joint reduces the rated movements and can induce severe stresses into the joint material, thus causing reduced service life. Alignment is required to be within tolerances as specified by the expansion joint manufacturer.
- iii. *Anchoring*: Expansion joints shall be installed as close as possible to an anchor point. The control rods may be installed on the expansion joint where an anchoring system is not used, to prevent excessive movements from occurring due to pressure thrust of the line.
- iv. *Mechanical damage*: The expansion joints are required to be protected against mechanical damage where it is necessary.
- v. *Accessible location*: Expansion joints are required to be installed in accessible locations to permit regular inspection and/or periodic servicing.
- vi. *Mating flange*: Mating flanges are to be clean and usually of the flat faced type. The use of a ring gasket is permitted when attaching beaded end flange expansion joints to raised face flanges. Rubber expansion joints with beaded end flange shall not be installed next to wafer type check or butterfly valves. Serious damage to the rubber flange bead can occur due to lack of flange surface and/or bolt connection.

2.5.4. Mechanical Joints

In accordance with the manufacturer's assembly instructions, the installation of mechanical pipe joints, as covered by Section [2.3.3.5] and [2.3.6], is to be done. Where special tools and gauges are required for installation of the joints, these are to be specified and supplied as necessary by the manufacturer. These special tools shall be kept onboard.

2.5.5. Piping Penetrations Through Bulkheads, Decks and Tank Tops

2.5.5.1. Watertight Integrity

The penetrations are required to be made by methods which will maintain the watertight integrity, where it is necessary for pipes to penetrate watertight bulkheads, decks or tank tops. For this purpose, bolted connections are to have bolts threaded into the plating from one side; through bolts shall not be used. Welded connections are either to be welded on both sides or to have full penetration welds from one side.

2.5.5.2. Fire Tight Integrity

The penetrations are required to be made by approved methods which will maintain the same degree of fire tight or smoke tight integrity, where pipes penetrate bulkheads, decks or tank-tops which are required to be fire tight or smoke tight.

2.5.5.3. Collision Bulkhead Penetrations

- a) *Allowed Penetration*: A collision bulkhead may be penetrated only as follows.
- i. Except as provided in Section [2.5.5.3 (a) ii)], the collision bulkhead may be pierced below the bulkhead deck by not more than one pipe for dealing with fluid in the forepeak tank, provided that the pipe is fitted with a screw down or butterfly valve capable of being operated from above the bulkhead deck; the valve chest being secured to the collision bulkhead inside the forepeak.
 - ii. If the forepeak is divided to hold two kinds of liquids, the collision bulkhead may be pierced below the margin line by two pipes, each of which is fitted as required by (i), provided there is no practical alternative to the fitting of such a second pipe and that, having regard to the additional subdivision provided in the forepeak, the safety of the vessel is maintained.
- b) *Penetrations Details*. Piping penetrating collision bulkheads shall comply with the following requirements:
- i. Pipes which penetrate a collision bulkhead are required to be fitted with valves complying with the following:
 - The valves shall be secured directly to the collision bulkhead inside the forepeak. Alternatively, the valves may be located outside of the forepeak tank provided they are secured to the after side of the collision bulkhead and the valves are readily accessible at all times. These valves are not to be located in a cargo space.
 - The valves are to be operable (open and close) from a position above the bulkhead deck and are to have open/closed indicators locally and above the bulkhead deck, Refer Section [2.3.7.3 (i)].
 - Gray cast iron valves are not acceptable. The use of nodular iron valve is acceptable, refer Section [2.2.2.4].
 - ii. No valves or cocks for sluicing (draining) are to be fitted on a collision bulkhead.

2.5.5.4. Valve in Watertight Bulkhead for Sluicing Purposes

The valves are to be readily accessible at all times and are to be operable (open and close) from a position above the bulkhead deck, where valves are fitted directly onto watertight bulkheads without piping on either side for sluicing, drainage or liquid transfer. In order to show whether the valves are open or closed, indicators shall be provided.

2.5.6. Protection from Overpressure

2.5.6.1. General

Each piping system or part of a system which may be exposed to a pressure greater than that for which it is designed is to be protected by a relief valve from over-pressurization. Other protective devices, such as bursting discs, may be considered for some systems.

2.5.6.2. System Pressurized by Centrifugal Pumps

The valves are not necessary, where systems are served only by centrifugal pumps such that the pressure delivered by the pump cannot exceed the design pressure of the piping.

2.5.6.3. Relief Valve Discharges

Relief valves are to be arranged to discharge back to the suction side of the pump or to a tank for systems conveying flammable liquids or gases. The relief valve of a CO₂ system is required to discharge outside of the CO₂ container storage compartment. In all cases, while discharging directly to the atmosphere, the discharge is not to impinge on other piping or equipment and is to be directed away from areas used by personnel.

2.5.6.4. Setting

Relief valves are required to be set at pressures not exceeding the piping design pressure. For hydraulic systems, refer Section [6.2.4.2]; and for steering gear hydraulic piping systems, refer Ch-6, Sec-5/[5.1.6].

2.5.6.5. Pressure Vessels Associated with Piping System

A pressure vessel, which can be isolated from piping system relief valves, is required to have another relief valve fitted either directly on the pressure vessel or between the pressure vessel and the isolation valve.

2.5.7. Temperature and Pressure Sensing Devices

2.5.7.1. Temperature

Thermometer wells are required to be used, where thermometers or other temperature sensing devices are fitted in piping systems, so that the devices can be removed without impairing the integrity of the pressurized system.

2.5.7.2. Pressure

Valves are to be provided, where pressure gauges or other pressure sensing devices are fitted in piping systems, so that the devices can be isolated and removed without impairing the integrity of the pressurized system.

2.5.7.3. Tanks

Pressure, temperature and level sensing devices installed on tanks at locations where they are subjected to a static head of liquid are required to be fitted with valves or are arranged in such a way that they may be removed without emptying the tank.

2.5.8. Shell Connections

2.5.8.1. General

Positive closing valves are required to be fitted at the shell at inlets (including sea chests) and discharges. As required by Ch-9, Sec-2/ [2.2], discharges from scuppers and drains are to be fitted with valves. A distance piece can be provided where it is impractical to install the valve directly at the shell. Materials readily rendered ineffective by heat shall not be used for connection to the shell where the failure of the material in the event of a fire would give rise to danger of flooding. Discharges at the shell shall be located in such a way so as to prevent any discharge from falling onto a lowered lifeboat or rescue boat

2.5.8.2. Valves

Shell valves are required to comply with the following requirements:

- i. Gray cast iron valves I not be used as shell valves. Nodular iron valves are acceptable, refer Section [2.2.2.4].
- ii. Shell valves are required to be installed in such a way that the inboard piping can be removed and the valve can remain in place without impairing the watertight integrity. Wafer-type butterfly valves are not acceptable. However, butterfly valves with lugs may be accepted.
- iii. Controls for positive closing valves are required to be readily accessible and controllable from the floors or gratings. Open or closed indicators are required to be provided, refer Section [2.3.7.3 (i)].
- iv. Power-operated valves are required to be arranged for manual operation in the event of a failure of the power supply.
- v. Refer Section [2.4.2.2], for hydrostatic tests.

2.5.8.3. Connection Details

Studs can be used, where the valve is connected directly to the shell, if a reinforcing ring of substantial thickness (a heavy pad) is welded to the inside of the shell. In this case, the studs are required to be threaded into the reinforcing ring and should not penetrate the shell.

Where a distance piece is fitted between the shell and the shell valves, the pipe where substantial thickness is required to be of steel and of wall thickness not less than that specified below:

Nominal Size, d	Wall Thickness
= or < 80mm(3.15 in)	Not less than 7 mm (0.276 in.)
180mm(7.1 in)	Not less than 10 mm (0.394 in.)
= or > 220(8.7 in)	Not less than 12.5 mm (0.492 in.)
d = external diameter of pipes	

For intermediate nominal pipe sizes, where substantial thickness is not required, the sizes to be obtained by linear interpolation as follows:

Nominal Size, d	Wall Thickness
= or < 155mm(6.1 in)	Not less than 4.5 mm (0.177 in.)
= or > 230(9.1 in)	Not less than 6.0 mm (0.236 in.)
d = external diameter of pipes	

In general, the pipe is required to be as short as possible. The pipe is required to extend through the shell plating and should be welded on both sides or with full strength welds from one side. Consideration is required to be given to supporting the pipe to the surrounding structure.

Where an inlet or discharge is required to pass through a wing tank or a cargo hold, the valve may be installed on the inner bulkhead or similar location provided that the pipe between the valve and the shell is of wall thickness not less than as specified above, with all joints welded and with built-in provision for flexibility. Such pipes, where located in a cargo hold, should have protection from mechanical damage.

Threaded connections are not considered an acceptable method of connection outboard of the shell valves.

2.5.8.4. Boiler Blow-off

Boiler and evaporator blow-off overboard discharges shall have doubling plates or heavy inserts fitted. The pipe is required to extend through the doubling and the shell.

2.5.8.5. Sea Chests

Sea chests shall comply with the following requirements:

- i. Located in positions where the possibility of blanking off the suction is minimized;
- ii. Fitted with strainer plates through which the clear area is to be at least 1.5 times the area of the inlet valves;
- iii. Means are provided for clearing the strainer plates, such as by using compressed air or low pressure steam;

2.5.9. Control of Static Electricity

In order to prevent dangerous build-up of static charges resulting from the flow of fluid in piping, the following items are to be earthed (grounded) to the hull such that the resistance between any point on the piping and the hull (across joints, pipe to hull) does not exceed 1 MΩ:

- Piping and independent tanks containing fluids having flash point of 60°C (140°F) or less.
- Piping that is routed through hazardous areas.

This can be achieved if the items are directly, or via their supports, either welded or bolted to the hull. Bonding straps are required for items not permanently connected to the hull, for example:

- Independent cargo tanks
- Piping which is electrically insulated from the hull
- Piping which has spool pieces arranged for removal

Bonding straps are to be:

- Installed in visible locations
- Protected from mechanical damage
- Made of corrosion-resistant material

This requirement does not apply to tank containers.

2.5.10. Accessibility of Valves

Where the valves are required by the Rules to be readily accessible, their controls, during normal operating conditions, are to be as follows:

- i. Within operator's reach;
- ii. Located in a space normally entered without using tools; and
- iii. Clear of or protected from obstructions, moving equipment and hot surfaces that prevent operation or servicing.

For propulsion machinery spaces intended for centralized or unattended operations (**CCS/UM** notation), the location of the controls of any valve serving a sea inlet, a discharge below the waterline or an emergency bilge system [Refer also Ch-9, Sec-3/[3.3.5 (c)]] is to be such 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 are to be made to operate the controls from a position above such level.

2.5.11. Common Overboard Discharge

In general, various types of systems which discharge overboard shall not be interconnected without special approval; that is, closed pumping systems, deck scuppers, soil lines or sanitary drains shall not have a common overboard discharge.

Table 8.2.2: Allowable Stress Values *S* for Steel Pipes; N/mm² (kgf/mm², psi) (Refer Section 2.3.1.2)

Material INTLREG Gr. ASTM Gr. Nominal Composition	Tensile Strength N/mm ² Kgf/mm ² psi	Service Temperature									
		-29°C (0°F) to 344°C (650°F)	372°C 700°F	399°C 750°F	427°C 800°F	455°C 850°F	483°C 900°F	510°C 950°F	538°C 1000°F	566°C 1050°F	593°C 1100°F
M		0.8	0.8	0.8	0.8	0.8	0.8	1.0	1.4	1.4	1.4
Gr.1 A53-FBW	310 31.5 45000	46.9 4.78 6800	46.6 4.75 6500								
Gr. 2 A53-A, ERW C, Mn	330 33.7 48000	70.3 7.17 10200	68.3 6.96 9900	62.8 6.40 9100	53.1 5.41 7700						
Gr.2 A53-A, SML C, Mn	330 33.7 48000	82.8 8.44 12000	80.6 8.22 11700	73.7 7.52 10700	62.1 6.33 9000						
Gr.3 A53-B, ERW C, Mn	415 42 60000	88.3 9.0 12800	84.1 8.58 12200	75.8 7.73 11000	63.4 6.47 9200						
Gr.3 A53-B, SML C, Mn	415 42 60000	103.5 10.55 15000	99.2 10.12 14400	89.6 9.14 13000	74.4 7.59 10800						
Gr.4 A106-A C, Mn, Si	330 33.7 48000	82.8 8.44 12000	80.7 8.23 11700	73.7 7.52 10700	62.1 6.33 9000						
Gr.5 A106-B C, Mn, Si	415 42 60000	103.5 10.55 15000	99.2 10.12 14400	89.6 9.14 13000	74.4 7.59 10800						
Gr.6 A355-P1 1/2 Mo	380 39 55000	95.1 9.70 13800	95.1 9.70 13800	95.1 9.70 13800	93.1 9.49 13500	90.3 9.21 13100					
Gr. 7 A335-P2 1/2 Cr 1/2 Mo	380 39 55000	95.1 9.70 13800	95.1 9.70 13800	95.1 9.70 13800	93.1 9.49 13500	90.3 9.21 13100	88.3 9.0 12800	63.4 6.47 9200	40.7 4.15 5900		
Gr. 8 A135-A	330 33.7 48000	70.3 7.17 10200	68.3 6.96 9900	62.8 6.40 9100	53.1 5.41 7700						
Gr. 9 A135-B	415 42 60000	88.3 9.0 12800	84.1 8.58 12200	75.8 7.73 11000	63.4 6.47 9200						

PART 5A
CHAPTER 8

INTLREG Rules and Regulations for Classification of Steel Vessels

Gr.11 A335-P11 1-1/4 Cr 1/2 Mo	415 42 60000	103.5 10.55 15000	103.5 10.55 15000	103.5 10.55 15000	103.5 10.55 15000	99.2 10.12 14400	90.3 9.21 13100	75.8 7.73 11000	45.4 4.64 6600	28.2 2.88 4100	20.7 2.11 3000
Gr. 12 A335-P12 1 Cr 1/2 Mo	415 42 60000	103.5 10.55 15000	103.5 10.55 15000	103.5 10.55 15000	101.7 10.37 14750	91.9 9.98 14200	90.3 9.21 13100	75.8 7.73 11000	45.5 4.64 6600	28.2 2.88 4100	19.3 1.97 2800
Gr. 13 A335-P22 2-1/4 Cr 1 Mo	415 42 60000	103.5 10.55 15000	103.5 10.55 15000	103.5 10.55 15000	103.5 10.55 15000	99.2 10.12 14400	90.3 9.21 13100	75.8 7.73 11000	53.7 5.48 7800	35.9 3.66 5200	28.9 2.95 4200
Notes 1. Intermediate values of S and M may be determined by interpolation. 2. For grades of pipe other than those given in this Table, S values may be obtained from ANSI/ASME B31.1 Code for Pressure Piping. 3. Consideration to be given to the possibility of graphite formation in the following steels: Carbon steel above 425°C (800°F); carbon-molybdenum steel above 468°C (875°F); chrome-molybdenum steel (with chromium under 0.60%) above 524°C (975°F).											

Table 8.2.3: Allowable Stress S for Copper and Copper Alloy Pipes (Refer [2.3.1.1])

Material	Minimum Tensile Strength	Allowable Stress S, N/mm ² , kgf/mm ² , psi										
	N/mm ² kgf/mm ² psi	50°C 122°F	75°C 167°F	100°C 212°F	125°C 257°F	150°C 302°F	175°C 347°F	200°C 392°F	225°C 437°F	250°C 482°F	275°C 527°F	300°C 572°F
Copper	215 22 31200	41 4.2 5950	41 4.2 5950	40 4.1 5800	40 4.1 5800	34 3.5 4930	27.5 2.8 3990	18.5 1.9 2680				
Brass	325 33 47100	78 8.0 11310	78 8.0 11310	78 8.0 11310	78 8.0 11310	78 8.0 11310	51 5.2 7395	24.5 2.5 3550				
Copper nickel (with less than 10% nickel)	275 28 39900	68 6.9 9860	68 6.9 9860	67 6.8 9715	65.5 6.7 9500	64 6.5 9280	62 6.3 8990	59 6.0 8555	56 5.7 8120	52 5.3 7540	48 4.9 6960	44 4.5 6380
Copper nickel (with 10% or more nickel)	365 37.2 52900	81 8.3 11745	79 8.1 11455	77 7.8 11165	75 7.6 10875	73 7.4 10585	71 7.2 10295	69 7.0 10005	67 6.8 9715	65.5 6.7 9500	64 6.5 9280	62 6.3 8990
Notes: 1. Intermediate values are to be determined by interpolation 2. Materials not listed in this table can be used upon approval of the permissible stress												

Table 8.2.4: Corrosion Allowance c for Steel Pipes (Refer Section [2.3.1.1])

Piping Service	Corrosion Allowance, c	
	mm	in.
Superheated steam	0.3	0.012
Saturated steam	0.8	0.032
Steam heating coils in cargo tanks	2.0	0.079
Feed water for boilers in open circuits	1.5	0.059
Feed water for boilers in closed circuits	0.5	0.020
Blow down for boilers	1.5	0.059
Compressed air	1.0	0.039

INTLREG Rules and Regulations for Classification of Steel Vessels

Hydraulic oil	0.3	0.012
Lubricating oil	0.3	0.012
Fuel oil	1.0	0.039
Cargo oil	2.0	0.079
Refrigerant	0.3	0.012
Fresh water	0.8	0.032
Sea water	3.0	0.118
Notes: 1. The corrosion allowance may be reduced by 50% where pipes and any integral joints are protected against corrosion by means of coating, lining, etc. 2. For pipes passing through tanks, the proper additional corrosion allowance is to be taken into account for the external medium. 3. For special alloy steels which are considered to be corrosion resistant, the corrosion allowance can be reduced to zero.		

Table 8.2.5: Minimum Wall Thickness for Steel Pipes (Refer Section [2.3.1.3])

Nom. Size mm (in.)	Outside Dia. mm (inch.)	Wall Thickness, mm (inch.)				
		A	B	C	D	E
6 (1/8)	10.2 (0.405)	1.6 (0.063)				
8 (1/4)	13.5 (0.54)	1.8 (0.071)				
10 (3/8)	17.2 (0.675)	1.8 (0.071)				
15 (1/2)	21.3 (0.84)	2 (0.079)	2.8 (0.11)			
20 (3/4)	26.9 (1.05)	2 (0.079)	2.8 (0.11)			
25 (1)	33.7 (1.315)	2 (0.079)	3.2 (0.126)	4.2 (0.165)	6.3 (0.248)	6.3 (0.248)
32 (1 1/4)	42.4 (1.66)	2.3 (0.091)	3.5 (0.138)	4.2 (0.165)	6.3 (0.248)	6.3 (0.248)
40 (1 1/2)	48.3 (1.9)	2.3 (0.091)	3.5 (0.138)	4.2 (0.165)	6.3 (0.248)	6.3 (0.248)
50 (2)	60.3 (2.375)	2.3 (0.091)	3.8 (0.15)	4.2 (0.165)	6.3 (0.248)	6.3 (0.248)
65 (2 1/2)	76.1 (2.875)	2.6 (0.102)	4.2 (0.165)	4.2 (0.165)	6.3 (0.248)	7 (0.276)
80 (3)	88.9 (3.5)	2.9 (0.114)	4.2 (0.165)	4.2 (0.165)	7.1 (0.28)	7.6 (0.3)
90 (3 1/2)	101.6 (4)	2.9 (0.114)	4.5 (0.177)	4.5 (0.177)	7.1 (0.315)	8.1 (0.318)
100 (4)	114.3 (4.5)	3.2 (0.126)	4.5 (0.177)	4.5 (0.177)	8 (0.315)	8.6 (0.337)
125 (5)	139.7 (5.563)	3.6 (0.142)	4.5 (0.177)	4.5 (0.177)	8 (0.346)	9.5 (0.375)
150 (6)	168.3 (6.625)	4 (0.157)	4.5 (0.177)	4.5 (0.177)	8.8 (0.346)	11 (0.432)
200 (8)	219.1 (8.625)	4.5 (0.177)	5.8 (0.228)	5.8 (0.228)	8.8 (0.346)	12.5 (0.5)
250 (10)	273 (10.75)	5 (0.197)	6.3 (0.248)	6.3 (0.248)	8.8 (0.346)	12.5 (0.5)
300 (12)	323.9 (12.75)	5.6 (0.22)	6.3 (0.248)	6.3 (0.248)	8.8 (0.346)	12.5 (0.5)
350 (14)	355.6 (14)	5.6 (0.22)	6.3 (0.248)	6.3 (0.248)	8.8 (0.346)	12.5 (0.5)
400 (16)	406.4 (16)	6.3 (0.248)	6.3 (0.248)	6.3 (0.248)	8.8 (0.346)	12.5 (0.5)
450 (18)	457 (18)	6.3 (0.248)	6.3 (0.248)	6.3 (0.248)	8.8 (0.346)	12.5 (0.5)
Columns: A. Pipes in general, except where Columns B, C, D or E are applicable B. Bilge, ballast and sea water pipes except those covered by column D. C. Vent, overflow and sounding pipes for integral tanks except those covered by column D (Refer Notes 6 and 7) and fuel oil pipes passing through fuel oil tanks. D. Bilge, ballast, vent, overflow and sounding pipes passing through fuel tanks (Refer Notes 6, 7 and 8). Bilge, vent, overflow, sounding and fuel pipes passing through ballast tanks (Refer Notes 6, 7 and 8). E. Ballast pipes passing through cargo oil tanks (Refer Note 9). Cargo pipes passing through ballast tanks (Refer Note 9).						

Notes:

1. The minimum thicknesses are the smallest thicknesses selected from those thicknesses specified in ISO 4200 Series 1, JIS, or ASTM Standards. Notwithstanding the requirements of this Table, diameters and thicknesses specified in other recognized standards will also be acceptable.
2. For threaded pipes, where approved, the thickness is to be measured to the bottom of the thread.
3. For pipes protected against corrosion, a reduction of thickness not exceeding 1 mm (0.039 in.) may be considered.
4. For minimum wall thicknesses of copper, copper alloy and austenitic stainless steel pipes, Refer Table 8.2.6 & Table 8.2.7.
5. This table is not applicable to exhaust gas pipes.
6. For that part of a vent pipe exposed to weather, pipe wall is to be as specified in Ch-9, Sec-5/ [5.2.2 (a)].
7. The thickness indicated for sounding pipes is for the portions outside the tanks to which the pipe is opened. Within bilge well, to which the pipe is not opened, the thickness is to be extra-heavy; Refer Ch-9, Sec-6/[6.2.3 (iv)].
8. For bilge pipes, column D thickness applies only where required by Ch-9, Sec-3/ [3.3.4 (c)].
9. For nominal sizes larger than 450 mm (18 in.), the minimum wall thickness specified for 450 mm (18 in.) nominal size pipe is applicable.

Table 8.2.6: Minimum Wall Thickness for Copper and Copper Alloy Pipes (Refer Section [2.3.1.3])

External Diameter		Minimum Wall Thickness			
		Copper		Copper Alloy	
mm	in.	mm	in.	mm	in.
8 – 10	0.30 – 0.40	1	0.039	0.8	0.031
12 – 20	0.475 – 0.80	1.2	0.047	1	0.039
25 – 44.5	1.00 – 1.75	1.5	0.059	1.2	0.047
50 – 76.1	2.00 – 3.00	2	0.079	1.5	0.059
88.9 – 108	3.50 – 4.25	2.5	0.098	2	0.079
133 – 159	5.25 – 6.25	3	0.118	2.5	0.098
193.7 – 267	7.625 – 10.50	3.5	0.138	3	0.118
273 – 457.2	10.75 – 18.00	4	0.157	3.5	0.138
470	18.5	4	0.157	3.5	0.138
508	20	4.5	0.177	4	0.157
Note: The above minimum thicknesses are taken from those thicknesses available in ISO Standards. Diameter and thickness according to other recognized standards will be accepted.					

Table 8.2.7: Minimum Wall Thickness for Austenitic Stainless Steel Pipes, (Refer Section [2.3.1.3])

External Diameter		Minimum Wall thickness	
mm	in.	mm	in.
10.2 – 17.2	0.40 – 0.68	1	0.039
21.3 – 48.3	0.84 – 1.90	1.6	0.063
60.3 – 88.9	2.37 – 3.50	2	0.079
114.3 – 168.3	4.50 – 6.63	2.3	0.091
219.1	8.63	2.6	0.102
273	10.75	2.9	0.114
323.9 – 406.4	12.75 – 16.00	3.6	0.142
Over 406.4	Over 16.00	4	0.157

Note: Diameters and thicknesses according to national or international standards may be accepted.

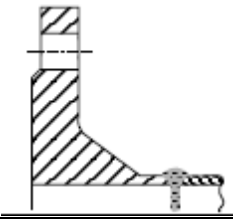
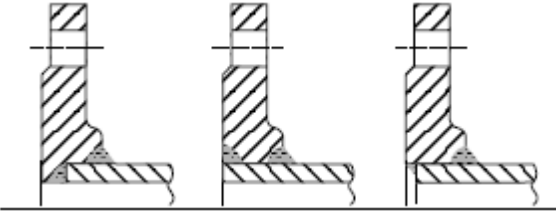
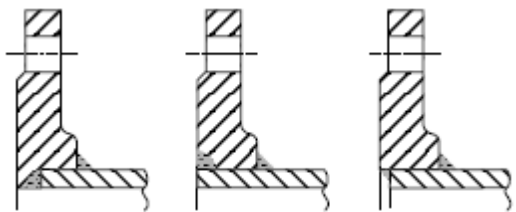
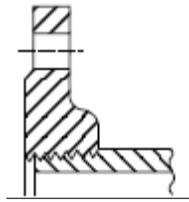
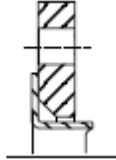
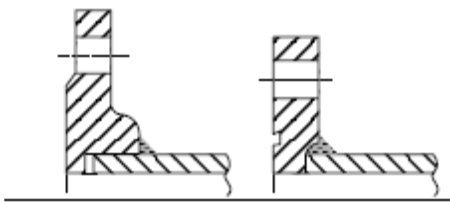
Flange type	Typical Configuration
Type A Weld neck flange, raised face or flat face with ring type gasket.	
Type B Slip-on welded hub (or without hub) flange; attached to pipe with at least a groove weld deposited from the back of the flange and a fillet weld or equivalent on the other side; raised face or flat face with ring type gasket.	
Type C Slip-on welded hub (or without hub) flange; attached to pipe with double fillet welds or equivalent; raised face or flat face with ring type gasket.	 (Must be with hub)
Type D Threaded hub flange; attached to pipe by tapered threads; some designs require the pipe be expanded, or the threaded ends be seal-welded; raised face or flat face with ring type gasket.	
Type E Unattached flange; no attachment to pipe.	
Type G Socket-welded flange; attached to pipe by single fillet weld, with or without groove weld, deposited from one side of the flange only; raised face (with gasket) or flat face (with O-ring).	
Notes: 1. "Integral" flanges are designs where the flange is cast or forged integrally with the pipe wall, or otherwise welded in such a manner that the flange and the pipe wall are considered to be the equivalent of an integral structure. 2. "Loose" flanges are designs where the method of attachment of the flange to the pipe is not considered to give the mechanical strength equivalent of an integral flange, or in which the flange has no direct connection to the pipe wall. Slip-on welded flange attached to pipe with fillet welds only is generally considered a loose flange.	

Table 8.2.8: Typical Flange Types (Refer Section [2.3.3.4])

Table 8.2.9: Limitation of Use for Typical Flange Types(Refer Section [2.3.3.4])

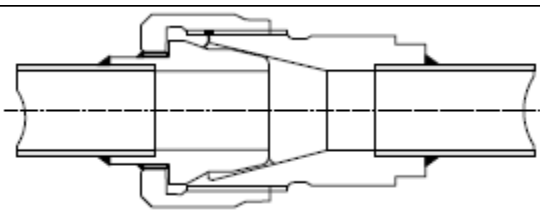
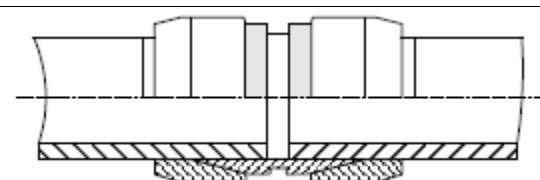
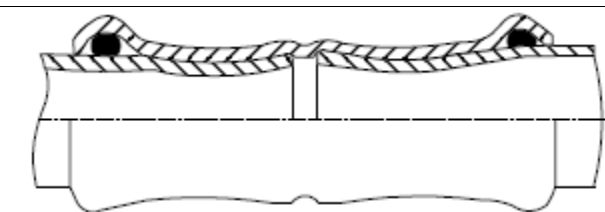
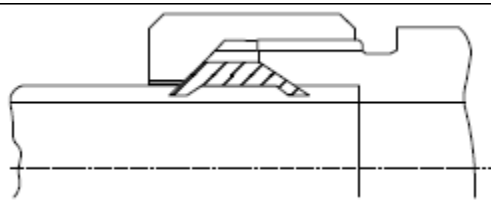
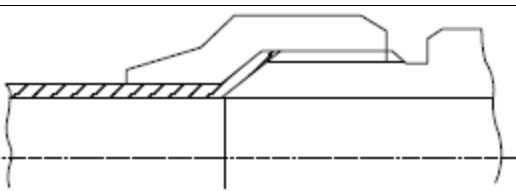
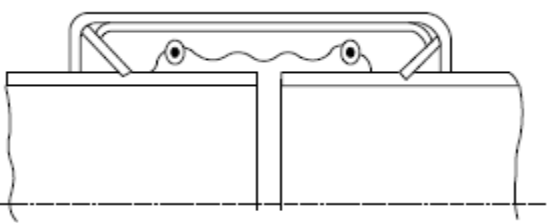
Flange Type	Class of Piping	Limitations
A	I, II, III	None
B	I, II, III	Pressure/temperature rating $\leq$ ASME B16.5 Class 300 or equivalent recognized national standard. For steam piping additionally limited to pipe sizes $d \leq$ NPS 100 mm (4 in.) Slip-on flanges for higher ratings, which comply with ASME or other recognized standards, will be subject to special consideration. [Ref. Part-2, Ch-3, [3.3.4], [4.3.4]]
C	I, II, III	Same as for type B above.
D	II, III	Not for toxic fluid, corrosive fluid, volatile flammable liquid (Refer note), liquefied gas, fuel oil, lubricating oil, thermal oil and flammable hydraulic oil. For other services as per limitations for type B above.
E	II, III	Not for toxic fluid, corrosive fluid, volatile flammable liquid (Refer note), liquefied gas, fuel oil, lubricating oil, thermal oil, flammable hydraulic oil and steam systems. For water and open-ended lines. For other services, Refer Section [2.3.9].
G	I, II, III	Pressure/temperature rating $\leq$ ASME B16.5 Class 600 and NPS $\leq$ 80 mm (3 in.), or equivalent recognized national standard. Pressure/temperature rating $\leq$ ASME B16.5 Class 1500 and NPS $\leq$ 65 mm (2.5 in.), or equivalent recognized national standard Not to be used in steering gear and controllable pitch propeller systems. [Ref. Part-2, Ch-3, [4.3.4]]
Note: Volatile flammable liquid is a flammable liquid heated to above its flash point, or a flammable liquid having a flash point at or below 60°C (140°F) other than cargo oil.		

Table 8.2.10: Commercial Pipe Sizes and Wall Thicknesses

Nominal Pipe size	Outer diameter in mm	Nominal Wall Thickness (in., mm)					
		Standard	Sch.40	Extra Strong	Sch. 80	Sch.160	Double Extra Strong
1/8 in. 6 mm	0.405 10.287	0.068 1.727	0.068 1.727	0.095 2.413	0.095 2.413		
1/4 in. 8 mm	0.54 13.716	0.088 2.235	0.088 2.235	0.119 3.023	0.119 3.023		
3/8 in. 10 mm	0.675 17.145	0.091 2.311	0.091 2.311	0.126 3.2	0.126 3.2		
1/2 in. 15 mm	0.84 21.336	0.109 2.769	0.109 2.769	0.147 3.734	0.147 3.734	0.188 4.775	0.294 7.468
3/4 in. 20 mm	1.05 26.67	0.113 2.87	0.113 2.87	0.154 3.912	0.154 3.912	0.219 5.563	0.308 7.823
1 in. 25 mm	1.315 33.401	0.133 3.378	0.133 3.378	0.179 4.547	0.179 4.547	0.25 6.35	0.358 9.903
1 1/4 in. 32 mm	1.66 42.164	0.14 3.556	0.14 3.556	0.191 4.851	0.191 4.851	0.25 6.35	0.382 9.703
1 1/2 in. 40 mm	1.9 48.26	0.145 3.683	0.145 3.683	0.2 5.08	0.2 5.08	0.281 7.137	0.4 10.16
2 in. 50 mm	2.375 60.325	0.154 3.912	0.154 3.912	0.218 5.537	0.218 5.537	0.344 8.738	0.436 11.074
2 1/2 in. 65 mm	2.875 73.025	0.203 5.156	0.203 5.156	0.276 7.01	0.276 7.01	0.375 9.525	0.552 14.021
3 in. 80 mm	3.5 88.9	0.216 5.486	0.216 5.486	0.3 7.62	0.3 7.62	0.438 11.125	0.6 15.24
3 1/2 in. 90 mm	4 101.6	0.226 5.74	0.226 5.74	0.318 8.077	0.318 8.077		
4 in. 100 mm	4.5 114.3	0.237 6.02	0.237 6.02	0.337 8.56	0.337 8.56	0.531 13.487	0.674 17.12
5 in. 125 mm	5.563 141.3	0.258 6.553	0.258 6.553	0.375 9.525	0.375 9.525	0.625 15.875	0.75 19.05
6 in. 150 mm	6.625 168.275	0.28 7.112	0.28 7.112	0.432 10.973	0.432 10.973	0.719 18.263	0.864 21.946
8 in. 200 mm	8.625 219.075	0.322 8.179	0.322 8.179	0.5 12.7	0.5 12.7	0.906 23.012	0.875 22.225
10 in. 250 mm	10.75 273.05	0.365 9.271	0.365 9.271	0.5 12.7	0.594 15.088	1.125 28.575	1 25.4
12 in. 300 mm	12.75 323.85	0.375 9.525	0.406 10.312	0.5 12.7	0.688 17.475	1.312 33.325	1 25.4
14 in. 350 mm	14 355.6	0.375 9.525	0.438 11.125	0.5 12.7	0.75 19.05	1.406 35.712	
16 in. 400 mm	16 406.4	0.375 9.525	0.5 12.7	0.5 12.7	0.844 21.438	1.594 40.488	
18 in. 450 mm	18 457.2	0.375 9.525	0.562 14.275	0.5 12.7	0.938 23.825	1.781 45.231	
20 in. 500 mm	20 508	0.375 9.525	0.594 15.088	0.5 12.7	1.031 26.187	1.969 50.013	
22 in. 550 mm	22 558.8	0.375 9.525		0.5 12.7	1.125 28.575	2.125 53.975	
24 in. 600 mm	24 609.6	0.375 9.525	0.688 17.475	0.5 12.7	1.219 30.963	2.344 59.538	

These pipe sizes and wall thicknesses are according to ANSI B36.10.

Table 8.2.11: Examples of Mechanical Joints

Pipe Unions	
Welded and Brazed Types	
Compression Couplings	
Swage Type	
Press Type	
Bite Type	
Flared Type	
Slip-on Joints	
Grip Type	

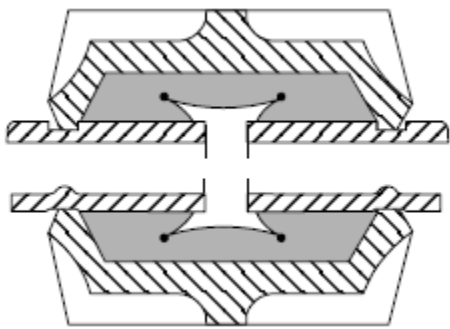
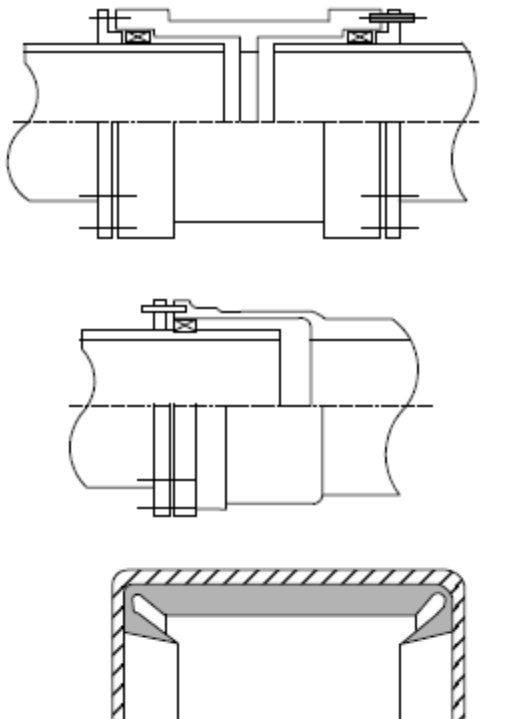
Machine Grooved Type	
Slip Type	

Table 8.2.12: Application of Mechanical Joints

The following table indicates systems where the various kinds of joints may be accepted. However, in all cases, acceptance of the joint type is to be subject to approval for the intended application, and subject to conditions of the approval and applicable Rules.

Systems		Kind of Connections		
		Pipe Unions	Compression Couplings (Refer note 6)	Slip-on Joints
Flammable Fluids (Flash Point ≤ 60°)				
1	Cargo oil lines	Y	Y	Y (Refer note 5, 11)
2	Crude oil washing lines	Y	Y	Y (Refer note 5)
3	Vent lines	Y	Y	Y (Refer note 3, 13)
Inert gas				
4	Water seal effluent lines	Y	Y	Y (Refer note 16)
5	Scrubber effluent lines	Y	Y	Y
6	Main lines	Y	Y	Y (Refer note 2, 5)
7	Distributions lines	Y	Y	Y (Refer note 5)
Flammable Fluids (Flash Point > 60°)				
8	Cargo oil lines	Y	Y	Y (Refer note 5, 11)
9	Fuel oil lines	Y	Y	Y (Refer note 2, 3)
10	Lubricating oil lines	Y	Y	Y (Refer note 2, 3)
11	Hydraulic oil	Y	Y	Y (Refer note 2, 3, 12)
12	Thermal oil	Y	Y	Y (Refer note 2, 3)
Sea Water				
13	Bilge lines	Y	Y	Y (Refer note 1, 8)
14	Fire main and water spray	Y	Y	Y (Refer note 3, 7)
15	Foam system	Y	Y	Y (Refer note 3, 7)
16	Sprinkler system	Y	Y	Y (Refer note 3, 7)
17	Ballast system	Y	Y	Y (Refer note 1, 9, 10)
18	Cooling water system	Y	Y	Y (Refer note 1)
19	Tank cleaning services	Y	Y	Y
20	Non-essential systems	Y	Y	Y
21	Cooling water system	Y	Y	Y (Refer note 1, 8)
22	Condensate return	Y	Y	Y (Refer note 1, 8)
23	Non-essential system	Y	Y	Y
Sanitary/Drains/Scuppers				
24	Deck drains (internal)	Y	Y	Y (Refer note 4)
25	Sanitary drains	Y	Y	Y
26	Scuppers and discharge (overboard)	Y	Y	N (Refer note 14)
Sounding/Vent				
27	Water tanks/Dry spaces	Y	Y	Y
28	Oil tanks (f.p.> 60°C)	Y	Y	Y (Refer note 2, 3)

Miscellaneous				
29	Starting/Control air (Refer note 1)	Y	Y	N
30	Service air (non-essential)	Y	Y	Y
31	Brine	Y	Y	Y
32	CO ₂ system (Refer note 1)	Y	Y	N
33	Steam	Y	Y	Y (Refer note 15)

Abbreviations:

Y – Application is allowed

N – Application is not allowed

Footnotes:

1. Inside machinery spaces of category A – only approved fire resistant types.
2. Not 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.
4. Above freeboard deck only.
5. In pump rooms and open decks – only approved fire resistant types.
6. If Compression Couplings include any components which readily deteriorate in case of fire, they are to be of approved fire resistant type as required for Slip-on joints.
7. In accessible locations at all times under normal condition.
8. In accessible locations in machinery spaces, container holds carrying non-dangerous goods, shaft tunnels, pipe, tunnels, etc.
9. In accessible locations in machinery spaces, shaft tunnels, pipe tunnels, etc. In pipelines located within other ballast tanks. For tankers, in clean or dirty ballast lines provided lines terminate in cargo pump room.
10. Inside pump room – only with approved fire resistant types.
11. Within cargo tanks.
12. Not permitted in steering gear hydraulic systems, otherwise Class III systems only.
13. On vent risers on decks only.
14. Accessible location inboard of required shell valve(s) may be permitted. Slip-on joints are not permitted where there are no shell valve(s), for example, when outboard end > 450 mm below freeboard deck or outboard end < 600 mm above summer waterline. For such instances, the overboard piping is required to be of substantial thickness per definition in Section [2.5.8.3].
15. Permitted in Class III piping in machinery spaces of Category A, other machinery spaces, accommodation spaces and open deck. Additionally, on open decks restrained slip type joints only are permitted for pressures up to 10 bar (10.2 kgf/cm², 145 psi).
16. On the open deck only.

Table 8.2.13: Application of Mechanical Joints Depending Upon the Class of Piping

Type of Joints	Class of Piping Systems		
	Class I	Class II	Class III
Pipe Unions			
Welded and brazed type	Y (OD ≤ 60.3 mm)	Y (OD ≤ 60.3 mm)	Y
Compression Couplings			
Swage type	Y	Y	Y
Bite type	Y (OD ≤ 60.3 mm)	Y (OD ≤ 60.3 mm)	Y
Flared type	Y (OD ≤ 60.3 mm)	Y (OD ≤ 60.3 mm)	Y
Press type	N	N	Y
Slip-on joints			
Machine grooved type	Y	Y	Y

Grip type	N	Y	Y
Slip type	N	Y	Y
Abbreviations: Y – Application is allowed N – Application is not allowed			

Table 8.2.14: Testing Requirements for Mechanical Joints

Test		Types of Mechanical Joints (Refer note 1)			Notes and References
		Compression Couplings and Pipe Unions	Slip-on Joints		
			Grip & Machine Grooved Type	Slip Type	
1	Tightness test	Y	Y	Y	Section [2.3.6.3 (a)]
2	Vibration (fatigue) test	Y	Y	N	Section [2.3.6.3 (b)]
3	Pressure pulsation test (Refer note 2)	Y	Y	N	Section [2.3.6.3 (c)]
4	Burst pressure test	Y	Y	Y	Section [2.3.6.3 (d)]
5	Pull-out test	Y	Y	N	Section [2.3.6.3 (e)]
6	Fire endurance test	Y	Y	Y	Section [2.3.6.3 (f)] If required by Section [2.3.6.1 (f)]
7	Vacuum test	Y (Refer note 3)	Y	Y	Section [2.3.6.3 (g)] for suctions lines only
8	Repeated assembly test	Y (Refer note 4)	Y	N	Section [2.3.6.3 (h)]
Notes					
1. Abbreviations: Y - Test is required N - Test is not required					
2. For use in those systems where pressure pulsation other than water hammer is expected (e.g., systems using positive displacement pumps).					
3. Except joints with metal-to-metal tightening surfaces.					
4. Except press type.					

SECTION 3 PLASTIC PIPING

Contents

3.1. Scope	360
3.2. Documents to be submitted	360
3.3. Design of Plastic Pipes.....	361
3.4. Manufacturing of Plastic Pipes	364
3.5. Plastic Pipe Bonding Procedure Qualification	364
3.6. Tests by Manufacturer – General.....	365
3.7. Tests by Manufacturer – Fire Endurance Testing of Plastic Piping in the Dry Condition (for Level 1 and Level 2)	365
3.8. Test by Manufacturer – Fire Endurance Testing of Water-filled Plastic Piping (for Level 3)	367
3.9. Tests by Manufacturer – Flame Spread.....	370
3.10 Installation of Plastic Pipes	371
3.11 Testing Onboard After Installation.....	373

3.1. Scope

Pipes and piping components made of thermoplastic or thermosetting plastic materials, with or without reinforcement, may be used in piping systems referred to in Table 8.3.1 subject to compliance with the following requirements. In order to serve the purpose of these Rules “plastic” means both thermoplastic and thermosetting plastic materials, with or without reinforcement, such as polyvinyl chloride (PVC) and fiber reinforced plastics (FRP). Plastic includes synthetic rubber and materials of similar thermo/mechanical properties.

3.2. Documents to be submitted

Rigid plastic piping should be done in accordance with a recognized national or international standard that are acceptable to INTLREG. For reviewing together with the spacing of the piping supports, specifications of the plastic piping, including thermal and mechanical properties and chemical resistance are required to be submitted.

The following information for the plastic pipes, fittings and joints are also required to be submitted for approval.

3.2.1. General Information

- a) Working temperature range
- b) Pipe and fitting dimensions
- c) Maximum internal and external working pressure
- d) Fire endurance level
- e) Intended services and installation locations
- f) Electrical conductivity
- g) Limits on flow rates
- h) Intended fluids
- i) Serviceable life
- j) Installation instructions
- k) Marking details

3.2.2. Drawings and Supporting Documentation

- i) Certificates and reports for relevant tests previously carried out. Refer Section [3.4]
- ii) Details of relevant standards. Refer Table 8.3.2 & 8.3.3
- iii) All relevant design drawings, catalogues, data sheets, calculations and functional descriptions
- iv) Fully detailed sectional assembly drawings showing pipe, fittings and pipe connections
- v) Documentation verifying the certification of the manufacturer’s quality system and that the system addresses the testing requirements in [3.3.1] through [3.3.9]. Refer [3.4] of this section.

3.2.3. Materials

- i) Resin type
- ii) A statement detailing all reinforcements employed where the reference number does not identify the mass per unit area or the strand count (Tex System or Yardage System) of a roving used in a filament winding process
- iii) Catalyst and accelerator types and concentration employed in the case of reinforced polyester resin pipes or hardeners where epoxide resins are employed
- iv) Cure/post-cure conditions: The cure and post-cure temperatures and times employed for given resin/reinforcement ratio

- v) Full information regarding the type of gel-coat or thermoplastic liner employed during construction, as appropriate
- vi) Winding angle and orientation.
- vii) Joint bonding procedures and qualification tests results. Refer [3.5] of this section.

3.3. Design of Plastic Pipes

3.3.1. Internal Pressure

A pipe is required to be designed for an internal pressure of not less than the design pressure of the system in which it will be used. The maximum internal pressure, P_{int} , for a pipe is required to be lesser of the following:

$$P_{int} = \frac{P_{sth}}{4} \text{ or } P_{int} = \frac{P_{lth}}{2.5}$$

Where;

P_{sth} = short-term hydrostatic test failure pressure

P_{lth} = long-term hydrostatic test failure pressure (> 100,000 hours)

The hydrostatic tests are to be carried out under the following standard conditions:

Atmospheric pressure = 1 bar (1 kgf/cm², 14.5 psi)

Fluid temperature = 25°C (77°F)

Relative humidity = 30%

The hydrostatic test failure pressure may be verified experimentally or determined by a combination of testing and calculation methods which are required to be submitted to INTLREG for approval.

3.3.2. External Pressure

External pressure is required to be considered for any installation which may be subjected to vacuum conditions inside the pipe or a head of liquid on the outside of the pipe. A pipe is required to be designed for an external pressure of not less than the sum of the pressure imposed by the maximum potential head of liquid outside the pipe plus full vacuum, 1 bar (1 kgf/cm², 14.5 psi), inside the pipe. The maximum external pressure for a pipe can be determined by dividing the collapse test pressure by a safety factor of 3. The collapse test pressure may be verified experimentally or determined by a combination of testing and calculation methods which are required to be submitted to INTLREG for approval.

3.3.3. Axial Strength

The sum of the longitudinal stresses due to pressure, weight and other dynamic and sustained loads shall not exceed the allowable stress in the longitudinal direction. When determining the longitudinal stresses in the system, forces due to thermal expansion, contraction and external load are required to be considered, wherever applicable.

In the case of fiber reinforced plastic pipes, the sum of the longitudinal stresses shall not exceed one-half of the nominal circumferential stress derived from the maximum internal pressure determined according to Section [3.3.1]. The allowable longitudinal stress may alternatively be verified experimentally or by a combination of testing and calculation methods.

3.3.4. Temperature

The maximum allowable working temperature of a pipe is required to be in accordance with the manufacturer's recommendations. In each case, it should be of at least 20°C (36°F) lower than the minimum heat distortion temperature of the pipe material determined according to ISO 75 method A or equivalent.

The minimum heat distortion temperature is to be not less than 80°C (176°F). This minimum heat distortion temperature requirement cannot be applied to pipes and pipe components made of thermoplastic materials, such as polyethylene (PE), polypropylene (PP), polybutylene (PB) and intended for non-essential services. Special attention is required to be given with respect to material properties, where low temperature services are considered.

3.3.5. Impact Resistance

Plastic pipes and joints are required to have a minimum resistance to impact in accordance with a recognized national or international standard such as ASTM D2444 or equivalent. The specimen should be subjected to hydrostatic pressure equal to 2.5 times the design pressure for at least one, after the impact resistance is tested.

3.3.6. Fire Endurance

Table 8.3.1 specifies fire endurance requirements for pipes based upon system and location. Pipes and their associated fittings whose functions or integrity are essential to the safety of the vessel are required to meet the indicated fire endurance requirements which are described below:

3.3.6.1. Level 1

Level 1 will ensure the integrity of a system during a full-scale hydrocarbon fire and is particularly can be applied to systems where the loss of integrity may result in the outflow of flammable liquids and may worsen the fire situation. Piping having passed the fire endurance test as specified in [3.7] of this section for duration of a minimum of one hour without loss of integrity in the dry condition is considered to meet the 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. The flow loss must be taken into account when dimensioning the system.

3.3.6.2. Level 2

Level 2 intends to ensure the availability of systems essential to the safe operation of the vessel after a fire of short duration, allowing the system to be restored after the fire has been extinguished. Piping having passed the fire endurance test as specified in [3.7] of this section for duration of a minimum of 30 minutes without loss of integrity in the dry condition is considered to meet the 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. The flow loss must be taken into account when dimensioning the system.

3.3.6.3. Level 3

Level 3 is considered to provide the fire endurance necessary for a water-filled piping system in order to survive a local fire of short duration. The system's functions are capable of being restored after the fire has been extinguished. Piping having passed the fire endurance test specified in [3.8] of this section for duration of a minimum of 30 minutes without loss of integrity in the wet condition is considered to meet the Level 3 fire endurance standard (L3).

3.3.7. Fire Endurance Coating

The applications of the following requirements are to be made where a fire protective coating of pipes and fittings is necessary to achieve the fire endurance standard are required:

- i) Pipes are generally to be delivered from the manufacturer with the protective coating applied, with on-site application limited to that necessary for installation purposes (i.e., joints). Regarding the application of the fire protection coating on joints, refer [3.10.7] of this section.
- ii) The fire protection properties of the coating are not to be diminished when exposed to salt water, oil or bilge slops. It is required to be demonstrated that the coating is resistant to products likely to come in contact with the piping.
- iii) In considering fire protection coatings, characteristics such as thermal expansion, resistance against vibrations and elasticity are required to be taken into account.
- iv) The fire protection coatings are required to have sufficient resistance to impact to retain their integrity.
- v) In order to determine the adhesion qualities of the coating to the pipe, random samples of pipe are required to be tested.

3.3.8. Flame Spread

3.3.8.1. Plastic Pipes

All pipes, except those fitted on open decks and within tanks, cofferdams, void spaces, pipe tunnels and ducts are required to have low flame spread characteristics. For determining the flame spread characteristics, the test procedures in IMO Resolution A.653 (16) Recommendation on Improved Fire Test Procedures for Surface Flammability of Bulkhead, Ceiling, and Deck Finish Materials, modified for pipes as indicated in [3.9] of this section, is required. Piping materials giving average values for all of the surface flammability criteria not exceeding the values listed in Resolution A.653 (16) are required to meet the requirements for low flame spread.

Alternatively, flame spread testing in accordance with ASTM D635 or equivalent may be used in lieu of the IMO flame spread test provided such testing is acceptable to the appropriate administration of the vessel's registry.

3.3.8.2. Multi-core Metallic Tubes Sheathed by Plastic Materials

The multi-core tubes in "bundles" made of stainless steel or copper tubes covered by an outer sheath of plastic material are required to comply with the flammability test criteria of IEC 60332-3-22 or 60332-3-21, for, Category A/F or A/F/R respectively. Alternatively, the tube bundles complying with at least the flammability test criteria of IEC 60332-1-2, or a test procedure equivalent thereto are acceptable, provided they are installed in compliance with approved fire stop arrangements.

3.3.9. Electrical Conductivity

3.3.9.1. Pipe Conductivity

Piping conveying fluids with a conductivity of less than 1000 pico-siemens per meter is required to be electrically conductive.

3.3.9.2. Hazardous Areas

Plastic piping shall be electrically conductive if the piping passes through a hazardous area, regardless of the fluid being conveyed.

3.3.9.3. Electrical Resistance

The resistance per unit length of the pipes and fittings shall not exceed 1.105 Ω /m (3.104 Ω /ft), where electrically conductive piping is required. Also refer Sect [3.10.4].

3.3.9.4. Non-homogeneous Conductivity

Protection of the pipes and fittings with layers having different conductivity are required to be ensured against the possibility of spark damage to the pipe wall.

3.3.10. Marking

In accordance with a recognized standard, pipes and other components are required to be permanently marked with identification. Identification should include pressure ratings, the design standard that the pipe or fitting is manufactured in accordance with, the material with which the pipe or fitting is made, and the date of fabrication.

3.4. Manufacturing of Plastic Pipes

- 3.4.1. In accordance with Part-1, Ch-1, Sec-11 or ISO 9001 (or equivalent), the manufacturer is required to have a quality system and are to be certified. The quality system consists of elements necessary to ensure that pipes and components are produced with consistent and uniform mechanical and physical properties in accordance with recognized standards, including testing to demonstrate the compliance of plastic pipes, fittings and joints with Section [3.3.1] through [3.3.9] and [3.6], as applicable.
- 3.4.2. Tests in [3.3.1] through [3.3.9] and [3.6], as per application, will be required using samples from each batch of pipes being supplied for use aboard the vessel and are to be carried out in the presence of the Surveyor, where the manufacturer does not have a certified quality system in accordance with Part-1, Ch-1, Sect 11 or ISO 9001 (or equivalent).
- 3.4.3. Each length of pipe and each fitting is required to be tested at the manufacturer's production facility to a hydrostatic pressure not less than 1.5 times the maximum allowable internal pressure of the pipe in Sect [3.3.1] above.
- 3.4.4. Alternatively, for pipes and fittings which are not employing hand lay-up techniques, the hydrostatic pressure test may be carried out in accordance with the hydrostatic testing requirements as 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.
- 3.4.5. INTLREG reserves the right to require the hydrostatic pressure testing of each pipe and/or fitting, depending upon the intended application.
- 3.4.6. The production testing is required to be witnessed by the Surveyor if the facility does not have a certified quality system according to Part-1, Ch-1, Sec-11 or ISO 9001 (or equivalent).
- 3.4.7. The manufacturer is required to provide documentation certifying that all piping and piping components supplied are to be in compliance with the requirements of Section 3 of this chapter.

3.5. Plastic Pipe Bonding Procedure Qualification

3.5.1. Procedure Qualification Requirements

3.5.1.1. Joint Bonding Parameters

In order to qualify joint bonding procedures, the tests and examinations specified herein shall be successfully completed. The procedure for making bonds is to include the following:

- Materials used
- Tools and fixtures
- Cure temperature
- Dimensional requirements and tolerances
- Joint preparation requirements
- Environmental requirements
- Test acceptance criteria for the completed assembly

3.5.1.2. Requalification

Any change in the bonding procedure which will affect the physical and mechanical properties of the joint will require the procedure to be qualified again.

3.5.2. Procedure Qualification Testing

3.5.2.1. Test Assembly

A test assembly is required to be fabricated according to the procedure that is required to be qualified, and it should consist of at least one pipe-to-pipe joint and one pipe-to-fitting joint. When the test assembly has been cured, it is required to be subjected to a hydrostatic test pressure at a safety factor of 2.5 times the design pressure of the test assembly for not less than one hour. No leakage or separation of joints should be allowed. The test is required to be conducted so that the joint is loaded in both longitudinal and circumferential direction.

3.5.2.2. Pipe Size

The selection of the pipes used for test assembly is to be done in accordance with the following:

- i) The test assembly is required to be the largest pipe size to be joined, when the largest size to be joined is 200 mm (8 in.) nominal outside diameter or smaller,
- ii) The size of the test assembly shall be either 200 mm (8 in.) or 25% of the largest piping size to be joined, whichever is greater, when the largest size to be joined is greater than 200 mm (8 in.) nominal outside diameter.

3.5.2.3. Bonding Operator Qualification

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.

3.6. Tests by Manufacturer – General

Testing is to demonstrate the compliance with [3.3.1] through [3.3.9], as applicable, for plastic pipes, fittings and joints for which approval in accordance with Section 3 of this chapter is requested. These tests are required to be in compliance with the requirements of relevant standards as per Table 8.3.2 & Table 8.3.3. Other recognized standards may be considered.

3.7. Tests by Manufacturer – Fire Endurance Testing of Plastic Piping in the Dry Condition (for Level 1 and Level 2)

3.7.1. Test Method

3.7.1.1. Furnace Test Temperature

The specimen is required to be subjected to a furnace test with fast temperature increase similar to that likely to occur in a fully developed liquid hydrocarbon fire. The time/temperature shall be as follows:

At the end of 5 minutes 945°C (1733°F)

At the end of 10 minutes 1033°C (1891°F)

At the end of 15 minutes 1071°C (1960°F)

At the end of 30 minutes 1098°C (2008°F)

At the end of 60 minutes 1100°C (2012°F)

3.7.1.2. Furnace Temperature Control

The accuracy of the furnace control is to be as follows:

- i) During the first 10 minutes of the test, variation in the area under the curve of mean furnace temperature is required to be within $\pm 15\%$ of the area under the standard curve.
- ii) During the first 30 minutes of the test, variation in the area under the curve of mean furnace temperature is required to be within $\pm 10\%$ of the area under the standard curve.
- iii) For any period after the first 30 minutes of the test, variation in the area under the curve of mean furnace temperature is required to be within $\pm 5\%$ of the area under the standard curve.
- iv) At any time after the first 10 minutes of the test, the difference in the mean furnace temperature from the standard curve is required to be within $\pm 100^{\circ}\text{C}$ ($\pm 180^{\circ}\text{F}$).

3.7.1.3. Furnace Temperature Measurement

INTLREG shall approve the locations where the temperatures are measured, the number of temperature measurements and the measurement techniques.

3.7.2. Test Specimen

3.7.2.1. Pipe Joints and Fittings

The test specimen is required to be prepared with the joints and fittings which are intended for use in the proposed application.

3.7.2.2. Number of Specimens

The number of specimens is required to be sufficient to test typical joints and fittings including joints between non-metal and metal pipes and metal fittings to be used.

3.7.2.3. End Closure

The ends of the specimen are required to be closed. One of the ends shall allow pressurized nitrogen to be connected. The pipe ends and closures may be outside the furnace.

3.7.2.4. Orientation

The general orientation of the specimen shall be horizontal and it is required to be supported by one fixed support with the remaining supports allowing free movement. The free length between supports shall not be less than 8 times the pipe diameter.

3.7.2.5. Insulation

Most of the materials will require a thermal insulation to pass this test. The test procedure is required to include the insulation and its covering.

3.7.2.6. Moisture Condition of Insulation

If the insulation contains or is liable to absorb moisture, the specimen shall not be tested until the insulation has reached an air dry-condition, defined as equilibrium with an ambient atmosphere of 50% relative humidity at $20 \pm 5^{\circ}\text{C}$ ($68 \pm 9^{\circ}\text{F}$). Accelerated conditioning is permissible provided the method does not alter the properties of the component material. Special samples are required to be used for moisture content determination and conditioned with the test specimen. These samples are to be constructed in such a way so that it represents the loss of water vapor from the specimen having similar thickness and exposed faces.

3.7.3. Test Condition

A nitrogen pressure inside the test specimen is required to be automatically maintained at 0.7 ± 0.1 bar (0.7 ± 0.1 kgf/cm², 10 ± 1.5 psi) during the test. Means are required to be provided to record the pressure inside the pipe and the nitrogen flow into and out of the specimen in order to indicate leakage.

3.7.4. Acceptance Criteria**3.7.4.1. During the Test**

No nitrogen leakage from the sample shall occur during the test.

3.7.4.2. After the Test

The test specimen together with fire protective coating, if any, is required to be allowed to cool in still air to ambient temperature and then tested to the maximum allowable pressure of the pipes, as defined in [3.3.1] & [3.3.2] of this section, after termination of the furnace test. The pressure is required to be held for a minimum of 15 minutes without leakage. The hydrostatic test is required to be conducted on bare pipe (i.e., coverings and insulation removed) where practicable, so that any leakage will be visible.

3.7.4.3. Alternative Tests

Alternative test methods and/or test procedures, which are considered to be at least equivalent, including open pit testing method, may be accepted in cases where the pipes are too large for the test furnace.

3.8. Test by Manufacturer – Fire Endurance Testing of Water-filled Plastic Piping (for Level 3)**3.8.1. Test Method****3.8.1.1. Burner**

A propane multiple burner test with a fast temperature increase is required to be used.

3.8.1.2. Pipes up to 152 mm (6 in.) OD

The fire source shall consist of two rows of five burners for piping up to and including 152 mm (6 in.) OD, as shown in Figure 8.3.1. A constant heat flux averaging 113.6 kW/m^2 ($36,000 \text{ BTU/hft}^2$) $\pm 10\%$ is required to be maintained at the $12.5 \pm 1 \text{ cm}$ ($5 \pm 0.4 \text{ in.}$) height above the centerline of the burner array. This flux corresponds to a pre-mix flame of propane with a fuel flow rate of 5 kg/h (11 lb/h) for a total heat release of 65 kW (3700 BTU/min.). The gas consumption is required to be measured with an accuracy of at least $\pm 3\%$ in order to maintain a constant heat flux. Propane with a minimum purity of 95% shall be used.

3.8.1.3. Pipes More than 152 mm (6 in.) OD

One additional row of burners is required to be included for each 50 mm (2 in.) increase in pipe diameter for piping greater than 152 mm (6 in.) OD. A constant heat flux averaging 113.6 kW/m^2 ($36,000 \text{ BTU/h-ft}^2$) $\pm 10\%$ is still to be maintained at the $12.5 \pm 1 \text{ cm}$ ($5 \pm 0.4 \text{ in.}$) height above the centerline of the burner array. The fuel flow should be increased as required to maintain the designated heat flux.

3.8.1.4. Burner Type and Arrangement

The burners are required to be type “Siefert No. 2942” or equivalent which produces an air mixed flame. The inner diameter of the burner heads is to be 29 mm (1.14 in.) as shown in Figure 8.3.1. The burner heads shall be mounted in the same plane and

supplied with gas from a manifold. Each burner is required to be equipped with a valve if necessary, in order to adjust the flame height.

3.8.1.5. Burner Position

The height of the burner stand should be adjustable. It is required to be mounted centrally below the test pipe with the rows of burners parallel to the pipe's axis. The distance between the burner heads and the pipe is to be maintained at 12.5 ± 1 cm (5 ± 0.4 in.) during the test. The free length of the pipe between its supports is to be 0.8 ± 0.05 m (31.5 ± 2 in.) as shown in Figure 8.3.2.

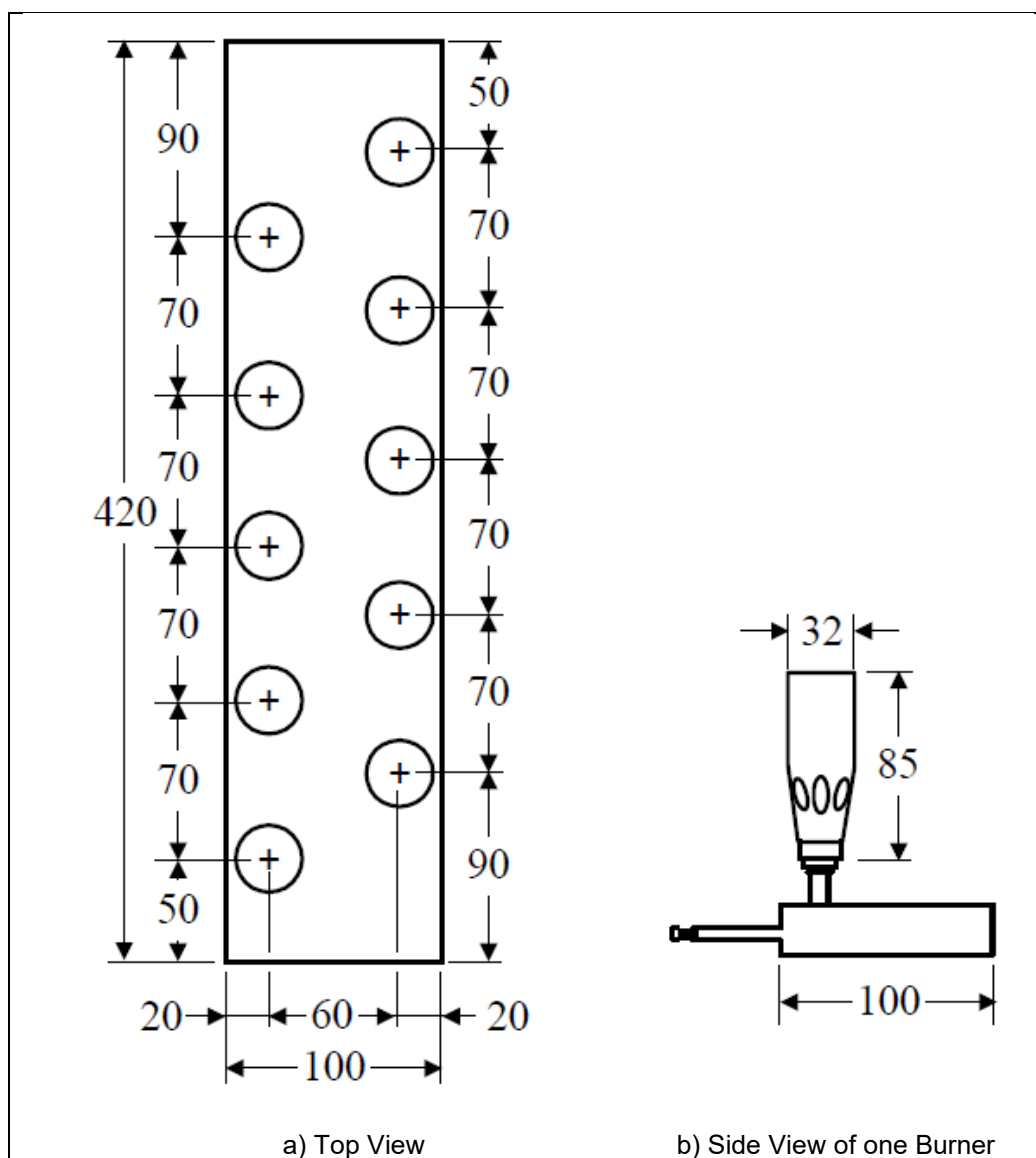


Figure 8.3.1: Fire Endurance Test Burner Assembly

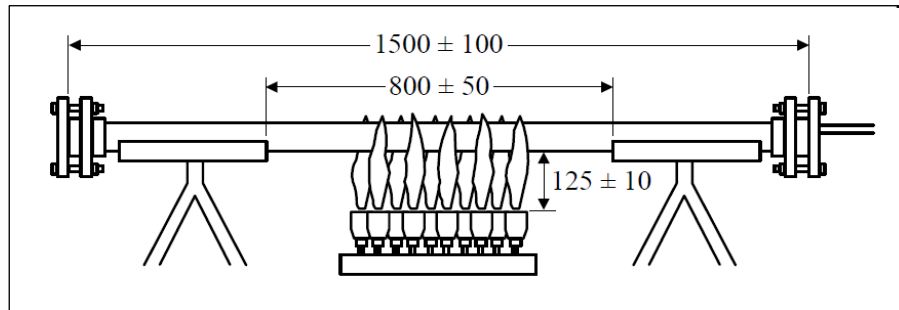


Figure 8.3.2: Fire Endurance Test Stand with Mounted Sample

3.8.2. Test Specimen

3.8.2.1. Pipe Length

Each pipe is required to have a length of approximately 1.5 m (5 ft).

3.8.2.2. Pipe Joints and Fittings

The test pipe is required to be prepared with the permanent joints and fittings intended to be used. Only valves and straight joints versus elbows and bends shall be tested as the adhesive in the joint is the primary point of failure.

3.8.2.3. Number of Specimens

The number of pipe specimens is required to be sufficient to test all typical joints and fittings.

3.8.2.4. End Closure

The ends of each pipe specimen are required to be closed, except to allow pressurized water and air vent to be connected.

3.8.2.5. Moisture of Insulation

If the insulation contains or is liable to absorb moisture, the specimen is not to be tested until the insulation has reached an air dry-condition, defined as equilibrium with an ambient atmosphere of 50% relative humidity at $20 \pm 5^{\circ}\text{C}$ ($68 \pm 9^{\circ}\text{F}$). Accelerated conditioning is permissible provided the method does not alter the properties of the component material. Special samples are to be used for moisture content determination and conditioned with the test specimen. These samples are required to be constructed in such a way so that it represents the loss of water vapor from the specimen having similar thickness and exposed faces.

3.8.2.6. Orientation

The pipe samples shall freely in a horizontal position on two V-shaped supports. The friction between pipe and supports is required to be minimized. The supports may consist of two stands, as shown in Figure 8.3.2.

3.8.2.7. Relief Valve

A relief valve is required to be connected to one of the end closures of each specimen.

3.8.3. Test Conditions

3.8.3.1. Sheltered Test Site

In order to prevent any draft influencing the test, the test is required to be carried out in a sheltered test site.

3.8.3.2. Water-filled

To exclude air bubbles, each pipe specimen is required to be completely filled with de-aerated water.

3.8.3.3. Water Temperature

The water temperature shall not be less than 15°C (59°F) at the start and is required to be measured continuously during the test. The water is to be stagnant and the pressure maintained at 3 ± 0.5 bar (3.1 ± 0.5 kgf/cm², 43.5 ± 7.25 psi) during the test.

3.8.4. Acceptance Criteria

3.8.4.1. During the Test

No leakage from the sample(s) shall occur during the test, except that slight weeping through the pipe wall may be accepted. During the test, no nitrogen leakage from the sample is to occur.

3.8.4.2. After the Test

As defined in [3.3.1] & [3.3.2] of this section, after termination of the burner test, the test specimen together with fire protective coating, if any, is to be allowed to cool to ambient temperature and then tested to the maximum allowable pressure of the pipes. The pressure is to be held for a minimum of 15 minutes without significant leakage [i.e., not exceeding 0.2 l/min. (0.05 gpm)]. Pipes without leakage qualify as Level 1 or 2 depending on the test duration. Pipes with negligible leakage (i.e., not exceeding 5% flow loss) qualify as Level 1W or Level 2W depending on the test duration. The hydrostatic test is to be conducted on bare pipe (i.e., coverings and insulation removed) where practicable, so that any leakage will be visible.

3.8.4.3. Alternative Tests

Alternative test methods and/or test procedures considered to be at least equivalent, including open pit testing method, may be accepted in cases where the pipes are too large for the test furnace.

3.9. Tests by Manufacturer – Flame Spread

3.9.1. Test Method

Flame spread of plastic piping is required to be determined by IMO Resolution A.653 (16) Recommendation on Improved Fire Test Procedures for Surface Flammability of Bulkhead, Ceiling, and Deck Finish Materials with the following modifications:

- i) Tests are required to be made for each pipe material and size.
- ii) The test sample shall be fabricated by cutting pipes lengthwise into individual sections and then assembling the sections into a test sample as representative as possible of a flat surface. A test sample is required to consist of at least two sections. The test sample is to be at least 800 ± 5 mm (31.5 ± 0.2 in.) long. All cuts are to be made normal to the pipe wall.
- iii) The number of sections that must be assembled together to form a test sample is to be that which corresponds to the nearest integral number of sections which makes up a test sample with an equivalent linearized surface width between 155 mm (6 in.) and 180 mm (7 in.). The surface width is defined as the measured sum of the outer

circumference of the assembled pipe sections that are exposed to the flux from the radiant panel.

- iv) The assembled test sample shall have no gaps between individual sections.
- v) The assembled test sample is required to be constructed in such a way that the edges of two adjacent sections coincide with the centerline of the test holder.
- vi) The individual test sections shall be attached to the backing calcium silicate board using wire (No. 18 recommended) inserted at 50 mm (2 in.) intervals through the board and tightened by twisting at the back.
- vii) The individual pipe sections are required to be mounted in such a way so that the highest point of the exposed surface is in the same plane as the exposed flat surface of a normal surface.
- viii) The space between the concave unexposed surface of the test sample and the surface of the calcium silicate backing board is required to be left void.
- ix) The void space between the top of the exposed test surface and the bottom edge of the sample holder frame is required to be filled with a high temperature insulating wool if the width of the pipe segments extends under the side edges of the sample holding frame.

3.10. Installation of Plastic Pipes

3.10.1. Supports

3.10.1.1. Spacing

Selection and spacing of pipe supports in shipboard systems are required to be determined as a function of allowable stresses and maximum deflection criteria. Support spacing shall not be greater than the pipe manufacturer's recommended spacing. The selection and spacing of pipe supports are to take into account mechanical and physical properties of the pipe material, pipe dimensions, length of the piping, mass of pipe and contained fluid, external pressure, operating temperature, thermal expansion effects, loads due to external forces, thrust forces, water hammer and vibrations to which the system may be subjected. Combinations of these loads are required to be checked.

3.10.1.2. Bearing

Each support is required to evenly distribute the load of the pipe and its contents over the full width of the support. Measures shall be taken to minimize wear of the pipes where they contact the supports.

3.10.1.3. Heavy Components

Heavy components in the piping system such as valves and expansion joints are required to be independently supported.

3.10.1.4. Working of the Hull

The supports shall allow for relative movement between the pipes and the vessel's structure, having due regard to the difference in the coefficients of thermal expansion and deformations of the vessel's hull and its structure.

3.10.1.5. Thermal Expansion

The system working temperature and the temperature at which assembling is performed is required to be taken into account, when calculating the thermal expansion.

3.10.2. External Loads

Allowance is required to be made for temporary point loads when installing the piping, where applicable. Such allowances shall include at least the force exerted by a load (person) of 980 N (100 kgf, 220 lbf) at midspan on any pipe more than 100 mm (4 in.) nominal diameter. Pipes should be protected from mechanical damage, wherever necessary.

3.10.3. Plastic Pipe Connections

3.10.3.1. General Requirements

The following general principles are applicable to all pipe connections:

- i) The strength of fittings and joints shall not be less than that of the piping they connect.
- ii) Pipes may be joined using adhesive-bonded, flanged, welded, or other joints.
- iii) In accordance with manufacturer's instructions, tightening of flanged or mechanically coupled joints is required to be performed.
- iv) Adhesives are to be suitable for providing a permanent seal between the pipes and fittings throughout the temperature and pressure range of the intended application, when used for joint assembly.

3.10.3.2. Procedure and Personal Qualifications

In accordance with manufacturer's installation guidelines, joining techniques are to be done. Personnel performing these tasks are required to be qualified to the satisfaction of INTLREG, and each bonding procedure is to be qualified before shipboard piping installation commences. Requirements for joint bonding procedures are in accordance with [3.5] of this section.

3.10.4. Electrical Conductivity

Installation of the pipe is required to be done in accordance with the following provisions, where electrically conductive pipe is required by [3.3.9] of this section.

3.10.4.1. Resistance Measurement

The resistance to earth (ground) from any point in the system shall not exceed 1 MΩ. In the presence of the Surveyor, the resistance is to be checked.

3.10.4.2. Earthing Wire

The earthing wires or bonding straps where used, are to be accessible for inspection. The Surveyor shall verify that they are in visible locations.

3.10.5. Shell Connections

The valves installed on the shell and the pipe connection to the shell is to be metallic, where plastic pipes are permitted in systems connected to the shell of the vessel. The side shell valves are to be arranged for remote control from outside the space in which the valves are located. Refer to Sec-2, [2.5.8], for further details of the shell valve installation, their connections and material.

3.10.6. Bulkhead and Deck Penetrations

Where it is required to pass plastic pipes through bulkheads or decks, the following general principles are to be complied with:

- i) The integrity of watertight bulkheads and decks is required to be maintained where plastic pipes pass through them.
- ii) Arrangements are to be made to ensure that the fire endurance is not impaired, where plastic pipes pass through "A" or "B" class divisions. These arrangements are to be tested in accordance with IMO Resolution. A.754 (18), Recommendation on Fire Resistance Tests for "A", "B" and "F" Class Divisions, as amended.

- iii) If the bulkhead or deck is also a fire division and destruction by fire of plastic pipes may cause inflow of liquid from a tank, then a metallic shutoff valve operable from above the bulkhead deck is required to be fitted at the bulkhead or deck.

3.10.7. Application of Fire Protection Coatings

After performing hydrostatic pressure tests of the piping system (Refer [3.6] of this section), fire protection coatings are to be applied on the joints, where necessary for meeting the required fire endurance criteria in [3.3.6] of this section.

In accordance with the manufacturer's recommendations, the fire protection coatings are to be applied, using a procedure approved in each particular case.

3.11. Testing Onboard After Installation

Piping systems are required to be subjected to a hydrostatic test pressure of not less than 1.5 times the design pressure to the satisfaction of the Surveyor. Earthing is to be checked and random resistance testing should be conducted to the satisfaction of the Surveyor for piping required to be electrically conductive.

Table 8.3.1: Fire Endurance Requirement Matrix

PIPING SYSTEMS		LOCATION										
		A	B	C	D	E	F	G	H	I	J	K
CARGO (Flammable cargoes with flash point ≤ 60°C (140°F))												
1	Cargo lines	NA	NA	L1	NA	NA	0	NA	0(Refer note 10)	0	NA	L1(Refer note 2)
2	Crude oil washing lines	NA	NA	L1	NA	NA	0	NA	0(Refer note 10)	0	NA	L1(Refer note 2)
3	Vent lines	NA	NA	NA	NA	NA	0	NA	0(Refer note 10)	0	NA	X
INERT GAS												
4	Water seal effluent line	NA	NA	0(Refer note 1)	NA	NA	0(Refer note 1)	0(Refer note 1)	0(Refer note 1)	0(Refer note 1)	NA	0
5	Scrubber effluent line	0(Refer note 1)	0(Refer note 1)	NA	NA	NA	NA	NA	0(Refer note 1)	0(Refer note 1)	NA	0
6	Main line	0	0	L1	NA	NA	NA	NA	NA	0	NA	L1(Refer note 6)
7	Distribution lines	NA	NA	L1	NA	NA	0	NA	NA	0	NA	L1(Refer note 2)
FLAMMABLE LIQUIDS [flash point > 60°C (140°F)]												
8	Cargo lines	X	X	L1	X	X	NA(Refer note 3)	0	0(10)	0	NA	L1
9	Fuel oil	X	X	L1	X	X	NA(Refer note 3)	0	0	0	L1	L1

INTLREG Rules and Regulations for Classification of Steel Vessels

10	Lubricating oil	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
SEA WATER (Refer Note 1)												
12	Bilge main and branches	L1(Refer note 7)	L1(Refer note 7)	L1	X	X	NA	0	0	0	NA	L1
13	Fire main and water spray	L1	L1	L1	X	NA	NA	NA	0	0	X	L1
14	Foam system	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(Refer note 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(Refer note 2)
19	Non-essential systems	0	0	0	0	0	NA	0	0	0	0	0
FRESH WATER												
20	Cooling water, essential services	L3	L3	NA	NA	NA	NA	0	0	0	L3	L3
21	Condensate return	L3	L3	L3	0	0	NA	NA	NA	0	0	0
22	Non-essential systems	0	0	0	0	0	NA	0	0	0	0	0
SANITARY/DRAINS/SCUPPERS												
23	Deck drains (internal)	L1W(Refer note 4)	L1W(Refer note 4)	NA	L1W(Refer note 4)	0	NA	0	0	0	0	0
24	Sanitary drains (internal)	0	0	NA	0	0	NA	0	0	0	0	0
25	Scuppers and discharges (overboard)	0(Refer note 1,8)	0(Refer note 1,8)	0(Refer note 1,8)	0(Refer note 1,8)	0(Refer note 1,8)	0	0	0	0	0(Refer note 1,8)	0
VENTS/SOUNDING												
26	Water tanks/dry spaces	0	0	0	0	0	0(Refer note 10)	0	0	0	0	0
27	Oil tanks [flashpoint > 60°C (140°F)]	X	X	X	X	X	X(Refer note 3)	0	0(Refer note 10)	0	X	X
MISCELLANEOUS												
28	Control air	L1(Refer note 5)	L1(Refer note 5)	L1(Refer note 5)	L1(Refer note 5)	L1(Refer note 5)	NA	0	0	0	L1(Refer note 5)	L1(Refer note 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 [Pressure ≤ 7 bar (7 kgf/cm ² , 100 psi)]	L2W	L2W	0(Refer note 9)	0(Refer note 9)	0(Refer note 9)	0	0	0	0	0(Refer note 9)	0(Refer note 9)
Locations						Abbreviations						

A: Category A machinery spaces B: Other machinery spaces C: Cargo pump rooms D: Ro-ro cargo holds E: Other dry cargo holds F: Cargo tanks G: Fuel oil tanks H: Ballast water tanks I: Cofferdams, void spaces, pipe tunnels and ducts J: Accommodation, service and control spaces K: Open decks	L1: Fire endurance test in dry conditions, 60 minutes, in accordance with Section [3.7] L2: Fire endurance test in dry conditions, 30 minutes, in accordance with Section [3.7] L3: Fire endurance test in wet conditions, 30 minutes, in accordance with Section [3.8] 0 No fire endurance test required NA: Not applicable X: Metallic materials having a melting point greater than 925°C (1700°F).
Notes: 1. Where non-metallic piping is used, remotely controlled valves are to be provided at the vessel's side. These valves are to be controlled from outside the space. 2. Remote closing valves are to be provided at the cargo tanks. 3. When cargo tanks contain flammable liquids with a flash point greater than 60°C (140°F), "0" may replace "NA" or "X". 4. For drains serving only the space concerned, "0" may replace "L1W". 5. When controlling functions are not required by statutory requirements, "0" may replace "L1". 6. For pipe 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 positions 1 and 2, as defined in Regulation 13 of the International Convention on Load Lines, 1966, are to be "X" throughout unless fitted at the upper end with the means of closing capable of being operated from a position above the freeboard deck in order to prevent down flooding`. 9. For essential services, such as fuel oil tank heating and ship's whistle, "X" is to replace "0". 10. For tankers where compliance with Section 3(f) of Regulation 13F of Annex I of MARPOL 73/78 is required, "NA" is to replace "0".	

Table 8.3.2: Standards for Plastic Pipes – Typical Requirements for All Systems

	Test	Typical Standards	Notes
1	Internal pressure (Refer note 1)	Section/[3.3.1] ASTM D 1599, ASTM D 2992 ISO 15493 or equivalent	Top, Middle, Bottom (of each pressure range) Tests are to be carried out on pipe spools made of different pipe sizes, fittings and pipe connections.
2	External pressure (Refer note 1)	Section/[3.3.2] ISO 15493 or equivalent	As above, for straight pipes only.
3	Axial strength (Refer note 1)	Section [3.3.3]	As above.
4	Load deformation	ASTM D 2412 or equivalent	Top, Middle, Bottom (of each pressure range)
5	Temperature limitations (Refer note 1)	Section/[3.3.4] ISO 75 Method A GRP piping system: HDT test on each type of resin acc. to ISO75 method A. Thermoplastic piping systems: ISO 75 Method AISO 306 Plastics - Thermoplastic materials - Determination of VICAT softening temperature (VST) VICAT test according to ISO 2507 Polyesters with an HDT below 80°C should not be used.	Each type of resin

INTLREG Rules and Regulations for Classification of Steel Vessels

6	Impact resistance (Refer note 1)	Section/[3.3.5] ISO 9854: 1994, ISO 9653: 1991 ISO 15493 ASTM D 2444, or equivalent	Representative sample of each type of construction
7	Ageing	Manufacturer's standard ISO 9142:1990	Each type of construction
8	Fatigue	Manufacturer's standard or service experience.	Each type of construction
9	Fluid absorption	ISO 8361:1991	
10	Material compatibility (Refer note 2)	ASTM C581 Manufacturer's standard	
Notes: 1). The test is to be witnessed by the Surveyor, where the manufacturer does not have a certified quality system. Refer Section [3.4]. 2). If applicable.			

Table 8.3.3: Standards for Plastic Pipes – Additional Requirements Depending on Service and/or Location of Piping

	Test	Typical Standards	Notes
1	Fire endurance (Refer note 1,2)	Section [3.3.6]	Representative samples of each type of construction and type of pipe connection.
2	Flame spread (Refer note 1,2)	Section [3.3.8]	Representative samples of each type of construction.
3	Smoke generation (Refer note 2)	IMO Fire Test Procedures Code	Representative samples of each type of construction.
4	Toxicity (Refer note 2)	IMO Fire Test Procedures Code	Representative samples of each type of construction.
5	Electrical conductivity (Refer note 1,2)	Section/[3.3.9] ASTM F1173-95 or ASTM D 257, NS 6126/ 11.2 or equivalent	Representative samples of each type of construction.
Notes: 1) Where the manufacturer does not have a certified quality system, test to be witnessed by the Surveyor. Section [3.4]. 2) If applicable. 3) Test items 1, 2 and 5 in this Table are optional. However, if not carried out, the range of approve applications for the pipes will be limited accordingly (Table 8.3.1).			

SECTION 4 PIPING SYSTEMS FOR INTERNAL COMBUSTION ENGINES

Contents

4.1. Scope	379
4.2. Fuel Oil Systems	379
4.3. Lubricating Oil Systems.....	383
4.4. Cooling System	386
4.5. Starting Air System.....	390
4.6. Exhaust Gas Piping	393
4.7. Crankcase Ventilation and Drainage.....	394

4.1. Scope

The provisions of this section are applicable to those systems which are essential for operation of internal combustion engines (diesel engines and gas turbines) and associated reduction gears intended for propulsion and electric power generation. These systems include fuel oil, lubricating oil, starting air, cooling, exhaust gas and crankcase ventilation. Reference should be made to Ch-2, Sec-1 and Ch-2, Sec-3 for engine accessories of diesel engines and gas turbines, respectively. These provisions contain requirements for system design, system components and specific installation details. Requirements for plans that are to be submitted, pipe materials, pipe and pipe fitting designs, fabrication, testing, general installation details and component certification are given in Section 1 & Section 2 of this chapter. Refer Section 3 of this chapter, for plastic piping.

4.2. Fuel Oil Systems**4.2.1. General****4.2.1.1. Application**

The provisions of Section [4.2] are applicable to systems supplying fuel oil to internal combustion engines intended for propulsion and power generation. Requirements for shipboard fuel oil storage, transfer, heating and purification, as provided in Ch-9, Sec-7, shall be complied with. Application of system component requirements in Ch-9, Sec-7/ [7.4] is also done.

4.2.1.2. Fuel Oil Flash Point

The provisions of Section [4.2] are applicable for internal combustion engines burning fuel oils having a flash point (closed cup test) above 60°C (140°F). Engines burning fuel oil of a lesser flash point are subjected to special consideration. In general, for vessels classed for services in specific geographical areas, fuel oil with a flash point of 60°C (140°F) or below, but not less than 43°C (110°F), may only be used. The climatic conditions in these areas are required to preclude the ambient temperature of spaces where such fuel oil is stored from rising to within 10°C (18°F) below its flash point.

Engines driving emergency generators may use fuel oil with a flash point of 60°C (140°F) or below, but not less than 43°C (110°F).

4.2.1.3. Basic Requirement

The intent of the provisions of Section [4.2] along with those of Ch-9, Sec-7, is:

- To provide for a reliable source of fuel oil supply to the prime movers for propulsion and power generation, primarily by means of certification of critical components and providing redundancy in the system, so that propulsion and maneuvering of the vessel may still be possible in the event of single failure in the system;
- To minimize the possibility of fire due to fuel oil, primarily by identifying and segregating likely fuel leakages from ignition sources, collection and drainage of fuel leakages and proper design of fuel containment systems.

4.2.2. Fuel Oil Service System for Propulsion Diesel Engines**4.2.2.1 Service and Booster Pumps****a) Standby pump**

An independently driven standby pump is required to be provided for each service pump, booster pump and other pumps serving the same purpose.

b) Multiple engine installation

For vessels which are fitted with two or more propulsion engines, the provision of a common standby pump (for each service pump, booster pump, etc.) capable of serving all engines will suffice rather than providing individual standby pumps for each engine.

c) Attached pumps

Engines having service, booster or similar pumps attached to and driven by the engine may, in lieu of the standby pump, shall be provided with a complete pump carried on board as a spare. Upon being installed, the spare pump is required to allow the operation of the engine at the rated power. However, this alternative is only permitted for multiple-engine installations where one of the engines may not be in operation (while its pump is being changed) without completely disrupting the propulsion capability of the vessel.

d) Emergency shutdown

Independently driven fuel oil service pumps, booster pumps and other pumps serving the same purpose are required to be fitted with remote means of controls situated outside the space in which they are located so that they may be stopped in the event of fire arising in that space.

e) Certification of pumps

In accordance with Sec-1, [1.4.2], fuel oil transfer pumps and fuel oil service and booster pumps associated with propulsion gas turbine and propulsion diesel engines with bores greater than 300 mm (11.8 in.) are required to be certified.

4.2.2.2 Fuel-injector Cooling Pumps

Where pumps are provided for fuel injector cooling, a standby pump is required to be fitted as per Sect [4.4.2.1].

4.2.2.3 Heaters

At least two heaters of approximately equal size should be installed, when fuel oil heaters are required for propulsion engine operation. The combined capacity of the heaters shall not be less than that required by the engine(s) at rated power. Refer Ch-9, Sec-7/ [7.4.4] for heater design requirements.

4.2.2.4 Filters or Strainers

Filters or strainers are required to be provided in the fuel oil injection-pump suction lines and should be arranged such that they can be cleaned without interrupting the fuel supply. This may be achieved by installing two such filters or strainers in parallel or installing the duplex type with a changeover facility that will enable cleaning without interrupting the fuel supply. An auto-backwash filter satisfying the same intent may also be accepted. For depressurization and venting requirements, refer Ch-9, Sec-7/ [7.4.5].

Filters and strainers are required to be arranged and located so that, in the event of leakage, oil will not spray onto surfaces with temperature in excess of 220°C (428°F).

4.2.2.5 Purifiers

Where heavy fuel oil is used, the number and capacity of purifiers are to be such that with any unit not in operation, the remaining unit(s) shall have a capacity of not less than that required by the engines at rated power.

4.2.2.6 Piping Between Booster Pump and Injection Pumps

In addition to complying with Ch-9, Sec-7/[7.4.1], pipes from booster pump to injection pump should be seamless steel pipe of at least standard wall thickness. Pipe fittings and joints are required to be done in accordance with Table 9.7.2, subject to further limitations as follows:

- Connections to valves and equipment may be of taper-thread joints up to 50 mm (2 in.) nominal diameter; and
- Pipe joints using taper-thread fittings and screw unions are not to be in sizes of 25 mm (1 in.) nominal diameter and over.

Spray shields should be fitted around flanged joints, flanged bonnets and any other flanged or threaded connections in fuel oil piping systems under pressure exceeding 0.18 N/mm^2 (1.84 kgf/cm^2 , 26 psi) which are located above or near units of high temperature, including boilers, steam pipes, exhaust manifolds, silencers or other equipment required to be insulated by Ch-9, Sec-7/[7.2.2], and to avoid, as far as possible, oil spray or oil leakage into machinery air intakes or other sources of ignition. The number of joints in such piping systems should be kept to a minimum.

4.2.2.7 Piping Between Injection Pump and Injectors

a) Injection piping

In order to avoid high-pressure line failure, all external high-pressure fuel delivery lines between the high pressure fuel pumps and fuel injectors are required to be protected with a jacketed piping system capable of containing fuel. A jacketed pipe incorporates an outer pipe into which the high-pressure fuel pipe is placed, forming a permanent assembly. Metallic hose of approved design may be accepted as the outer pipe, where outer piping flexibility is required for the manufacturing process of the permanent assembly. The jacketed piping system shall include means for collection of leakages, and arrangements are required to be provided for an alarm to be given of a fuel line failure.

b) Fuel oil returns piping

Jacketing of the return pipes is also required, when the peak-to-peak pressure pulsation in the fuel oil return piping from the injectors exceeds 20 bar (20.5 kgf/cm^2 , 285 lb/in^2).

c) High pressure common rail system

Where a high pressure common rail system is fitted to an engine, the high pressure common rail is required to be done in accordance with Ch-10, Sec-1 for pressure vessels, or a recognized standard as listed in Ch-10, Sec-1/[1.3]. Alternatively, the design may be verified by certified burst tests. Components should be made of steel or cast steel. Components made of steel, other than cast steel, are to withstand not less than 4 times the maximum allowable working pressure. The cast steel common rails are to withstand not less than 5 times the maximum allowable working pressure. The use of non-ferrous materials, cast iron and nodular iron is prohibited.

Materials are required to comply with Part-2, Chapter-2.

In case of a failure of the high pressure common rail system, the high pressure common rail systems is required to be properly enclosed and provided with arrangement for leak collection and alarm, refer Section [4.2.2.7 (a)].

4.2.2.8 Isolating Valves in Fuel Supply and Spill Piping

A means of isolating the fuel supply and spill (return) piping to individual engines is required to be provided in multi-engine installations which are supplied from the same fuel source. The means of isolation shall not affect the operation of the other engines and is required to be operable from a position not rendered inaccessible by a fire on any of the engines.

4.2.3. Fuel Oil Service System for Auxiliary Diesel Engines

4.2.3.1 Service Pumps

A standby pump capable of serving all engines is to be installed, where generator engines are provided with a common fuel oil service pump or similar. A stand by pump is not required to be provided to the engines having individual service pumps, or having service pumps attached to and driven by the engines.

4.2.3.2 Fuel Injector Cooling Pumps

The provision for a standby pump is required where pumps are provided for fuel injector cooling in order to be in accordance with Section [4.2.3.1].

4.2.3.3 Heaters

At least two heaters of approximately equal size are required to be installed, when fuel oil heaters are required for generator engine operation. The capacity of the heaters, with one heater out of operation, shall not be less than that required by the engine(s) at a power output for the normal sea load as specified in Part-6, Ch-2, Sec-2, [2.1]. For generator engines arranged for alternately burning heavy fuel oil and diesel oil, consideration may be given to providing one heater only.

4.2.3.4 Filters or Strainers

Where common filters or strainers are provided to serve the fuel oil injection-pump suction lines of all of the generator engines, they are required to be arranged in such a way so that they can be cleaned without interrupting the power supply specified in Part-6, Ch-2, Sec-2/ [2.1]. In the case where each of the generator engines is fitted with its own strainer or filter, this arrangement alone will suffice.

4.2.3.5 Piping

The applicable requirements of [4.2.2.6] & [4.2.2.7] are required to be complied with.

4.2.3.6 Isolating Valves in Fuel Supply and Spill Piping

For multi-engine installations, the applicable requirements of Sect [4.2.2.8] are required to be complied with.

4.2.4. Fuel Oil Service System for Gas Turbines

4.2.4.1 General

The fuel oil service system is required to be in accordance with [4.2.2] for propulsion gas turbines and [4.2.3] for generator gas turbines, as applicable, and the provisions in [4.2.4].

4.2.4.2 Shielding of Fuel Oil Service Piping

Piping between the service pump and the combustors should be effectively jacketed or shielded as in [4.2.2.6] or [4.2.2.7], respectively.

4.2.4.3 Fuel Oil Shutoff

a. Automatic shutoff

Each gas turbine is required to be fitted with a quick closing device which will automatically shut off the fuel supply upon sensing malfunction in its operation, Refer Ch 2 Sec-3, [3.4.4.2] for a complete list of automatic shutdowns.

b. Hand trip gear

For shutting off the fuel supply in an emergency, hand trip gear is also required to be fitted, Refer Ch 2, Sec-3, [3.4.5].

4.2.5. System Monitoring and Shutdown

Table 8.4.1 summarizes the basic alarms and shutdown required for fuel oil systems, as required by Ch-9, Sec-7 and Section [4.2]above

Propulsion machinery spaces intended for centralized or unattended operation are required to be fitted with additional alarms and automatic safety system functions. Refer, e.g., Part-Pt 6 , Ch-8, Table 8.2.2, Table 8.2.3 & Table 8.2.5 for propulsion engines and Pt 6, Ch-8, Table 8.2.10 for auxiliary engines

4.2.6. Testing and Trials

Hydrostatic tests are required to be done in accordance with Sec-2, [2.4.2.1] & [2.4.2.3] of this chapter. The surveyor should be present when the system is tried under working condition.

Table 8.4.1: Fuel Oil System Alarms and Shutdown

Equipment	Requirement	Reference
Overflow tank	High-level alarm	Ch-9, Sec-7/ [7.3.4]
Fuel oil tank	High-level alarm, unless overflow is fitted	Ch-9, Sec-7/[7.3.6 (e)]
Fuel oil heaters	High-temperature alarm unless heating medium precludes overheating.	Ch-9, Sec-7/[7.3.7 (b)] and Ch-9, Sec-7/ [7.4.4 (b)]
Fuel oil pumps	Remote manual shutdown	Section [4.2.2.1(d)]
Fuel oil supply to gas turbines	Automatic shutdown and alarms for specified conditions	Section [4.2.4.3(a)]
Fuel delivery pipes	Leak alarm	Section[4.2.2.7(a)], [4.2.3.5] & [4.2.4.2]

4.3. Lubricating Oil Systems

4.3.1. General

4.3.1.1. Application

Application of the provisions of Section [4.3] is done to lubricating oil systems of internal combustion engines and their associated reduction gears intended for propulsion and power generation. Requirements for lubricating oil storage and transfer systems as provided in Ch-9, Sec-8 are required to be complied with. System component requirements in Ch-9, Sec-8/[8.3] are applicable here also.

4.3.1.2. Basic Requirement

The intent of the provisions of Section [4.3] and Ch-9, Sec-8 is to:

- Provide for the continuity of the supply of lubricating oil or to provide reasonable redundancy in lubricating oil supply to the propulsion and auxiliary machinery;
- Provide warning of failure of lubricating oil system and other measures to prevent rapid deterioration of propulsion and auxiliary machinery;
- Minimize the fire risks of lubricating oil.

4.3.1.3. Vessel Inclination

The lubricating oil systems and the associated equipment are required to have the capability of satisfactory operation when the vessel is inclined at the angles indicated in Ch-1, Sec-4/ [4.6].

4.3.1.4. Dedicated Piping

The lubricating oil piping, including vents and overflows, is required to be entirely separated from other piping systems.

4.3.2. Lubricating Oil Systems for Propulsion Engines

4.3.2.1. Lubricating Oil Pumps

a. Standby pump

At least two lubricating oil pumps are required to be provided to each pressurized lubricating oil system which are essential for operating the propulsion engine turbine or gear, at least one of which is required to be driven independently. For continuous operation at rated power, the capacity of the pump is required to be sufficient, with any one pump out of service. For multiple propulsion unit installations, one or more independently driven standby pumps may be provided such that all units can be operated at rated power in the event of any one lubricating oil pump for normal service being out of service.

b. Attached pump

Where the lubricating oil pump is attached to and driven by the engine, the turbine or the gear, and where lubrication before starting is not necessary, the independently driven standby pump required in (a) above is not required if a complete duplicate of the attached pump is carried onboard as a spare. This alternative, however, is only permitted for multiple propulsion unit installations, where one of the units may be inoperable, while its pump is being changed without completely disrupting the propulsion capability of the vessel.

c. Certification of pumps

Certification of the lubricating oil pumps for propulsion gas turbine, propulsion diesel engines with bores greater than 300 mm (11.8 in.) and reduction gears associated with these propulsion engines and turbines are required to be done in accordance with Sec-1/ [1.4.2.1].

4.3.2.2. Lubricating Oil Failure Alarms

In order to provide warning of the failure of the lubricating oil system, audible and visual alarms are required to be fitted for each these systems of engine, turbine or gear.

4.3.2.3. Gas Turbines and Associated Reduction Gears

Propulsion gas turbines shall be fitted with an automatic quick acting device to shut off the fuel supply upon failure of the lubricating oil supply to the gas turbine or the associated gear.

4.3.2.4. Diesel Engines and Associated Reduction Gears

An automatic means is required to be fitted in order to stop the engines in the event of failure of the lubricating oil supply to the reduction gear, where reduction gears are driven by multiple (two or more) diesel engines.

4.3.2.5. Lubricating Oil Coolers

For all types of propulsion plants, oil coolers with means for controlling the lubricating oil temperature are required to be provided. Lubricating oil coolers are required to be provided with means to determine the oil temperature at the outlet. Also refer Section [4.4.4.3] for cooling water requirements.

4.3.2.6. Filters and Strainers

- a. Safety requirements: Arrangements and location of the strainers and filters are required to be done in such a manner so that in the event of leakage, oil will not spray on the surfaces with temperature in excess of 220°C (428°F). For depressurization and venting, refer Ch-9, Sec-7/ [7.4.5].
- b. Gas turbines: A magnetic strainer and a fine mesh filter are required to be fitted in the lubricating oil piping to the turbines. In order to clean without interrupting the flow of oil, arrangements of each filter and strainer should be of the duplex type or otherwise.
- c. Diesel engines: An oil filter of the duplex type shall be provided or otherwise arranged so that it may be cleaned without interrupting the flow of oil. In the case of main propulsion engines which are equipped with full-flow-type filters, the arrangement should be such that the filters may be cleaned without interrupting the oil supply.
- d. Reduction gears: A magnetic strainer and a fine mesh filter are required to be fitted. In order to clean the filter and strainer without interrupting the oil flow, each of these are required to be of the duplex type or otherwise arranged.

4.3.2.7. Purifiers

To separate dirt and water from the lubricating oil in systems containing more than 4.0 m³ (4000 liters, 1057 gallons) of lubricating oil, a purifier of the mechanical type is required to be provided for main propulsion gas turbines.

4.3.2.8. Drain Pipes

Lubricating oil drain pipes from the engine sumps to the drain tank are required to be submerged at their outlet ends.

4.3.3. Lubricating Oil Systems for Auxiliary Engines

Lubricating oil systems for auxiliary engines driving generators are required to meet applicable requirements of [4.3.2] above, except as provided below.

4.3.3.1. Lubricating Oil Pumps

A standby lubricating oil pump is not required for generator diesel engines and gas turbines. A standby means of lubrication is required to be fitted for generators driven by the propulsion system, the lubrication of the drive system, provided if independent of that of the propulsion system. This requirement need not be applied to drive systems that can be disengaged from the propulsion system.

4.3.3.2. Strainers and Filters

Each diesel engine or gas turbine may be fitted with a simplex strainer and/or filter in multiple-generator installations, provided the arrangements are such that the cleaning can be readily performed by changeover to a standby unit without the loss of propulsion capability.

4.3.3.3. System Monitoring and Safety Shutdown

Table 8.4.2 summarizes the basic alarms of the lubricating oil system and the safety shutdowns as required by Section [4.3].

Additional alarms and automatic safety system functions are required to be fitted to propulsion machinery spaces which are intended for centralized or unattended operation. Refer e.g., Pt 6, Ch-8, Table 8.2.2, Table 8.2.3 & Table 8.2.5 for propulsion engines and Part-5, Ch-8, Table 8.2.10 for generator engines.

4.3.4. Testing and Trials

According to the reference Sec-2/ [2.4.2.1] & [2.4.2.3], hydrostatic tests are required to be done. The surveyor should be present when the system is tried under working condition, including simulated functioning of alarms and automatic shutdowns.

Table 8.4.2: Lubrication Oil System Basic Alarms and Safety Shutdown

Equipment	Requirement	Reference
Lub. oil system for engines, turbines and gears – propulsion and auxiliary	Failure alarm	Section [4.3.2.2]
Propulsion gas turbines and gears, auxiliary gas turbines	Shutdown in case of – turbine of gear lub. oil system failure	Section [4.3.2.3]
Common reduction gears of multiple propulsion diesel engines	Engines shutdown in case of gear lub. oil system failure	Section [4.3.2.4]

4.4. Cooling System

4.4.1. General

4.4.1.1. Application

The provisions of Section [4.4] are applicable to cooling systems of diesel engines and gas turbines and their associated reduction gears, as applicable, intended for propulsion and electric power generation.

4.4.1.2. Basic Requirements

The requirements for cooling systems are intended to provide for continuity of supply of cooling medium through providing redundancy in the system to the propulsion and auxiliary machinery.

4.4.2. Cooling System Components

4.4.2.1. Pumps

Certification in accordance with Sec-1/ [1.4.2] are required to be done to cooling water pumps of propulsion gas turbine and associated reduction gear and cooling water pumps of propulsion diesel engines with bores greater than 300 mm and associated reduction gears. Same requirements are made for pumps supplying cooling media other than water.

4.4.2.2. Coolers

- a. General: Water and air coolers having either of the following design parameters are required to be certified by INTLREG:
 - Design pressure > 6.9 bar (7 kgf/cm², 100 lb/in²) on either side
 - Design pressure > 1 bar (1 kgf/cm², 15 lb/in²), internal volume > 0.14 m³ (5 ft³) and design temperature > 149°C (300°F) on either side.
- b. Charge air coolers: Charge air coolers are not subject to (a) above. They are to be hydrostatically tested on the water side to 4 bar (4.1 kgf/cm², 57 psi), but not less than 1.5 times the design pressure on the water side, either in the manufacturer's plant or in the presence of the Surveyor, after installation onboard the vessel. Also refer Ch-2, Sec-1/ [1.8.2] for acceptance of manufacturer's certificate.

4.4.2.3. Pipe Fittings and Joints

Pipe fittings and joints are required to meet the requirements for certification in Sec-1, [1.4.1]; materials in Sec-2, [2.2]; and design in Sec-2/ [2.3.3] & [2.3.9] subject to limitations in Table 8.4.3. Molded non-metallic expansion joints, where used, are to be of an approved type; Refer Sec-2/ [2.3.5.1].

Table 8.4.3: Pipe Joint Limitations for Cooling Water Systems

Pipe joints	Class I	Class II	Class III
Butt welded joint	No limitation	No limitation	No limitation
Socket welded joint (Refer note 1)	Max. 80 mm (3 in.)	Max. 80 mm (3 in.)	No limitation
Slip-on welded sleeve joint (Refer note 2)	Max. 80 mm (3 in.)	Max. 80 mm (3 in.)	No limitation
Flanged joint	Types A & B	Types A, B, C & D	Types A, B, C & D
Taper-thread joint	≤ 80 mm (3 in.) Permissible pressure/ size, Refer Sec-2/ [2.3.3.5 (a)].	≤ 80 mm (3 in.) Permissible pressure/size, Refer	No limitation

		Sec-2/ [2.3.3.5 (a)].	
Compression couplings	≤ 60 mm (2.4 in.) OD	≤ 60 mm (2.4 in.) OD	No limitation
Slip-on joints	Refer Note 3	Refer Note 3	Refer Note 3
Notes: 1. Refer Sec-2, [2.3.3.2] for further operational limitations. 2. Refer Sec-2, [2.3.3.3] for further operational limitations. 3. Refer Sec-2, [2.3.6] for further limitations. 4. Pipe sizes indicated are nominal diameter, except where specified otherwise.			

4.4.3. Sea Chests

At least two sea chests, located below the lightest waterline, as far apart as possible and preferably on opposite sides of the vessel, are required to be provided. Each of the sea chests shall be capable of supporting the cooling of propulsion and auxiliary machinery and other services drawing sea water from the same sea chest. For smaller Ships alternate arrangement of Sea Chest/ Sea Tubes is acceptable with prior approval with INTLREG.

For shell valve and sea chest requirements, Refer Sec-2/ [2.5.8.2] & [2.5.8.5].

4.4.4. Cooling Systems for Propulsion and Auxiliary Engines

4.4.4.1. Cooling Water Pumps

- a. Standby pump: There are required to be at least two means of supplying cooling water or other medium to propulsion and auxiliary engines, air compressors, reduction gears, coolers etc. The capacity of each means is required to be sufficient for continuous operation of the propulsion unit and its essential auxiliary services at rated power. One of these means is required to be driven independently and may consists of a connection from a suitable pump of adequate size normally used for other purposes, such as a general service pump, or in the case of fresh water cooling, one of the vessel's fresh water pumps.
- b. Attached pumps: The standby pump will not be required if a complete duplicate of the attached pump is carried onboard as a spare, where the cooling pump is attached to and driven by the engine, and the connection to an independently driven pump is impracticable. However, this alternative is only permitted for multiple-engine installations where one of the engines may be inoperable while its pump is being changed without completely disrupting the propulsion capability of the vessel.
- c. Multiple auxiliary engines: Multiple auxiliary engine installations having individual cooling systems need not be provided with standby pumps.

4.4.4.2. Strainers

Suitable Strainers are required to be fitted between the sea valves and the pump suction where sea water is used for direct cooling of the engines. To avoid any kind of interruption in the cooling water supply, the strainers are required to be either of the duplex

The strainers are to be either of the duplex type or arranged such that they can be cleaned without interrupting the cooling water supply. This applies also to engines fitted with indirect cooling where direct sea water cooling is used as an emergency means of cooling.

4.4.4.3. Cooling Medium Circulation

In general, to indicate proper circulation of cooling medium means are required to be provided. This may be accomplished by means of pressure or flow and temperature indicators. For diesel engines, the primary cooling medium is required to be provided with a pressure indicator at the inlet and with a temperature indicator at the outlet.

All lubricating oil coolers are to be provided with temperature indicators at the cooling medium inlet and at the lubricating oil outlet. Means to determine the cooling medium and lubricating oil pressures are also required to be provided.

4.4.4.4. Overpressure Protection

In accordance with Sec-2/ [2.5.6], the cooling water system and all jackets are to be protected against over-pressurization.

4.4.4.5. System Monitoring and Safety Functions

For propulsion machinery spaces intended for centralized or unattended operations (**CCS/UM** notation), alarms for abnormal conditions (pressure and temperature) of the cooling media and automatic safety system functions are required to be provided. Refer e.g., Pt 6 Ch-8, Table 8.2.2, Table 8.2.3 & Table 8.2.5 for propulsion engines and Pt 6 Ch-8, Table 8.2.10 for generator engines.

4.4.5. Cooler Installations External to the Hull

4.4.5.1. General

The inlet and discharge connections of external cooler installations are required to be done in accordance with Sec-2/ [2.5.8.1] through Sec-2/ [2.5.8.3] & [2.5.10], except that wafer type valves are acceptable.

4.4.5.2. Integral Keel Cooler Installations

If the keel (skin) cooler installation is integral with the hull, the positive closing valves required by Sect [4.4.5.1] above need not be provided. To be considered integral with the hull, the installation is to be constructed such that channels are welded to the hull with the hull structure forming part of the channel; the channel material is to be at least the same thickness and quality as that required for the hull and the forward end of the cooler is to be faired to the hull with a slope of not greater than 4 to 1.

All flexible hoses or joints are to be positioned above the deepest load waterline or be provided with an isolation valve, if positive closing valves are not required at the shell.

4.4.5.3. Non-integral Keel Cooler Installations

If the shell penetrations are not fully welded where non-integral keel coolers are used, the penetration is to be encased in a watertight enclosure.

Non-integral keel coolers are required to be suitably protected against damage from debris and grounding by recessing the unit into the hull or by the placement of protective guards.

4.4.6. Testing and Trials

Hydrostatic tests are required to be done in accordance with Sec-2/ [2.4.2.1] & [2.4.2.3]. The system is to be tried under working condition in the presence of a Surveyor.

4.5. Starting Air System

4.5.1. General

4.5.1.1. Application

The provision of Section [4.5] applies to the starting air systems for propulsion diesel engines and gas turbines.

4.5.1.2. Basic Requirements

The intent of the requirements in Section [4.5] for starting air system is:

- To provide propulsion engines with ready and adequate supply, as well as an adequate reserve, of starting air; and
- To provide for proper design and protection of the compressed air system

4.5.1.3. Overpressure Protection

To prevent overpressure in any part of the compressed air system, means are required to be provided. This is to include parts of air compressors not normally subjected to air pressure, as indicated in Sect [4.5.2.2] below.

4.5.1.4. Oil and Water Contamination

To minimize the entry of oil or water into the compressed air system, provisions are required to be made. Suitable separation and drainage arrangements are required to be provided before the air enters the reservoirs.

4.5.2. Air Compressors

4.5.2.1. Number and Capacity of Air Compressors

There are to be two or more air compressors, at least one of which is required to be driven independently of the propulsion engines, and the total capacity of the air compressors driven independently of the propulsion engines shall not be less than 50% of the total required.

Within one hour, the total capacity of air compressors is required to be sufficient to supply the quantity of air needed to satisfy Sect [4.5.3.1] below by charging the reservoirs from atmospheric pressure.

The total capacity (V), required by Sect [4.5.3.1] below is required to be approximately equally divided between the number of compressors fitted (n), excluding the emergency air compressor, where fitted. However, one of the air compressors can have a capacity larger than the approximate equal share V/n , provided the capacity of each remaining air compressor is approximately V/n .

4.5.2.2. Overpressure Protection

Water jackets or casing of air compressors and coolers which may be subjected to dangerous overpressure due to leakage into them from air pressure parts are required to be provided with suitable pressure relief arrangements.

4.5.2.3. Air Compressor Acceptance Test

Air compressors are not required to be certified by INTLREG. They may be accepted based on satisfactory performance and verification of capacity stated in Section [4.5.2.1] after installation onboard.

4.5.3. Air Reservoirs

4.5.3.1. Number and Capacity of Air Reservoirs

At least two starting air reservoirs of approximately equal are required to be provided for vessels having internal combustion engines arranged for air starting. The total capacity of the starting air reservoirs shall be sufficient to provide, without recharging the reservoirs, at least the number of consecutive starts stated in (a) or (b) below plus the requirement in (c) below. For vessels whose propulsion machinery spaces are intended for centralized or unattended operation (**CCS** or **UM** notation), all starts are required to be demonstrated from the engine control room or from the engine control panel on the navigation bridge, whichever location is more demanding on air consumption.

a) Diesel or turbine propulsion

The minimum number of consecutive starts (total) required to be provided from the starting air reservoirs shall be based upon the arrangement of the engines and shafting systems, as specified in Table 8.4.4.

Table 8.4.4: Required Number of Starts for Propulsion Engines

Engine Type	Single propeller vessels		Multiple propeller vessels	
	One engine coupled to shaft directly or through reduction gear	Two or more engines coupled to shaft through clutch and reduction gear	One engine coupled to each shaft directly or through reduction gear	Two or more engines coupled to each shaft through clutch and reduction gear
Reversible	12	16	16	16
Non-reversible	6	8	8	8

b) Diesel-electric or turbine-electric propulsion

In accordance with the following equation, the minimum number of consecutive starts (total) required to be provided from the starting air reservoirs can be determined:

$$S = 6 + G (G - 1)$$

Where;

S = total number of consecutive starts

G = number of engines necessary to maintain sufficient electrical load to permit vessel transit at full seagoing power and maneuvering. The value of G need not exceed 3.

c) Other compressed air systems

If other compressed air consuming systems, such as control air, are supplied from the starting air reservoirs, the aggregate capacity of the reservoirs is required to be sufficient for continued operation of these systems after the air necessary for the required number of starts has been used.

4.5.3.2. Certification of Starting Air Reservoirs

Starting air reservoirs having a design pressure greater than 6.9 bar (7 kgf/cm², 100 psi) or with a design pressure greater than 1.0 bar (1.0 kgf/cm², 15 psi) and design temperature greater than 149°C (300°F) are required to be certified by INTLREG, refer Ch-10, Sec-1/ [1.1].

4.5.3.3. Air Reservoir Fixtures

Air reservoirs are required to be installed with drain connections effective under extreme conditions of trim. Air reservoirs are also to be provided with their own relief

valves or equivalent devices, where they can be isolated from the system relief valve.

4.5.3.4. Automatic Charging

In order to maintain air reservoir pressure automatically at a predetermined level arrangements are to be made accordingly.

4.5.4. Starting Air Piping

4.5.4.1. Pipe Fittings and Joints

Pipe fittings and joints are required to meet the requirements for certification in Sec-1/ [1.4.1]; materials in Sec-2/ [2.2]; and design in Sec-2/ [2.3.3] & [2.3.9], subject to limitations in Table 8.4.5.

Table 8.4.5: Pipe Joint Limitations for Starting Air Systems

Pipe joints	Class I	Class II	Class III
Butt welded joint	No limitation	No limitation	No limitation
Socket welded joint (Refer note 1)	Max. 80 mm (3 in.)	Max. 80 mm (3 in.)	No limitation
Slip-on welded sleeve joint (Refer note 2)	Max. 80 mm (3 in.)	Max. 80 mm (3 in.)	No limitation
Flanged joint	Types A & B & G only For type B < 150 mm (6 in.) and ≤ 400° C (752°F) For type G, Refer Pt 5A-8-2/ Table 8.2.8	Types A, B, C, D & G only For type D ≤ 250° C (482°F) For type G, Refer Pt 5A-8-2/ Table 8.2.8	Types A, B, C, D & G only For type G, Refer Pt 5A-8-2/ Table 8.2.8
Taper-thread joint	≤ 80 mm (3 in.) Permissible pressure/size, Refer Sec-2/ [2.3.3.5 (a)]	≤ 80 mm (3 in.) Permissible pressure/size, Refer Sec-2/ [2.3.3.5 (a)]	No limitation
Compression couplings	≤ 60 mm (2.4 in.) OD	≤ 60 mm (2.4 in.) OD	No limitation
Notes: - Refer Sec-2, [2.3.3.2] for further operational limitations. - Refer Sec-2, [2.3.3.3] for further operational limitations. - Pipe sizes indicated are nominal diameter, except where specified otherwise.			

4.5.4.2. Piping from Compressor to Reservoir

All discharge pipes from starting air compressors are required to be led directly to the starting air reservoirs and all starting air pipes from the air reservoirs to propulsion or auxiliary engines are to be entirely separated from the compressor discharge piping system.

4.5.4.3. Starting Air Mains

Where engine starting is by direct injection of air into engine cylinders, an isolation non-return valve or equivalent is required to be installed at the starting air supply connection of each engine in order to protect starting air mains against explosions arising from improper functioning of starting valves. Where engine bore exceeds 230 mm (9 1/16 in.), a bursting disc or flame arrester is required to be fitted in way of the

starting valve of each cylinder for direct reversing engines having a main starting manifold or at the supply inlet to the starting air manifold for non-reversing engines.

4.5.5. System Alarms

Where a propulsion engine can be started from a remote propulsion control station, low starting air pressure is to be alarmed at that station. Propulsion machinery spaces intended for centralized or unattended operations (**CCS/UM** notation) are also required to be provided with alarms for low starting air pressures in the centralized control station.

4.5.6. Testing and Trials

In accordance with Sec-2/ [2.4.2.1] & [2.4.2.3], hydrostatic tests are required to be done. The system is to be tried under working condition in the presence of a Surveyor.

4.6. Exhaust Gas Piping

4.6.1. Application

This requirement applies to internal combustion engine exhaust gas piping led to the atmosphere through the funnel.

4.6.2. Insulation

Exhaust pipes are required to be water-jacketed or effectively insulated with non-combustible material. The insulation material shall not be of the oil-absorbing type unless encased in metal sheets or equivalent, in places where oil spray or leakage can occur.

4.6.3. Interconnections

Exhaust pipes of several engines shall not be connected together, but are required to be run separately to the atmosphere unless arranged to prevent the return of gases to an idle engine. Boiler uptakes and engine exhaust lines shall not be interconnected except when specially approved as in cases where the boilers are arranged to utilize the waste heat from the engines.

4.6.4. Installation

To prevent excessive strain on the pipes, exhaust pipes are required to be adequately supported and fitted with means to take account of the expansion and contraction. Expansion joints or equivalent may be used.

Precautions are required to be taken in the installation of equipment and piping handling fuel oil, lubricating oil and hydraulic oil, such that any oil that may escape under pressure will not come in contact with exhaust gas piping.

4.6.5. Diesel Engine Exhaust

4.6.5.1. Temperature Display

Propulsion diesel engines with bore exceeding 200 mm (7.87 in.) are required to be fitted with a means to display the exhaust gas temperature at the outlet of each cylinder.

4.6.5.2. Alarms

Propulsion machinery spaces intended for centralized or unattended operations (CCS/UM notation) are required to be provided with alarms for high exhaust gas temperature in the centralized control station.

4.6.6. Gas Turbines Exhaust

In accordance with the turbine manufacturer's recommendations, the exhaust gas system of gas turbines is required to be installed. In addition, reference is made to Ch-2, Sec-3/ [3.4.7] for the installation of silencers, and to Part-6, Ch-8, Table 8.2.5 for exhaust gas temperature indication, alarm and automatic shutdown for propulsion machinery spaces intended for centralized or unattended operation.

4.7. Crankcase Ventilation and Drainage

4.7.1. General

In accordance with engine manufacturer's recommendations, crankcase ventilation is to be provided.

In general, ventilation of the crankcase or any arrangement which could produce a flow of external air into the crankcase is required to be avoided, except for dual fuel engines where crankcase ventilation is to be provided. Where provided, vent pipes are required to be as small as possible to minimize the inrush of air after a crankcase explosion.

If a forced extraction of the oil mist atmosphere in the crankcase is provided (for oil mist detection purposes, for example), the vacuum in the crankcase shall not to exceed 2.5 mbar (2.55 mkgf/cm², 36.26 mpsi).

4.7.2. Crankcase Vent Piping Arrangement

4.7.2.1. General Arrangements

Crankcase ventilation piping shall not be directly connected with any other piping system. The crankcase ventilation pipe from each engine is normally required to be led independently to the weather. However, in accordance with Sect [4.7.2.2] below, manifold arrangements may also be accepted.

4.7.2.2. Manifold Arrangements

Where a manifold is employed, its arrangements are required to be as follows:

- i) The vent pipe from each engine is to:
 - Run independently to the manifold, and
 - Be fitted with a corrosion resistant flame screen within the manifold.
- ii) The manifold is required to be accessible for inspection and maintenance of the flame screens.
- iii) The manifold is required to be located as high as possible so as to allow a substantial length of piping separating the crankcases. It is not to be located lower than one deck above the main deck.
- iv) The manifold is required to be vented to the weather, such that the clear open area of the vent outlet is not less than the aggregate area of the individual crankcase vent pipes entering the manifold.
- v) The manifold is required to be provided with drainage arrangements.

4.7.3. Crankcase Drainage

No interconnections from crankcases are allowed between drain pipes. Each drain pipe is required to be led separately to the drain tank and is to be submerged at its outlet, refer [4.3.2.8] of this section.

SECTION 5 PIPING SYSTEMS FOR STEAM PLANTS

Contents

5.1. Scope	396
5.2. Steam Piping System	396
5.3. Boiler Feed Water and Condensate Systems	401
5.4. Boiler Fuel Oil Piping System.....	405
5.5. Lubricating Oil Systems for Steam Turbines and Reduction Gears	407
5.6. Sea Water Circulation and Cooling Systems	410
5.7. Exhaust Gas Piping.....	411

5.1. Scope

Section 6 encloses requirements for piping systems engaged in operation of boilers, steam turbines and associated reduction gears which carry out vital jobs like propulsion, heating electric power generation and other services. These systems include steam, feed water, condensate, fuel oil for boiler, exhaust gas, lubricating oil and cooling.

This section specifically addresses all the system requirements. However, additional requirements which are not specifically addressed in this section are plans to be submitted, piping material, design, fabrication, testing, general installation details and component certification. They are discussed separately in Section 1, Section 2 & Section 3 of this chapter.

5.2. Steam Piping System

5.2.1. General

5.2.1.1. Application

The provisions given in Section [5.2] are applicable to steam piping external to propulsion and auxiliary boilers and includes piping that take steam to steam turbines, steam heaters, auxiliary steam turbines, etc. Provisions for boilers and piping i.e. internal to boilers, and mounting on the boilers viz. main steam valve, safety valve, level gauge, etc., are given in Chapter 10 of this Part.

5.2.1.2. Basic Requirement

The provisions of Section [5.2] intend to furnish adequate design of steam piping for the intended temperatures and pressure, as well as mechanical loads such as thermal expansion and contraction.

5.2.2. Steam Piping Components

5.2.2.1. Pipes and Fittings

- a) Pipes. The certification for pipes is to meet general requirements in Sec-1/ [1.4.1]; materials in Sec-2/ [2.2]; and design Sec-2/ [2.3.1]. Plastic pipes may be used in an auxiliary steam system of 7 bar (7 kgf/cm², 100 psi) or less, as per Table 8.3.1. Pipes which pass through fuel oil and other oil tanks are to be made of steel, and other materials may be considered only when it is demonstrated that the material is apt for the intended service.
- b) Pipe fittings and joints. The certification for pipe fittings and joints are to meet general requirements in Sec-1/ [1.4.1]; materials in Sec-2/ [2.2]; and design in Sec-2/ [2.3.3] and Sec-2/ [2.3.9], subject to limitations stated in Table 8.5.1. Plastic pipe fittings and joints for low pressure systems stated in Section [5.2.2.1 (a)] are to be as per the provisions of Section 3.

5.2.2.2. Valves

The certification for valves is to meet the general requirements given in Sec-1, [1.4.1], materials in Sec-2/ [2.2]; and design in Sec-2/ [2.3.7] & [2.3.8]. For valves attached to boilers, including bypass valves where required by Ch-10, Sec-5/ [5.3.2], Refer Ch-10, Sec-5/[5.2.2] for limitation on valve materials.

Table 8.5.1: Joint Limitations for Steam Piping Systems

Types of joint	Class I	Class II	Class III
Butt welded joint	No limitation	No limitation	No limitation
Socket welded joint (Refer note 1)	Max. 80 mm (3 in.)	Max. 80 mm (3 in.)	No limitation
Slip-on welded sleeve joint (Refer note 2)	Max. 80 mm (3 in.)	Max. 80 mm (3 in.)	No limitation
Flanged joint (Refer note 3)	Types A, B & G only. For type B, < 150mm or ≤ 400°C (752°F) For type G, Refer Part 5A-8-2/ Table 8.2.8	Types A, B, C, D & G only For type D, ≤250°C (482°F). For type G, Refer Pt5A-8-2/ Table 8.2.8	Types A, B, C, D & G only For type G, Refer Part 5A-8-2/ Table 8.2.8
Taper-thread joint (Refer note 4)	≤80 mm (3 in.), or ≤ 495°C (923°F), permissible pressure/size: Refer Sec-2, [2.3.3.5 (a)]	As Class I	No limitation
Compression couplings (Refer note 5)	≤ 60 mm (2.4 in.) OD.	As Class I	No limitation.
Metallic bellow type expansion joint	No limitation.	No limitation.	No limitation.
Slip-on Joints	Not permitted	No limitation (Refer note 3)	Refer Note 3
Notes: 1. Refer Sec-2, [2.3.3.2] for further operational limitations. 2. Refer Sec-2, [2.3.3.3] for further operational limitations. 3. Refer Sec-2, [2.3.6] for further limitations. 4. Pipe sizes are nominal pipe size unless where indicated otherwise.			

5.2.3. Steam Piping Design

Steam piping is required to be designed in such a way so that it withstands the internal temperatures and pressures of the system, as per Sec-2/ [2.3.1.1]. Besides, it is to be designed to take into account ample expansion and contraction without causing undue strain on the components of piping system. Where design temperature exceeds 427°C (800°F), a thermal-expansion stress analysis is to be done as per Sect [5.2.4] below.

5.2.4. Steam Piping Exceeding 427°C (800°F) Design Temperature

5.2.4.1. Plans and Data to be Submitted

- Isometric diagram.* A completely dimensioned one-line isometric drawing of the piping system is required to be submitted, including all data that is used in doing thermal expansion stress analyses.
- Thermal-expansion stress analysis.* For review purposes, a thermal expansion stress analysis of the piping system is to be conducted and submitted. Consideration is to be given to the possibility of excessive reactions on attached equipment or flange joints, and also to the possibility arising because of special configurations or severe service conditions, leading to excessive local strains in the piping system as a result of expansion loading. Provisions are to be made by redesign of the piping system or cold-springing, where required, to prevent

excessive local strains or excessive reactions on attached equipment or flanged joints. The hangers and braces are to be so arranged that they provide adequate support to the piping without interfering with thermal expansion, except as explicitly considered in flexibility calculations.

- c) *Computer analysis.* When a computer does thermal expansion stress analyses, data submitted is to include combined expansion stresses for each pipe, forces and moments at anchor points, and a printout of input data including thermal expansion coefficients, elastic moduli and anchor movements. For information, sketches used in preparing the piping systems for computer solution are also to be submitted and data may be submitted in an electronic file format.

5.2.4.2. Expansion Stresses

Calculations for expansion stresses are to be made from the equations given below:

$$S_E = \sqrt{S_b^2 + 4 S_t^2}$$

$$S_b = \frac{\sqrt{(i M_{bp})^2 + (i M_{bt})^2}}{Z}$$

$$S_t = \frac{K M_t}{2 Z}$$

Where;

S_E = computed expansion stress; N/mm² (kgf/mm², lbf/in²)

S_b = resultant bending stress; N/mm² (kgf/mm², lbf/in²)

S_t = torsional stress; N/mm² (kgf/mm², lbf/in²)

M_{bp} = bending moment in plane of member; kN-m (kgf-mm, lbf-in)

M_{bt} = bending moment transverse to plane of member; kN-m (kgf-mm, lbf-in)

M_t = torsional moment; kN-m (kgf-mm, lbf-in)

i = stress intensification factor, Refer [5.2.4.4] below.

Z = section modulus of pipe; mm³ (in³)

K = 10⁶ (1.0, 1.0), for SI (MKS and US) units of measure, respectively

The computed expansion stresses S_E shall not exceed the allowable range of stress S_A obtained from the following equation:

$$S_A = 1.25 S_c + 0.25 S_h$$

Where;

S_c = allowable stress in cold condition; and

S_h = allowable stress in hot condition. These allowable stresses are to be taken from Table 8.2.2.

The sum of the longitudinal stresses due to weight, pressure and other sustained external loading is not to exceed S_h . Where sum of these stresses is less than S_h , difference between this sum and S_h may be added to the term $0.25 S_h$ in the above equation.

5.2.4.3. Moments

On basis of 100% of thermal expansion, the resultant moments, M_{bp} , M_{bt} , and M_t , are required to be calculated, without allowance for cold-springing, using modulus of elasticity for the cold condition.

5.2.4.4. Stress-intensification Factors

For welded elbows or pipe bends, the stress-intensification factor i may be calculated as:

$$i = \frac{0.9}{h^{2/3}}$$

And in no case, it is to be taken as less than one, where the flexibility characteristics h is obtained from the equation given below:

$$h = \frac{tR}{r^2}$$

Where;

t = nominal pipe wall thickness; mm (in.)

R = nominal radius of bend; mm (in.)

r = nominal radius of pipe; mm (in.)

For other components, stress intensification factor is to be as per the best available data.

5.2.5. General Installation Details

Steam pipes for propulsion, auxiliary services and steam exhaust pipes are not to be led through cargo holds. Where this is not possible, it is to be done, provided they are sufficiently secured, insulated and situated to prevent injuries to personnel and against mechanical damage. The joints in the lines are to be kept to a minimum and preferably butt welded. In all cases, arrangement and installation details are subject to approval by INTLREG on a case-by-case basis.

5.2.6. Steam Piping for Propulsion Turbines

5.2.6.1. Strainers

Steam strainers are to be provided near to the inlet to ahead and astern high pressure turbines, or alternatively, to inlet to the maneuvering valves.

5.2.6.2. Water Accumulation and Drain

Steam supply piping is to be installed in such a manner that it will prevent water accumulation to prevent water hammer. Where this is inevitable, drains to ascertain adequate water draining from the steam lines are to be provided.

The drains are to be positioned from where water can be effectively drained from any part of the steam piping system when the vessel is in the normal trim, is either upright or has a list of up to 5 degrees. Apt valves or cocks are to be fitted in these drains and those are to be readily accessible.

5.2.6.3. Extraction Steam

Where steam is extracted from the turbines, approved means to prevent steam from entering the turbines via the bleeder connections are to be provided.

5.2.6.4. Astern Steam Supply

The steam supply to an astern turbine is to be so arranged that it is available as and when the steam is cut-off to the ahead turbine. This does not prevent use of a guarding valve in the steam supply line to the astern turbine, if this valve can be operated from the same location as the ahead and astern control valves location.

5.2.6.5. Devices for Emergency Operation of Propulsion Steam Turbines

In single screw ships fitted with cross compound steam turbines, arrangements are to be such as to enable safe navigation when the steam supply to any one of the turbines needs to be isolated. For this emergency operation, the steam may be directly led to the L.P. turbine and either the H.P. or M.P. turbine can exhaust directly to the condenser. Arrangements and controls for these operating conditions are required to be adequate so that steam pressure and temperature will not exceed beyond which the turbines and condenser cannot safely resist. The pipes and valves vital for these arrangements are to be readily available and distinctively marked.

Before first sea trials, a fit up test of all combinations of pipes and valves is to be executed.

The permissible power/speeds are to be specified when operating without one of the turbines (all combinations) and information is to be provided on board.

The turbine operations under emergency conditions are to be assessed for the potential influence on gear teeth loading conditions and shaft alignment.

5.2.7. **Steam Piping for Auxiliary Turbines and Other Services**

5.2.7.1. Steam Availability for Essential Auxiliaries

The steam piping arrangements are to be such that steam is available all the time for turbo-generators and other auxiliaries vital to propulsion and safety.

5.2.7.2. Water Accumulation and Drainage

The requisites of Sect [5.2.6.2] above are also applicable for steam supply lines to the auxiliaries.

5.2.7.3. Relief Valves

Where steam piping receives steam from any source at higher pressure than that for which it is designed, or where auxiliary steam piping is not designed to withstand boiler pressure, an appropriate reducing valve, relief valve or pressure gauge are to be fitted. The installed safety valve is to have adequate discharge capacity to safeguard the piping against excessive pressure.

5.2.7.4. Steam Heating System

- a) *Steam heating system for fuel oil tanks.* Steam heating arrangements of fuel oil tanks, temperature control and alarms, and provision of observation tanks are to be as per Ch-9, Sec-7/[7.3.7].
- b) *Steam heaters.* Steam heater housing, temperature control and alarm and fitting of relief valves, are to be as per Ch-9, Sec-7, [7.4.4].

5.2.8. **Blow-off Piping**

Blow-off piping is to be designed to the maximum allowable working pressure plus 15.5 bar (15.8 kgf/cm², 225 psi) or a pressure of minimum 1.25 times the maximum allowable working pressure of the boiler, whichever is less. Where blow-off pipes of two or more boilers are connected to a common discharge, a non-return valve is to be provided in the piping from each boiler.

5.2.9. **System Monitoring**

Propulsion machinery spaces intended for centralized or unattended operations (CCS/UM notation) are required to be provided with displays, system alarms and shutdowns as in Pt 6, Ch-8, Table 8.2.9 and Table 8.2.10 for auxiliary steam and Part-6

, Ch-8, Table 8.2.4 and Table 8.2.8 for propulsion steam.

5.2.10. Testing and Trials

Hydrostatic tests are to be as per Sec-2/ [2.4.2.1] & [2.4.2.3]. The system is to be put to trial under working condition in Surveyor's presence.

5.3. Boiler Feed Water and Condensate Systems**5.3.1. General****5.3.1.1. Definitions**

Boiler feed water is distilled or fresh water is used in boilers for steam generation. Condensate is nothing but the water derived from condensed steam.

5.3.1.2. Application

The provisions given in [5.3] apply to feed water and condensate systems of steam turbines and boilers intended primarily for propulsion and auxiliary services.

5.3.1.3. Basic Requirements

The intent is to provide:

- Redundant feed water pumps for any boiler so that when a feed pump fails, the safety of the boiler is not compromised;
- Redundancy in feed water supply to boilers of propulsion and power generation boilers;
- Safety for maintaining integrity of feed water piping;
- Redundant means for condensate circulation.

5.3.2. Feed Water System Design**5.3.2.1. Feed Water Piping Design Pressure**

Feed water piping between boiler, the required stop valve and screw down check valve (Refer Sect [5.3.3.2] & [5.3.4.2] below), including these valves, are required to be designed for a pressure not less than the smaller of the following:

- 1.25 times the maximum allowable working pressure of the boiler.
- Maximum allowable working pressure of the boiler plus 15.5 bar (15.8 kgf/cm², 225 psi).

The feed water piping from the feed water pump to the boiler is to be designed, in no case, to a pressure less than the feed pump relief valve setting or the shutoff head of the feed pump.

5.3.2.2. Feed Water Supply

Main boilers and auxiliary boilers for vital services are required to be provided with a reserve feed water tank. Alternatively, a connection to domestic fresh-water tanks is to be provided in place of the reserve feed water tank.

5.3.2.3. Automatic Control of Feed

The feed of each boiler is to be automatically controlled by the water level in the boiler. Local manual control of feed is to be provided as well. Refer to Ch-10, Sec-6 also for boiler controls.

5.3.2.4. Feed Water Pumps and Feed Piping

Refer Sections [5.3.3] & [5.3.4] below.

5.3.2.5. Feed Water Pipes and Tanks

Feed water pipes are neither to run through oil tanks, nor oil pipes is required to pass through boiler feed tanks. Piping connections to feed water tanks are required to be so arranged that accidental contamination of the feed water by salt water is prevented. The feed water tanks shall not be located adjacent to fuel oil tanks.

5.3.3. Propulsion and Electric Power Generation Boilers

5.3.3.1. Number of Feed Water Pumps

Two means of feeding each boiler intended for propulsion or electric power generation are required. The arrangements of feed pumps given below are acceptable.

- a) *Group-feed systems.* Group-feed systems are arrangements where all boilers are fed by the same group of pumps. Where two independently driven feed pumps are provided, each is to be dedicated for this purpose and is to supply all the boilers at their normally required operating capacity. Where more than two such feed pumps are provided, the aggregate capacity shall not be less than 200% of that required by all the boilers at their normally required capacity.
- b) *Alternative group-feed system.* Where one of the feed pumps is driven by propulsion shaft or propulsion turbine, the other is to be driven independently. Their capacity is to be such that they supply all the boilers at their normally required capacity. In addition, an independently driven feed pump is to be fitted to be used in emergency.

The capacity of the emergency feed pump is to be adequate to supply all the boilers at three-quarters of their normal operating capacity. For other purposes, the emergency feed pump may be used, such as harbor feed water service or other duties, but not in systems likely to have oil or oil-contaminated water.

- c) *Unit-feed systems.* A standby independently driven feed pump of the same capacity is required to be provided, where two or more boilers are provided and each boiler has its own independently driven feed pump capable of supplying the boiler at its normally required capacity, as stated below:
 - In vessels with two boilers, one such standby feed pump is to be provided for each boiler.
 - In vessels with three or more boilers, not more than two boilers are to be served by one such standby feed pump.

5.3.3.2. Feed Piping

- a) *Valves.* The feed line to each boiler is to be fitted with a stop valve, as per Ch-10, Sec-5, [5.3.3 (b)] and also a stop check valve is to be fitted as close as possible to this. However, a feed water regulator may be installed between the stop check valve and the stop valve, provided it is fitted with a by-pass as stated in (c) below.
- b) *Duplicated feed lines.* For group-feed systems, two independent feed lines are required to be provided between the pumps and each boiler. However, a single penetration in the steam drum is acceptable. In case where two feed lines are combined to form a single penetration at the boiler, the screw down check valve in (a) above is to be installed in each of those two. A single feed line between the pumps and each boiler will suffice, for boilers with unit-feed systems and where two or more boilers are installed.

- c) *By-pass arrangements.* Feed-water regulator and feed-water heaters, where fitted in the feed piping, are to be provided with by-pass arrangements to facilitate their maintenance without disturbing the feed water supply. By-pass for feed-water regulator is not required, provided it is full-flow type.

5.3.4. Other Boilers

5.3.4.1. Number of Pumps

There are to be at least two feed water pumps with adequate capacity to feed the boilers at their normally required capacity, when any one pump is out of order. For this purpose, all feed pumps are to be permanently connected.

5.3.4.2. Feed Piping

Each feed line is to be provided with a stop valve at the boiler and a screw down check valve in close proximity of the stop valve. A feed water regulator may be installed between the screw down check valve and the stop valve, provided it is fitted with a by-pass. For boilers vital to propulsion, like fuel oil heating, the feed line arrangements are to be as stated under Sect [5.3.3.2(b)] above.

In such cases, installation with a single boiler is to be fitted with duplicated feed lines.

5.3.5. Condensate System for Propulsion and Power Generation Turbines

5.3.5.1. Number of Condensate Pumps

There are to be at least two condensate pumps and one of these is to be independent of the main propulsion machinery.

5.3.5.2. Observation Tanks

Steam condensate lines from the heaters and heating coils in tanks are to reach an observation tank to enable detection of oil contamination, if any.

5.3.6. System Components

5.3.6.1. Pumps

Feed pumps, condensate pumps and for condensers, condenser vacuum pumps associated with propulsion boilers and propulsion steam turbines are to be certified as per Sec-1/ [1.4.2].

Feed pumps are to be fitted with a relief valve, except where they are of the centrifugal type such that the shutoff pressure of the pump cannot exceed the piping's design pressure.

5.3.6.2. Condensers, Feed Water Heaters, and Other Heat Exchangers

- a) Certification. Feed water heaters, condensers, and other heat exchangers with either of the following design parameters or applications are to be INTLREG certified:

- Design pressure > 1 bar (1 kgf/cm², 15 lb/in²) but ≤ 6.9 bar on either side at design temperature > 149°C (300°F), with vessel internal volume > 0.14 m³ (5 ft³).
- Design pressure > 6.9 bar (7 kgf/cm², 100 lb/in²) on either side at all design temperatures;

Condensers [other than those in (c) below which are subject to pressure, and are vital for propulsion or power generation like those associated with

propulsion turbines but which are not required to be certified on basis of above specified criteria, are to be subjected to a hydrostatic test of 1.5 times the design pressure. This hydrostatic test of the condenser is to be conducted with all tubes and ferrules fitted, and in Surveyor's presence.

- b) Protection against condenser overpressure. A condenser which can be subjected to a pressure greater than its design pressure is required to be fitted with burst disc or a pressure relief valve of adequate capacity. These devices may be fitted in the steam piping between steam pressure control valve and the condenser, if they are of adequate capacity and cannot be isolated from the condenser. The vents of such relieving devices are to be to the weather in a location where personnel will be absent. The burst disc or relief valve need not be fitted, if fail-safe automatic means of preventing over-pressurization is provided. Such means may be an automatic valve, installed in the steam line upstream of the condenser, which will close upon sensing a preset high pressure in the condenser and which will also automatically close upon failure in its control system or during operation. Calculations are to be submitted demonstrating that when steam pressure to the condenser rises, the automatic valve will close before the condenser pressure exceeds its design pressure.
- c) Vacuum condensers. Condensers which are operated under full or partial vacuum and are vital for propulsion or power generation, like those associated with propulsion turbines, are required to be subjected to a hydrostatic test of 1 bar (1 kgf/cm², 15 psi). This hydrostatic test of the condenser is to be conducted with all tubes and ferrules fitted, and in Surveyor's presence.

5.3.6.3. Pipe Fittings and Joints

For certification for pipe fittings and joints, the requirements in Sec-1, [1.4.1] are to be met; for materials as in Sec-2/ [2.2]; and for design as in Sec-2/ [2.3.3] & [2.3.9], subject to limitations in Table 8.5.2

Table 8.5.2: Pipe Joint Limitations for Feed Water Systems

Pipe joints	Class I	Class II	Class III
Butt welded joint	No limitation	No limitation	No limitation
Socket welded joint (Refer note 1)	Max. 80 mm (3 in.)	Max. 80 mm (3 in.)	No limitation
Slip-on welded sleeve joint (Refer note 2)	Max. 80 mm (3 in.)	Max. 80 mm (3 in.)	No limitation
Flanged joint (Refer note 3)	Types A , B,& G only For type G, Refer Pt5A-8-2/ Table 8.2.8	Types A, B, C , D & G only For type G, Refer Pt 5A- 8-2/ Table 8.2.8	Types A, B, C, D& G only For type G, Refer Pt 5A-8-2/ Table 8.2.8
Taper-thread joint (Refer note 4)	≤80 mm (3 in.) permissible pressure/size: Refer Sec-2/[2.3.3.5 (a)]	≤80 mm (3 in.) permissible pressure/size: Refer Sec-2/[2.3.3.5 (a)]	No limitation
Compression couplings (Refer note 5)	≤ 60 mm (2.4 in.) OD.	≤ 60 mm (2.4 in.) OD.	No limitation.
Notes: 1. Refer Sec-2, [2.3.3.2] for further operational limitations. 2. Refer Sec-2, [2.3.3.3] for further operational limitations.			

3. Pipe sizes indicated are nominal diameter, except where specified otherwise.

5.3.7. System Monitoring

Propulsion machinery spaces intended for centralized or unattended operations (**CCS/UM** notation) are to be provided with displays, system alarms and shutdowns as in Pt 6, Ch-8, Table 8.2.4 and Table 8.2.8 for propulsion steam and Part-6, Ch-8, Table 8.2.9 and Table 8.2.10 for auxiliary steam.

5.3.8. Testing and Trials

Hydrostatic tests are to be done as per the provisions given in Sec-2/ [2.4.2.1] & [2.4.2.3]. The system is to be tried under working condition in Surveyor's presence.

5.4. Boiler Fuel Oil Piping System

5.4.1. General

5.4.1.1. Application

The provisions of [5.4] apply to fuel oil systems of boilers intended for propulsion, power generation, fuel oil and cargo heating, and other services. The requirements, however, for shipboard fuel oil storage, transfer, heating and purification as mentioned in Ch-9, Sec-7 are to be fulfilled. System component requirements in Ch-9, Sec-7/ [7.4] are applicable here as well. Requirements for fuel oil systems of diesel engines and gas turbines are mentioned in Sec-4/[4.2].

5.4.1.2. Fuel Oil Flash Point

The provisions of [5.4] are intended for boilers burning fuel oils with a flash point (closed cup test) above 60°C (140°F). Boilers burning fuel oil of a lesser flash point are subject to special consideration. In general, fuel oil with flash point of 60°C or below, but not less than 43°C (110°F), may only be used for vessels classed for services in some particular geographical areas. The climatic conditions in these areas are to preclude ambient temperature of spaces where such fuel oil is stored from rising within 10°C (18°F) below its flash point.

Boilers burning liquefied natural gas (LNG) or other gaseous fuel are to conform to the requirements of relevant sections in special type ships.

Boilers burning crude oil as fuel are to be specifically approved by INTLREG, prior implementation.

5.4.1.3. Basic Requirements

The intent of the requirements of [5.4] and of Ch-9, Sec-7 is to:

- i) Maintain the continuity of fuel oil supply to boilers for propulsion and for power generation, primarily via providing redundancy in the system;
- ii) Minimize fire risks due to storage and handling of fuel oil;
- iii) Maintain integrity of propulsion boiler fuel oil service pumps by testing and certification.

Boilers not used for propulsion or power generation, but vital for supporting vessel's propulsion and maneuvering functions (e.g., heating of heavy fuel oil) and for other safety functions, are to fulfill (i) & (ii) above. Boilers not related to these safety functions (e.g., cargo heating) need to meet (ii) above only.

5.4.2. Fuel Oil Service System for Propulsion Boilers

5.4.2.1. Fuel Oil Service Pumps

At least two independently driven fuel oil service pumps are required, each with such a capacity that in event of non-functionality of any one of them, other is sufficient to supply the boilers at their rated output. The pumps are to be arranged such that one may be overhauled while the other is in service. Fuel oil service pumps are to be fitted with remote means of control situated outside the space in which they are located so that they may be stopped in the event of fire. Fuel oil service pumps for boilers intended for steam propulsion are to be certified as per Sec-1/ [1.4.2.1 iii)].

5.4.2.2. Heaters

Where fuel oil heating is required, there shall be at least two heaters with adequate capacity to supply heated fuel oil to the boilers at their normal operating capacity when any one heater is out of operation.

5.4.2.3. Filters or Strainers

Filters or strainers are required to be provided in the suction lines and are to be arranged in a manner that they can be cleaned without disturbing the fuel supply. This can be achieved by installing two such filters or strainers in parallel or installing the duplex type with a changeover facility that will enable cleaning without interrupting the fuel supply. Refer to Ch-9, Sec-7/[7.4.5] for depressurization and venting requirements. Strainers are to be so arranged and located that if there is any leakage, spraying oil on surfaces with temperature exceeding 220°C (428°F) is prevented.

5.4.2.4. Pressure Piping Between Service Pumps and Burners

- a) General. Fuel oil piping between burners and service pumps is to be so placed so as to be easily noticeable, Refer Ch-9, Sec-7/ [7.2.3]. A master valve is to be fitted at the manifold supplying fuel oil to the burners. This valve is to be of the quick closing type and is to be readily operable during an emergency.
- b) Pipes. Fuel oil pipes between burners and service pumps are to be made of extra-heavy steel, and in addition, that pipe between the burner shutoff valves and the burners shall be a seamless type. However, short flexible connections of suitable materials (Refer Sec-2, [2.3.4]) may be used at the burners.
- c) Pipe fittings. Pipe fittings and joints are to be as per Ch-9, Sec-7, [7.4.1] except the following further restrictions are applicable to taper-thread joints:
 - Pipe joints using screw unions are not to be used in sizes of 25 mm (1 in.) nominal diameter and over.
 - Connections to valves and equipment may be of taper-thread joints up to 50 mm (2 in.) nominal diameter; and
- d) Automatic burner fuel shutoff. For safety, an alarm is to be fitted and fuel supply to the boiler burner is to be automatically shut off during flame failure or flame scanner failure; low water level; forced draft failure; boiler control power failure; Refer Ch-10, Sec-6/[6.3.1].

5.4.3. Fuel Oil Service System for Boilers Essential for Power Generation, Supporting Propulsion and Habitable Conditions

The requirements of Sect [5.4.2] above are applicable for boilers vital to power generation and supporting propulsion and habitable conditions. Where an exhaust gas boiler is fitted, and arranged such that steam services vital for propulsion can be supplied without the operation of the fuel oil system of the auxiliary boiler, requirements for dual fuel oil service pumps Section [5.4.2.1], dual heaters Section [5.4.2.2] and duplex strainers Sect [5.4.2.3] above may be omitted.

5.4.4. System Monitoring and Shutdown

Table 8.5.3 contains the summary of the required alarms for fuel oil systems in Ch-9, Sec-7 and Section [5.4].

Propulsion machinery spaces for centralized or unattended operation are required to be fitted with additional alarms and with automatic safety system functions. Refer to Part-6, Ch-8, Table-8.2.8 & Table-8.2.9 for propulsion and auxiliary boilers, respectively.

5.4.5. Testing and Trials

Hydrostatic tests are to be carried out as per the provisions of Sec-2/[2.4.2.1] & [2.4.2.3]. The system is to be tried under working condition in Surveyor's presence.

Table 8.5.3: Fuel Oil System Alarms and Shutdown

<i>Equipment</i>	<i>Requirement</i>	<i>Reference</i>
Overflow tank	High-level alarm	Ch-9, Sec-7/ [7.3.4]
Fuel oil tank	High-level alarm, unless overflow is fitted	Ch-9, Sec-7/[7.3.6 (e)]
Fuel oil heaters	High-temperature alarm unless heating medium precludes overheating	Ch-9, Sec-7/[7.3.7 (b)] and Ch-9, Sec-7/[7.4.4 (b)]
Fuel oil pumps	Remote manual shutdown	Section [5.4.2.1]
Fuel oil supply to burners	Automatic shutoff and alarms for specified conditions	Section [5.4.2.4 (d)]

5.5. Lubricating Oil Systems for Steam Turbines and Reduction Gears

5.5.1. General

5.5.1.1. Application

The provisions of [5.5] are applicable to lubricating oil systems of steam turbines and its allied reduction gears intended for propulsion and power generation. Requirements for lubricating oil storage and transfer systems in Ch-9, Sec-8 are to be conformed to, as appropriate. System component requirements in Ch-9, Sec-8/ [8.3] are also applicable here.

5.5.1.2. Basic Requirement

The intent of the requirements for lubricating oil service system in [5.5] and Ch-9, Sec-8 is to:

- Maintain continual supply of lubricating oil to propulsion machinery by means of redundancy in the lubricating oil system;
- Give warning of failure of the lubricating oil system and other measures to check rapid deterioration of propulsion and power generation machinery;
- Minimize possibility of fire due to lubricating oil.

5.5.1.3. Vessel Inclination

The lubricating oil systems and its allied equipment shall have the capability of satisfactory operation when the vessel is inclined at the angles stated under Ch-1, Sec-4, [4.6].

5.5.1.4. Dedicated Piping

The lubricating oil piping, including overflows and vents, is to be completely separated from other piping systems.

5.5.2. Lubricating Oil Systems for Propulsion Turbines and Gears

5.5.2.1. Lubricating Oil Pumps

- a) Turbines. At least two lubricating oil pumps are to be provided with pressure or gravity lubricating system, out of which at least one is to be independently driven. The capacity of the pumps with any one pump out of service is to be adequate for continuous turbine operation at rated power. For multiple turbine installations, one or more independently driven standby pumps is to be provided such that all turbines can be operated at rated power if any one lubricating oil pump for normal service goes out of order.
- b) Reduction gears. Where lubricating oil system of the propulsion reduction gear is independent of the propulsion turbine, it shall be provided with lubricating oil pumps as stated under (a) above.
- c) Attached pumps. Where the design and size of the reduction gear is such that lubrication prior to starting is not mandatory and where a self-driven attached pump is used, independently driven standby pump is not required provided a complete duplicate of the attached pumps is carried onboard. However, this alternative is only permitted for multiple-propeller installations, or similar ones, where one of the propulsion gear is inoperable while its pump is being changed without disrupting vessel's propulsion capability.
- d) Certification. Lubricating oil pumps associated with the propulsion steam turbine and reduction gears are to be certified as per Sec-1/ [1.4.2].

5.5.2.2. Automatic Steam Shutoff

To check rapid deterioration of the turbine or the gear when of pressure in the lubricating oil system of the turbine or the gear is lowered to a dangerous level, means to automatically shut off the steam supply to the turbine with aid of a quick acting device are to be fitted. At propulsion control stations, the activation of this device is to be alarmed. The steam shutoff shall not prevent entry of steam to the astern turbine for braking.

5.5.2.3. Emergency Lubricating Oil Supply

In addition to Sect [5.5.2.1] & [5.5.2.2] above, an emergency supply of lubricating oil is required to be provided which will automatically come into operation upon failure of the lubricating oil system. This emergency supply may be from a gravity tank (also refer Sect [5.5.3] below), provided that it has adequate oil to maintain satisfactory lubrication till turbines are ceased. If an independently driven lubricating oil pump or other oil supply means are used for this purpose, it must not be affected by loss of electrical power supply.

5.5.2.4. Lubricating Oil Failure Alarms

Audible and visual alarms are to be fitted in each lubricating oil system that serves propulsion turbines and reduction gears in order to warn the failure of the lubricating oil system.

5.5.2.5. Lubricating Oil Coolers

Lubricating oil coolers with oil temperature controlling means are to be provided. These coolers are also to be fitted with means to determine oil temperature at the outlet, as a minimum requirement.

5.5.2.6. Filters and Strainers

A fine mesh filter and magnetic strainer are to be fitted in the lubricating oil piping to the turbines and the reduction gears. Each filter and strainer shall be of the duplex type or otherwise arranged so that it may be cleaned without disturbing the oil flow. Filters and strainers are to be arranged and located so that, if any leakage occurs, oil will not spray on surfaces whose temperature exceeds 220°C (428°F). Refer to Ch-9, Sec-8/ [8.3.3] for venting and depressurization requirements.

5.5.2.7. Purifiers

A mechanical type of purifier is to be provided for separating dirt and water from the lubricating oil in systems carrying more than 4.0 m³ (4000 liters, 1057 gallons) of lubricating oil.

5.5.3. Lubricating Oil Tanks

In addition to Ch-9, Sec-8/ [8.2], in general, for lubricating oil tanks, where gravity tanks are used for lubrication, these tanks are to be provided with a low-level alarm and the overflow lines from these tanks to the sump tanks are to be fitted with a sight flow glass. Level gauges are to be provided for all gravity tanks and sumps.

5.5.4. Lubricating Oil Systems for Auxiliary Steam Turbines

5.5.4.1. Lubricating Oil Pumps

For generator turbines, a standby lubricating oil pump is not required.

5.5.4.2. Lubricating Oil System Alarm

Visual and audible alarms for failure of the lubricating oil system are to be fitted.

5.5.4.3. Automatic Shutoff

Generator turbines are to be fitted with means to automatically shut off the turbine steam supply when lubricating oil system fails.

5.5.4.4. Strainers and Filters

Requirements stated in Sect [5.5.2.6] above are applicable. However, in multiple-generator installations, each turbine may be fitted with simplex strainer and/or filter, provided arrangements are such that cleaning can be done without affecting full propulsion capability.

5.5.5. System Monitoring and Safety Shutdown

Table 8.5.4 briefs the basic alarms of the lubricating oil system and safety shutdowns, as required by [5.5].

Propulsion machinery spaces intended for centralized or unattended operation are to be fitted with additional alarms and automatic safety system functions. Refer e.g., Part-6, Ch-8, Table 8.2.4 for propulsion turbine and gear and Pt 6, Ch-8/Table 8.2.10 for generator turbine.

5.5.6. Testing and Trials

Hydrostatic tests are to be carried out as per provisions of Sec-2/ [2.4.2.1] & [2.4.2.3]. The system is to be tried under working condition in Surveyor's presence.

Table 8.5.4: Lubricating Oil System Alarms and Safety Shutdown

<i>Equipment</i>	<i>Requirement</i>	<i>Reference</i>
Lub. oil system for turbines and gears – propulsion and auxiliary	Failure alarm	Section [5.5.2.4] & [5.5.4.2]
Propulsion turbines and gear and auxiliary turbine	Shutdown in case of turbine or gear lub. oil system failure	Section [5.5.2.2] & [5.5.4.3]
Lub. Oil gravity tank	Low level alarm	Section [5.5.3]

5.6. Sea Water Circulation and Cooling Systems

5.6.1. General

5.6.1.1. Application

The provisions of [5.6] are applicable to condenser cooling systems and lubricating oil cooling water systems for steam turbines and allied reduction gears.

5.6.1.2. Basic Requirements

The intent of the requirements for cooling systems is to ensure continuity of supply of cooling medium.

5.6.2. Condenser Cooling System

5.6.2.1. Circulating Pumps

An emergency means of circulating water through the condenser is required to be provided besides the main circulating pump and it may consist of a connection from an independent power pump. Independent sea suction is to be provided for each of these pumps. A cross connection between circulating pumps in multiple-unit installations will be acceptable in place of an independent power pump connection.

5.6.2.2. Sea Inlet Scoop

Where sea inlet scoop circulation is provided for the condenser, minimum one independent circulating pump is to be fitted for use during low vessel speed. In addition, during low vessel speed, a permanent connection to the largest pump in the machinery spaces is to be provided as second means of circulation.

For propulsion machinery spaces intended for centralized or unattended operation (**CCS or UM** notation), independent circulating pump is to be arranged for an automatic start.

5.6.3. Lubricating Oil Cooling Systems

5.6.3.1. Lubricating Oil Coolers and Cooling Water Pumps

For propulsion turbines and its allied reduction gears, one or more lubricating oil coolers equipped with means for controlling the oil temperature is to be provided together with at least two distinct cooling water pumps. One of the pumps should at least be independently driven. The coolers shall have adequate capacity to maintain the required oil temperature as the propulsion plant operates continuously at its rated power.

5.6.3.2. Indicators

Indicators are to be fitted to ease determination of pressure and temperature of the water inlet and oil outlet of the coolers.

5.6.4. Cooling System Components

5.6.4.1. Pumps

Main circulating pumps (i.e., condenser cooling water pumps) are to be certified as per Sec-1/[1.4.2].

5.6.4.2. Heat Exchangers

- a) Certification. Refer Sect [5.3.6.2] above for heat exchangers are required to be certified by INTLREG.
- b) Lubricating oil coolers. The requirements of Ch-9, Sec-8/ [8.3.4] are applicable for lubricating oil coolers for internal combustion engines.

5.6.4.3. Molded Non-metallic Expansion Joints

Where used, molded non-metallic expansion joints are to be of an approved type. Refer to Sec-2/ [2.3.5].

5.6.5. System Monitoring

Propulsion machinery spaces intended for unattended or centralized operations (**CCS/UM** notation) are to be fitted with safety system and monitoring functions. Refer e.g., Part-6, Ch-8, Table 8.2.4 for propulsion turbines and gears and Part-6, Ch-8, Table 8.2.10 for generator turbines.

5.6.6. Testing and Trials

Hydrostatic tests are to be done as per the provisions stated in Sec-2/ [2.4.2]. The system is to be tried under working condition in Surveyor's presence.

5.7. Exhaust Gas Piping

The requirements of Sec-4/[4.6] apply to exhaust gas piping of internal combustion engines.

SECTION 6 OTHER PIPING SYSTEMS

Contents

6.1. General	413
6.2. Hydraulic Oil Systems	413
6.3. Pneumatic Systems	416
6.4. Fixed Oxygen-acetylene Systems	418
6.5. Helicopter Refueling Systems	420

6.1. General

Section 7 covers provisions for piping systems not covered in Section 4, Section 5 and Section 6. It also covers fluid power piping systems, helicopter refueling piping systems and oxygen-acetylene piping systems. The provisions of Section 1, Section 2 & Section 3 apply to piping systems in Section 7.

6.2. Hydraulic Oil Systems**6.2.1. Application**

The provisions of [6.2] are applicable to all shipboard hydraulic oil systems. Hydraulic oil systems fitted in self-contained equipment not associated with propulsion and maneuvering of the vessel (e.g., a crane) and completely assembled by the equipment manufacturer need not conform to this subsection. However, such hydraulic oil systems are to conform to the accepted industry standards.

Hydraulic oil systems which are essential for the propulsion and maneuvering of the vessel are subject to further requirements. Controllable pitch propeller hydraulic system and steering gear hydraulic systems are also to conform to the requirements in Chapter 5 and Chapter 6, respectively.

Hydraulic oil systems which are associated with remote propulsion control are also to conform to Part-6, Ch-8, Sec-2/ [2.15] for, among other requirements, duplication of hydraulic pumps. The same systems associated with propulsion machinery spaces intended for centralized or unattended operation (**CCS/UM** notation) are also to meet the provisions of Part-6, Ch-8 Sec-2/[2.2] for, among other requirements, flash point of hydraulic fluid.

6.2.2. Hydraulic Oil Storage Tanks**6.2.2.1. Location of Storage Tanks**

Hydraulic oil tanks shall not be located where spillage or leakage therefrom can be a hazard by falling on heated surfaces with temperature exceeding 220°C (428°F).

6.2.2.2. Tank Vents

Hydraulic tank vents shall meet the provisions of Ch-9, Sec-5. Vents from hydraulic oil tanks, other than double bottom or similar structural tanks, may be terminated in machinery and other enclosed spaces, provided that their outlets are so located that overflow therefrom will not have an impact on electrical equipment, heated surfaces or other ignition sources; refer to Ch-9, Sec-5, [5.2.4 (c)]. However, tank vents of hydraulic systems used for actuation of valves placed in cargo oil tanks are to be terminated in the weather.

6.2.2.3. Means of Sounding

Means of sounding is required to be fitted for each hydraulic oil tank; which meet the provisions of Ch-9, Sec-6. Tubular gauge glasses may be fitted to hydraulic oil tanks, subject to conditions stated in Ch-9, Sec 6 / [6.3.2 (b) & (c)].

6.2.3. Hydraulic System Components**6.2.3.1. Pipes and Fittings**

The certification for pipes, pipes fittings and joints is to meet general requirements of certification as stated in Sec-1, [1.4.1] (except that INTLREG certification is not required for all classes of hydraulic piping); materials in Sec-2, [2.2]; and design in Sec-2, [2.3], subject to limitations stated in Table 8.6.1.

Table 8.6.1: Pipe Joint Limitations for Hydraulic Piping

Pipe joints	Class I	Class II	Class III
Butt welded joint	No limitation	No limitation	No limitation
Socket welded joint (Refer note 1)	Max. 80 mm (3 in.)	Max. 80 mm (3 in.)	No limitation
Slip-on welded sleeve joint (Refer note 2)	Max. 80 mm (3 in.)	Max. 80 mm (3 in.)	No limitation
Flanged joint (Refer note 3)	Types A, B & G only For type B, $\leq 400^{\circ}\text{C}$ (752°F) For type G, Refer Table 8.2.9	Types A, B, C, D & G only For type D, $\leq 250^{\circ}\text{C}$ (482°F). For type G, Refer Table 8.2.9	Types A, B, C, D & G only. For type G, Refer Table 8.2.9
Taper-thread joint (Refer note 4)	≤ 80 mm (3 in.) permissible pressure/size: Refer Sec-2, [2.3.3.5 (a)]	As for Class I	No limitation
Straight thread O-ring joint	Straight thread O-ring type fittings may be used for pipe connection to equipment such as pumps, valves, cylinders, accumulators, gauges and hoses, without size and pressure limitations. However, such fittings are not to be used for connecting sections of pipe.		
Compression couplings (Refer note 5)	≤ 60 mm (2.4 in.) OD.	As for Class I	No size limitation.
Hoses	Subject to fire resistance test. Refer Sec-2, [2.3.4.3 (c)]	As for Class I	As for Class I
Molded non-metallic expansion joint	Not permitted	Not permitted	Not permitted
Molded expansion joint of composite construction	Subject to compliance with Sec-2, [2.3.5.1]	Subject to compliance with Sec-2, [2.3.5.1]	Subject to compliance with Sec-2, [2.3.5.1]
Slip-on Joints	Not permitted	Not permitted	Refer Note 5
Notes: 1. Refer Sec-2, [2.3.3.2] for further operational limitations. 2. Refer Sec-2, [2.3.3.3] for further operational limitations. 3. Split flanges are not permitted in steering gear system, certified thruster systems, nor in systems which are vital to the propulsion or safety of the vessel, and are subject to special consideration in other cases. 4. Taper-thread joints up to 80 mm (3 in.) may be used without pressure limitation for pipe connection to equipment, such as pumps, valves, cylinders, accumulators, gauges and hoses. When such joints are used to connect sections of pipe, they are to be in accordance with limitations shown. However, hydraulic systems for the following services are to comply with the stated limitations in all respects [Refer Sec-2/ [2.3.3.5 (b)] & [2.3.3.5 (c)]: - Steering gear hydraulic systems. - Controllable pitch propeller hydraulic systems. - Hydraulic systems associated with propulsion or propulsion control. 5. Refer Sec-2/ [2.3.6] for further limitations. 6. Pipe sizes indicated are nominal pipe size unless specified otherwise.			

6.2.3.2. Hoses

Hoses are to conform to the requirements of Sec-2/ [2.3.4] for flammable fluid service.

6.2.3.3. Valves

The certification for valves is to meet general requirements of certification stated in Sec-1/ [1.4.1]; materials in Sec-2/ [2.2]; and design in Sec-2/ [2.3.7] & [2.3.8]. Directional valves are to be treated as pipe fittings and are subject to manufacturer specified pressure, temperature and fluid service restrictions.

6.2.3.4. Hydraulic Accumulators

Hydraulic accumulators with operating pressures above 6.9 bar (7 kgf/cm², 100 psi) are required to be certified as per Ch-10, Sec-1 as pressure vessels, irrespective of their diameters. Each accumulator which may be isolated from the system is to be secured by its own relief valve or equivalent. A relief valve is to be provided on the gas side of the accumulator, where a gas charging system is used.

6.2.3.5. Hydraulic Power Cylinder

- a) *General*. As defined in Table 8.1.1, hydraulic cylinders subject to Classes I and II fluid temperatures and pressures are required to be designed, constructed and tested as per a recognized standard for fluid power cylinders. Acceptance will be based on the manufacturer's certification of compliance and verification of permanent identification on each cylinder bearing the manufacturer's name or trademark, standard of compliance and maximum allowable working temperature and pressure.
- b) *Non-compliance with a Recognized Standard*. As an substitute to (a) above, hydraulic cylinders subject to Classes I and II fluid temperatures and pressures and which are not constructed to a recognized standard may be accepted based on the following:
- i) Irrespective of diameter, the design of the cylinder is to be shown to conform to one of the following:
 - A recognized pressure vessel code,
 - Ch-10, Sec-1 of the Rules. For instance, cylinder is to have a wall thickness not less than that given by equation 2 of Chapter-10, [3.2.1], and the cylinder ends are required to meet the requirements of flat heads in Ch-10, Sec-3/ [3.3.4], or
 - Verification through burst tests. Steel cylinders (other than cast steel) are to resist not less than 4 times the maximum allowable working pressure, while cast steel, cast iron and nodular iron cylinders are to withstand not less than 5 times the maximum allowable working pressure.

In this respect, documentation is to be submitted for review.
 - ii) Each individual unit is to be hydrostatically tested to 1.5 times the maximum allowable working pressure (2 times, for cast iron and nodular iron cylinders) by the manufacturer.

A test certificate is required to be submitted.
 - iii) Each cylinder is to have a permanent nameplate or marking affixed upon it that bears manufacturer's name or trademark and the maximum allowable working temperature and pressure.

- c) *Materials*. The materials of hydraulic power cylinders addressed in (a) & (b) above are to conform to the following:
 - i) The materials of a cylinder are to conform to the requirements of the standard or code to which the cylinder is designed and constructed. Where the design is verified through burst tests, the materials of the cylinder are to conform to Ch-10, Sec-2 or other acceptable standards.
 - ii) Ordinary cast iron with an elongation of less than 12% is not to be used for cylinders expected to be subjected to shock loading.
 - iii) Copies of certified mill test reports are to be made available upon request by the manufacturer.
- d) *Rudder Actuators*. Rudder actuators are to conform to the material requirements of Ch-6, Sec-2, be designed as per Ch-6, Sec-4, and to be certified by INTLREG as per Ch-6, Sec-10.
- e) *Cylinders for Class III Piping Systems*. Cylinders subjected to Class III fluid temperatures and pressures may be used as per the specified manufacturer's rating.
- f) *Independently Manufactured and Assembled Units*. Cylinders which are a part of an independently manufactured and assembled unit that is not parts of vessel's piping system are not covered herein this sub-section.

6.2.4. System Requirements

6.2.4.1. Fire Precautions

Hydraulic power units, including pumps and other pressurized components, with working pressure above 15 bar (225 psi) that are installed within machinery spaces are to be placed in separate room or rooms or shielded, as required, to prevent oil or oil mist that may escape under pressure from coming into contact with surfaces with temperatures in excess of 220°C (428°F), electrical equipment or other ignition sources. Piping and other components are to have as few joints, as possible.

6.2.4.2. Relief Valves

Relief valves are required to be fitted to safeguard the system from overpressure. The relieving capacity shall not be less than full pump flow with a maximum pressure rise in the system of not more than 10% of the relief valve setting.

6.3. Pneumatic Systems

6.3.1. Application

The requirements of [6.3] are applicable to shipboard pneumatic systems for control and actuation services. The requirements for starting air system are given in Sec-4/ [4.5]. Pneumatic systems fitted in self-contained equipment not associated with the vessel's propulsion and maneuvering and completely assembled by the equipment manufacturer need not conform to this subsection. However, such pneumatic systems are to conform to the accepted industry practices.

6.3.2. Pneumatic System Components

6.3.2.1. Air Reservoir

Air reservoirs with a design pressure greater than 6.9 bar (7 kgf/cm², 100 lb/in²) are to be certified by INTLREG (Refer Ch-10, Sec-1/[1.5], and for accumulators Refer

Sect [6.2.3.4] above). Air reservoirs are required to be fitted with drain connections effective under extreme conditions of trim. Where they can be isolated from the system safety valve, they are to be provided with their own safety valves or equivalent devices.

6.3.2.2. Pipe Fittings and Joints

The certification for pipe fittings and joints is required to meet the general requirements of certification stated in Sec-1/ [1.4.1]; for materials in Sec-2/ [2.2]; and design in Sec-2/ [2.3.3] & [2.3.9], subject to limitations stated in Table 8.6.2.

6.3.2.3. Pneumatic Power Cylinders

The requirements of hydraulic cylinders in Sect [6.2.3.5] above are also applicable to pneumatic cylinders.

Table 8.6.2: Pipe Joint Limitations for Pneumatic Systems

Pipe joints	Class I	Class II	Class III
Butt welded joint	No limitation	No limitation	No limitation
Socket welded joint (Refer note 1)	Max. 80 mm (3 in.)	Max. 80 mm (3 in.)	No limitation
Slip-on welded sleeve joint (Refer note 2)	Max. 80 mm (3 in.)	Max. 80 mm (3 in.)	No limitation
Flanged joint (Refer note 3)	Types A, B & G For type G-Refer Part 5A.8.2/Table 8.2.8	Types A, B, C, D & G For type G-Refer Part 5A.8.2/Table 8.2.8	Types A, B, C, D & G For type G-Refer Part 5A.8.2/Table 8.2.8
Taper-thread joint (Refer note 4)	≤80 mm (3 in.) permissible pressure/size: Refer Sec-2/ [2.3.3.5-(a)]	≤80 mm (3 in.) permissible pressure/size: Refer Sec-2/ [2.3.3.5-(a)]	No limitation
Compression couplings (Refer note 5)	≤ 60 mm (2.4 in.) OD.	≤ 60 mm (2.4 in.) OD.	No limitation.
Note: 1. Refer Sec-2, [2.3.3.2] for further operational limitations. 2. Refer Sec-2, [2.3.3.3] for further operational limitations. 3. Pipe sizes indicated are nominal diameter, except where specified otherwise.			

6.3.3. Pneumatic System Requirements

6.3.3.1. Pneumatic Air Source

6.3.3.2.

For general pneumatic control and actuation services, compressed air may be drawn from engine starting air reservoirs, and in that case, the aggregate capacity of the starting air reservoirs is to be adequate for continued operation of these services after the air necessary for the required number of engine starts (as specified in Sec-4/ [4.5.3.1]) has been used.

For propulsion remote control purposes, pneumatic air should be available from at least two air compressors. For this purpose, starting air system, where having two air compressors, may be used. The required air pressure is to be automatically maintained. Pneumatic air supplies to safety and control systems may be derived from the same source but are to be via separate lines.

6.3.3.3. Air Quality

- a) General. Provisions are required to be made to minimize the entry of water or oil in the compressed air system. Appropriate separation and drainage arrangements for air are to be provided prior to it entering the reservoirs.
- b) Safety and Control Air Systems. For requirements of the quality of the air supplied to safety and control air systems, refer to, Pt 6 Ch-8, Sec-2/ [2.16]

6.3.3.4. Overpressure Protection

Means to prevent overpressure in any part of the pneumatic system are to be provided. This includes water jackets or casing of coolers and air compressors which may be subjected to dangerous overpressure due to leakage into them from air pressure parts.

6.4. Fixed Oxygen-acetylene Systems

6.4.1. Application

The provisions of [6.4.2] below apply to oxygen-acetylene installations with two or more cylinders of oxygen and acetylene, respectively. For this purpose, spare cylinders of gases need not be counted. Provisions of [6.4.3] & [6.4.4] below, as applicable, are to be conformed to for fixed installations irrespective of the number of cylinders.

6.4.2. Gas Storage

6.4.2.1. Storage of Gas Cylinders

- a) Storage room. The gas cylinders shall be stored in rooms dedicated for this purpose. A separate room is required to be provided for each gas. The rooms are to be on or above the uppermost continuous deck and are to be made from steel. Access to rooms is from the open deck and the door is to open outwards. Gastight boundaries should be there between the rooms and other enclosed spaces. Suitable drainage of the storage room or area is to be provided.
- b) Open area. Where no storage room is facilitated, the gas cylinders may be placed in an open storage area. In such cases, they are to be provided with weather protection (particularly from heavy seas and heat) and effectively safeguarded from mechanical damage. Suitable drainage of the open storage area or area is to be provided.
- c) Piping passing through storage room or area. Piping systems carrying flammable fluids shall not run through the open storage area or storage room.

6.4.2.2. Ventilation of Storage Room

Each gas cylinder storage room is to be fitted with ventilation systems that may provide at least 6 air changes every hour based on the gross volume of the room. The ventilation system is to be independent of ventilation systems of other spaces. The space within 3 m (10 ft) from the power ventilation exhaust, or 1 m (3 ft) from the natural ventilation exhaust is required to be considered a hazardous area, refer to Part-6, Ch-3, Sec-6/ [6.6]. The fan is to be of the non-sparking construction, refer to Part-6, Ch-3, Sec-6/ [6.17]. Small storage spaces provided with adequately large openings for natural ventilation need shall not be fitted with mechanical ventilation.

6.4.2.3. Electrical Installation in Storage Room

Electrical equipment installed within the storage room, including the ventilation fan motor, is required to be of the certified safe type, refer to Part-6, Ch-3, Sec-6.

6.4.3. Piping System Components

6.4.3.1. Pipe and Fittings

a) General

In general, all oxygen and acetylene pipes, pipe fittings, pipe joints and valves are to be as per the provisions of Section 2 for Class I piping systems, except as modified below. Further, only high pressure oxygen and acetylene piping is to be certified as Class I piping, Refer Table 8.1.2.

b) Piping materials

Materials for acetylene on the high-pressure side between the cylinders and the regulator are to be made of steel. Copper or copper alloys with more than 65% copper are not to be used in acetylene piping (high or low pressure). Materials for oxygen on the high-pressure side are to be steel or copper. In all pipes, both high- and low-pressure sides are to be seamless.

c) Design pressure

Pipes, pipe fittings and valves on the oxygen high-pressure side are to be designed for not less than 207 bar (211 kgf/cm², 3000 psi). Pipes which are used on the low pressure side are at least to be of standard wall thickness.

d) Pipe joints

All pipe joints outside the storage room or open storage area shall be welded.

e) Flexible hoses.

Flexible hoses used to connect acetylene or oxygen gas cylinders to a fixed piping system or manifold are to conform to an acceptable standard and be apt for the intended pressure and service. Further, internal surface of a hose used to connect an acetylene tank is to be of a material i.e. resistant to acetone and dimethyl formamide decomposition*. Where a flexible hose is connected from an oxygen cylinder to the piping system or manifold directly (i.e., no intervening pressure regulator), the internal liner of the oxygen hose is required to be of a material that has an auto-ignition temperature of not less than 400°C (752°F) in oxygen*.

* **Note:** Criteria based on ISO 14113:1997 Gas welding equipment – rubber and plastic hoses assembled for liquefied or compressed gases up to a maximum design pressure of 450 bar.

6.4.3.2. Pressure Relief Devices

Pressure relief devices are required to be provided in the gas piping, provided the maximum design pressure of the piping system can be exceeded. These devices are to be set to discharge at not more than the maximum design pressure of the piping system to a site in the weather, remote from sources of vapor ignition or openings to spaces or tanks. The area within 3 m (10 ft) of the pressure relief device discharge outlet is to be regarded as a hazardous area. The pressure relief devices may either be a rupture disc or relief valve.

6.4.3.3. System Arrangements

High pressure piping between each gas cylinder and the manifold is required to be fitted with a non-return valve, where two or more gas cylinders are connected to a manifold. The piping shall not run through accommodation spaces or unventilated spaces. Outlet stations are required to be fitted with shutoff valves and provided with appropriate protective devices to check back flow of gas and the passage of flame into the supply lines.

6.4.3.4. Gas Cylinders

Gas cylinders are required to be constructed, designed and certified as per the provisions of Ch-10, Sec-1/[1.6.4]. Each cylinder is to be fitted with an apt pressure relief device such as a fusible plug or a rupture disc. The area within 3 m (10 ft) of the pressure relief device discharge outlet shall be regarded as a hazardous area.

6.4.4. Testing

Piping on the oxygen high-pressure side is to be tested prior to installation to at least 207 bar (211 kgf/cm², 3000 psi) and the piping on the acetylene high-pressure side is to be tested as specified in Section 2.

The whole system is to be leak-tested with nitrogen or an apt inert gas after installation. Care is to be taken to cleanse the piping with suitable medium to remove oil, grease and dirt and to blow-through with oil-free nitrogen or using other suitable medium prior to putting system back into service.

6.5. Helicopter Refueling Systems

6.5.1. Application

The requirements of [6.5] are applicable to helicopter refueling facilities for fuel with a flash point at or below 60°C (140°F) close cup test. For fuel with a flash point above 60°C, the requirements for spill containment in [6.5.3] below and the requirements for fuel oil storage and transfer systems in Ch-9, Sec-7 are applicable, as appropriate.

6.5.2. Fuel Storage and Refueling Equipment Area

6.5.2.1. Isolation

The designated refueling areas and fuel storage are to be isolated from the following:

- Accommodation areas including vent openings;
- Escape routes;
- Embarkation stations;
- Helicopter landing area; and
- Areas with source of vapor ignition
- The isolation may be by means of a safe and adequate distance or appropriately erected barriers capable of preventing spread of fire.

6.5.2.2. Hazardous Area

The fuel storage and refueling area shall be permanently marked to identify it as a restricted area where smoking or other naked flame is prohibited. "NO SMOKING" signs are required to be displayed. Open spaces within 3 m (10 ft) of the refueling equipment or the storage tank vent outlet are to be considered as hazardous areas (Refer Part-6, Ch-3, Sec-6/ [6.9]).

6.5.3. Spill Containment

Arrangements are to be provided in the fuel storage area whereby fuel spillage can be collected and drained to a safe location. These arrangements are to be at least as provided hereunder.

6.5.3.1. Coaming

A coaming surrounding the fuel storage tanks and its associated piping and pumping unit is required to be provided. The height of this coaming is to be at least 150 mm (6 in.), so as to store fuel spillage and fire extinguishing agents. Where

pumping unit is located at a remote distance from the fuel storage tank, a separate coaming of the same minimum height shall be provided around the pumping unit.

6.5.3.2. Drainage

Drainage arrangements from within the coaming area are to be as given below:

- i) Suitable holding tank and permanent piping are to be fitted so that drainage can be either led to the holding tank (for draining oil) or discharged overboard (for draining water) via a three-way valve. In the drain piping, no other valve is permitted.
- ii) Drain pipe's cross-sectional area is to be twice that of the storage tank outlet pipe.
- iii) Area within the coaming is to be sloped towards the drain pipe.

The height of the coming is to be adequate to accommodate full volume of the fuel storage tank plus 150 mm (6 in.), where area within the coaming is not provided with drainage arrangements. For drainage of a helicopter deck, refer to Ch-9, Sec-2/ [2.5.2].

6.5.4. Fuel Storage Tanks

6.5.4.1. Construction

Fuel storage tanks are to be of metallic construction. Mounting, securing and electrical bonding arrangements are required to be submitted for approval. Helicopter Fuel Tanks are to be located in a designated area, as far removed from other areas of major fire risks & away from main escape route.

6.5.4.2. Tank Valves

Outlet valves of fuel storage tank are required to be provided with a means of remote closure. Such means shall not be cut off when there occurs a fire in the fuel storage and the refueling area. In general, the provisions of Ch-9, Sec-7/ [7.3.3] are to be conformed to.

6.5.4.3. Tank Vents and Sounding

In general, the provisions of Ch-9, Sec-5 & Sec-6 are applicable. However, tank vents are required to be extended at least 2.4 m (8 ft) above the weather deck. Other venting arrangements will also be considered.

6.5.5. Refueling Pumps

The refueling pump is to integrate a device that will prevent over-pressurization of the delivery hose or of the filling hose. A relief valve, where fitted, is to discharge either to the suction side of the pumps or to the storage tanks. Means for remotely stopping the refueling pumps from a position not likely to be cut off if there is a fire in the fuel storage and refueling area are to be provided.

6.5.6. Fuel Piping

The refueling pump is arranged so as to connect to one tank at a time. Piping between the refueling pump and the tank is to be as short as possible and guarded against damage. Fuel piping is to be of steel or equivalent material and shall conform to the provisions of Ch-9, Sec-7/[7.4.1] & [7.4.2]. There has to be electrical bonding in all equipment used during refueling operation and also in the piping system. All electrical equipment's in the vicinity of helicopter fueling system are to be intrinsically safe & explosion proof as per applicable international/ national standards.

6.5.7. Fuel Storage and Refueling Systems Installed in Enclosed Spaces

6.5.7.1. Machinery Spaces

In machinery spaces, helicopter refueling facilities for fuel with a flash point of 60°C or less are shall not be installed.

6.5.7.2. Arrangements of the Enclosed Space

The fuel storage and refueling compartment is to be bounded by gas-tight decks and bulkheads. Only open deck gives access to this compartment may be by means of a trunk as there is to be no access to this compartment from other compartments.

6.5.7.3. Machinery and Electrical Installations

In general, it is considered that the compartment containing refueling facilities have the same fire and explosion hazards as RO-RO cargo space. Refer Part 7B, special type ship relevant section.

6.5.7.4. Storage Tanks

- a. Independent tanks. Independent fuel tanks may be installed in the same compartment as the refueling system. The tank, vents, means of sounding and valves are to conform to Sect [6.5.4] above.
- b. Structural tanks. Fuel tanks may be integrated within the vessel's structure. Cofferdams are to be fitted in such separate fuel tanks from machinery spaces, accommodation, service spaces, cargo spaces, and other spaces containing an ignition source. The compartment that has the refueling equipment, ballast tanks and fuel oil tanks containing fuel oil with a flash point of more than 60°C may be referred to as a cofferdam. Tank vents, means of sounding and outlet valves are to be located as mentioned in (a) above. Particular attention is to be directed to the height of the tank vent/overflow with respect to the design head of the tank. Overflows, where fitted, are to conform to Ch-9, Sec-5/ [5.3.5].

6.5.8. Fire Extinguishing System

In accordance with the provisions of Ch 13/sec 5/[5.2] fixed fire extinguishing systems are required to be fitted to safeguard helicopter fuel storage and refueling equipment areas (or compartments).

CHAPTER 9 SHIP PIPING SYSTEMS**CONTENTS**

SECTION 1 GENERAL.....	424
SECTION 2 GRAVITY DRAIN SYSTEMS	426
SECTION 3 BILGE SYSTEM	433
SECTION 4 BALLAST SYSTEMS.....	442
SECTION 5 TANK VENTS AND OVERFLOWS	445
SECTION 6 MEANS OF SOUNDING	455
SECTION 7 FUEL OIL STORAGE AND TRANSFER SYSTEMS.....	460
SECTION 8 LUBRICATING OIL STORAGE AND TRANSFER SYSTEMS.....	471
SECTION 9 ADDITIONAL MEASURES FOR OIL POLLUTION PREVENTION	475

SECTION 1 GENERAL

Contents

1.1. Scope 425

1.2. Drainage 425

1.3. Consideration for Damage Stability 425

1.1. Scope

- 1.1.1. The Chapter gives the provisions which apply to piping systems – other than liquid cargo systems – serving tanks and normally dry spaces. For normally dry spaces, piping systems include bilge systems and gravity drains. Systems for tanks include ballast systems, fuel oil and lubricating oil storage and transfer systems, and overflow, vent and sounding systems.
- 1.1.2. Whilst the requirements satisfy the relevant regulations of the International Convention for the Safety of Life at Sea, 1974, and applicable amendments, attention should be given to any relevant regulations of the International Convention for the Prevention of Pollution from Ships, 1973, and applicable amendments, where these impact the design or construction of piping systems. Attention should also be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.
- 1.1.3. Additional requisites for liquid cargo piping, overflow and vent, sounding, bilge and ballast systems for specialized vessels, including passenger vessels, are given in Pt 7B.

1.2. Drainage

- 1.2.1. All vessels are to be rendered with effective means of pumping out or draining tanks. They are also required to have means of draining or pumping bilge water from normally dry compartments and void tanks.

1.3. Consideration for Damage Stability

- 1.3.1. Where installed within zones of assumed damage under damage stability conditions, piping that serves tanks and dry spaces, is also to be considered damaged. Damage to such piping shall not lead to progressive flooding of spaces not assumed damaged. If it is not feasible to route piping outside the zone of assumed damage, then means are to be facilitated to prevent progressive flooding. Such means, for example, may be the provision of a remotely operated valve in the affected piping or intact spaces that can be so flooded are to be assumed flooded in the damage stability conditions.
- 1.3.2. In addition, where open ended piping systems are situated below the bulkhead deck and penetrate watertight subdivision bulkheads, means operable from above the bulkhead deck are to be facilitated to prevent progressive flooding through those piping systems which remain intact following damage to the vessel.

SECTION 2 GRAVITY DRAIN SYSTEMS

Contents

2.1. General	427
2.2. Protection from Sea Water Entry.....	428
2.3. Gravity Drains of Cargo Spaces On or Above Freeboard Deck	431
2.4. Gravity Drains of Spaces other than Cargo Spaces	431
2.5. Gravity Drains of Non-watertight Spaces	432
2.6. Vessels Subject to Damage Stability.....	432
2.7. Vessels Receiving Subdivision Loadlines	432

2.1. General**2.1.1. Scope**

These requisites apply to gravity drain systems from watertight and non-watertight spaces located either above or below the freeboard deck.

2.1.2. General Definitions**a) Gravity drain system**

A gravity drain system is a piping system in which the flow is accomplished exclusively by the height difference between the inlet end and the outlet end. For the purpose of the Rules, gravity drain systems include those systems which discharge both inside and outside the vessel.

b) Gravity discharge

A gravity discharge is an overboard drain from a watertight space such as spaces below freeboard deck or within enclosed superstructures or deckhouses. The reserve buoyancy of the vessel would be affected by back flooding through a gravity discharge.

c) Inboard end

The inboard end of an overboard gravity discharge pipe is that part of the pipe at which the discharge originates. The inboard end to be considered for these requirements is the lowest inboard end where water would enter the vessel if back-flooding would occur. Also refer Sec 5/ [5.3.3], for exception to this definition.

d) Scupper

A scupper is an overboard drain from a non-watertight space or deck area. Back-flooding through a scupper would not affect the reserve buoyancy of the vessel.

2.1.3. Basic Principles

Enclosed watertight spaces (spaces below freeboard deck or within enclosed deckhouses or superstructures) are required to be rendered with means of draining. This may be accomplished by connection to the bilge system or by gravity drain. In general, a gravity drain is allowed, wherever the position of the space allows liquid to be discharged by gravity through a suitable opening in the boundary of the space. Unless specifically stated (Refer [2.3.2] of this section or the following Section), the discharge can be directed overboard or inboard. Where directed overboard, means are to be facilitated to prevent entry of sea water through the opening as per [2.2] below. Appropriate arrangements are required to be facilitated to collect and dispose of the drainage, where directed inboard.

Non-watertight spaces (open superstructures or deckhouses) and open decks, where liquid can collect, are also to be rendered with means of draining. In general, a gravity drain is permitted for all non-watertight spaces. All such drains are to be directed overboard.

Gravity drains are required to be capable of draining the space when the vessel is on even keel and either upright or listed 5 degrees on either side.

In addition to the requisites identified below, for liquid gas carriers Refer relevant Part in special type ship; for chemical carriers Refer Part 7B, Ch-6 and for passenger ships Refer Part 7B, Ch-2, .

2.2. Protection from Sea Water Entry

2.2.1. Overboard Gravity Discharges – Normally Open

a) General

- i) Discharges which drain spaces below the freeboard deck, or spaces within intact superstructures or deckhouses on the freeboard deck fitted with efficient weather tight doors, may be led overboard provided that the spaces drained are above the load waterline, and the pipes are fitted with efficient and accessible means of preventing water from passing inboard.
- ii) The drainage arrangements of enclosed 'tween deck spaces in ships with small freeboards are to be specially considered.
- iii) Discharges led through the shell from enclosed superstructures used for the carriage of cargo may be accepted only where the edge of the freeboard deck is not immersed when the ship heels 5° either way at a draught corresponding to the assigned summer freeboard. In other cases the drainage shall be led inboard.
- iv) All piping is to be adequately supported.
- v) In general, each separate overboard discharge is to be fitted with a screw-down non-return valve capable of being operated from a position always accessible and above the freeboard deck. An indicator is to be fitted at the control position showing whether the valve is open or closed. (Refer Figure 6.2.1).
- vi) It is considered that an acceptable equivalent to an automatic non-return valve with a positive means of closing from a position above the freeboard deck would be one automatic non-return valve and one sluice valve controlled from above the freeboard deck.
- vii) Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0.01Lfb [where L fb is the freeboard length of the vessel] the discharge may be fitted with two automatic non-return valves without positive means of closing, instead of the screw-down non-return valve, provided that the inboard valve is always accessible for examination under service conditions i.e. the inboard valve should be above the level of the tropical load waterline. If this is not practicable, then, provided a locally controlled sluice valve is interposed between the two automatic non-return valves, the inboard valve need not be fitted above the LWL.
- viii) Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0.02Lfb, a single automatic non-return valve without positive means of closing may be fitted.
- ix) In a ship to which timber freeboards are assigned, the summer load waterline is to be regarded as that corresponding to the timber summer freeboard.
- x) It is considered that requirements for non-return valves are applicable only to those discharges which remain open during the normal operation of a vessel. For discharges which must necessarily be closed at sea, such as gravity drains from topside ballast tanks, a single screw down valve operated from the deck is sufficient.
- xi) The inboard end of a gravity discharge which leads overboard from an enclosed superstructure or space is to be located above the waterline formed by a 5 degree heel, to port or starboard, at a draft corresponding to be assigned summer freeboard.
- xii) The gate valve controls and/or hinged cover are to be clearly marked: "Keep closed when not in use".

b) Manned Machinery Space

The fitting to the shell of a locally operated positive closing valve, together with a non-return valve inboard, will be acceptable where sanitary discharges and scuppers lead overboard through the shell in way of manned machinery spaces. The acceptable arrangements of scuppers, inlets and discharges are depicted in Figure 6.2.1.

Figure 6.2.1 Overboard Discharges – Valve Requirements

Discharges coming from enclosed spaces below the freeboard deck or on the freeboard deck				Discharges coming from other spaces	
General Requirement where Inboard End < 0.01 L above SWL	Discharges through manned machinery space	Alternatives where Inboard End		Outboard End > 450 mm below FB deck or < 600 mm above SWL	Otherwise
		> 0.01 L above SWL	> 0.02 L above SWL		
Superstructure or Deckhouse Deck 					
Symbols: Inboard End of Pipes Outboard End of Pipes Pipes terminating on the open deck Non Return Valve without positive means of closing Non Return Valve with positive means of closing controlled locally Valve Controlled Locally Remote Control Normal Thickness Substantial thickness					

2.2.2. Overboard Gravity Discharges – Normally Closed

For overboard discharges which are closed at sea, for example, gravity drains from topside ballast tanks, a single screw down valve operated from above the freeboard deck is acceptable.

2.2.3. Overboard Gravity Discharges from Spaces below the Freeboard Deck on Vessels Subject to SOLAS Requirements

For vessels subject to SOLAS requirements, instead of the requisites identified in Sect [2.2.1] above, each distinct gravity discharge led through the shell plating from spaces below the freeboard deck is to be rendered with either one automatic non-return valve fitted with a positive means of closing it from above the freeboard deck or with two automatic non-return valves without positive means of closing, provided that the inboard valve is located above the deepest subdivision load line (DSLL) and is always accessible for examination under service conditions. Where a valve with positive means of closing is fitted, the operating

position above the freeboard deck shall always be readily accessible and means shall be facilitated for indicating whether the valve is open or closed.

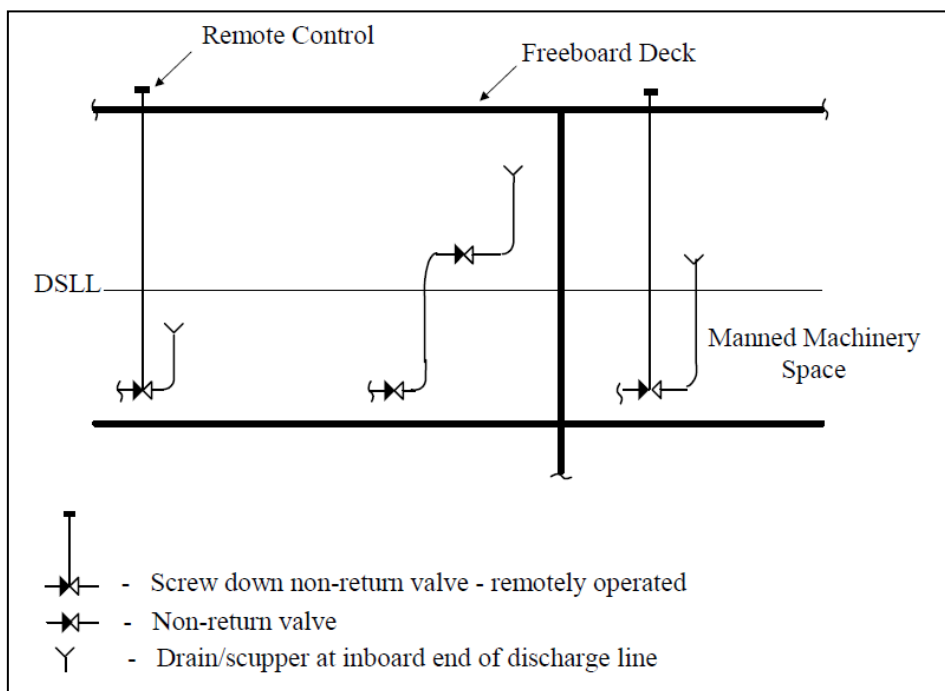


Figure 6.2.2: SOLAS Vessels – Overboard Discharges from Spaces below Freeboard Deck – Valve Requirements

2.2.4. Scuppers and Discharges below the Freeboard Deck – Shell Penetration

Scuppers and discharge pipes originating at any level and penetrating the shell either more than 450 mm (17.5 in.) below the freeboard deck or less than 600 mm (23.5 in.) above the summer load waterline is to be rendered with a non-return valve at the shell. This valve, unless required above may be omitted if the length of piping from the shell to freeboard deck has a wall thickness as per provisions of Ch-8, Sec 2/[2.5.8.3].

2.2.5. Required Minimum Wall Thicknesses for Pipes

The wall thickness of steel piping is not to be less than as given below for pipes in the gravity drain systems covered by [2.2]. The wall thickness of steel piping is not to be less than given below:

a) Piping where Substantial Thickness is Required

For scupper and discharge pipes between hull plating and the closeable or non-return valve, where substantial thickness is required:

- i) External diameter of pipes equal to or less than 80 mm (3.15 in.): thickness not less than 7.0 mm (0.276 in.)
- ii) External diameter of pipes 180 mm (7.1 in.): thickness not less than 10.0 mm (0.394 in.)
- iii) External diameter of pipes equal to or more than 220 mm (8.7 in.): thickness not less than 12.5 mm (0.5 in.)

Using linear interpolation, intermediate sizes are to be determined.

b) Piping where Substantial Thickness is not Required

For scupper and discharge pipes inboard of a closeable or non-return valve, where substantial thickness is not required:

- i) External diameter of pipes equal to or less than 155 mm (6.1 in.): thickness not less than 4.5 mm (0.177 in.)
- ii) External diameter of pipes equal to or more than 230 mm (9.1 in.): thickness not less than 6.0 mm (0.236 in.)

Using linear interpolation, intermediate sizes are to be determined.

2.3. Gravity Drains of Cargo Spaces On or Above Freeboard Deck**2.3.1. Overboard Drains**

Enclosed cargo spaces of a vessel, whose summer freeboard is such that, the deck edge of the cargo spaces being drained is not immersed when the vessel heels 5 degrees, may be drained via adequate number of suitably sized gravity drains discharging directly overboard. These drains are to be fitted with protection complying with [2.2] above.

2.3.2. Inboard Drains

Where the summer freeboard is such that the deck edge of the cargo space being drained is immersed when the vessel heels 5 degrees, the drains from these enclosed cargo spaces are required to be led to an appropriate space, or spaces, of enough capacity, having a high water level alarm and rendered with fixed pumping arrangement for discharge overboard. In addition, the system is to be designed such that:

- i. The size, number and disposition of the drain pipes shall prevent unreasonable accumulation of free water;
- ii. The pumping arrangements are to take into consideration the requirements for any fixed pressure water-spraying fire-extinguishing system;
- iii. Water contaminated with substances having flash point of 60°C (140°F) or below shall not be drained to machinery spaces or other spaces where sources of ignition may be present; and
- iv. Where the enclosed cargo space is secured by a fixed gas fire-extinguishing system, the drain pipes are required to be fitted with means to prevent the escape of the smothering gas. The U-tube water seal arrangement should not be used due to possible evaporation of water and the trouble in assuring its effectiveness.

2.3.3. Cargo Spaces Fitted with Fixed Water-spray System

Where the cargo space is fitted with a fixed water-spray fire extinguishing system, the drainage arrangements are required to be made in such a way so that it prevent the build-up of free surfaces. If this is not feasible, the undesirable effects upon stability of the added weight and free surface of water are to be taken into consideration for the approval of the stability information. Refer Chapter 13.

2.4. Gravity Drains of Spaces other than Cargo Spaces**2.4.1. Gravity Drains Terminating in Machinery Space**

Watertight spaces such as a steering gear compartment, voids, accommodations, etc. may be drained to the main machinery space; all such drains are to be fitted with a valve operable from above the freeboard deck or a quick-acting, self-closing valve. The valve shall be situated in an accessible and visible location and preferably in the main machinery spaces.

2.4.2. Gravity Drains Terminating in Cargo Holds

The cargo hold bilge well is required to be fitted with high level alarm, when gravity drains from other spaces are terminated in cargo holds.

2.4.3. Gravity Drains Terminating in a Drain Tank

Each drain pipe is required to be provided with a stop-check valve, where several watertight compartments are drained into the same drain tank.

2.4.4. Escape of Fire Extinguishing Medium

Gravity drains which terminate in spaces secured by fixed gas extinguishing systems are required to be fitted with means in order to prevent the escape of the extinguishing medium. Also refer [2.3.2] of this section.

2.5. Gravity Drains of Non-watertight Spaces

2.5.1. Scuppers leading from open deck and non-watertight superstructures or deckhouses shall be led overboard. The requisites of [2.2.4] of this section are also applicable.

2.5.2. For Helicopter Decks, steel is required to be used in the construction of drainage piping. The piping is to be independent of any other piping system and is to be led directly overboard close to the waterline. Onto any part of the vessel, the drain shall not discharge.

2.6. Vessels Subject to Damage Stability

2.6.1. Gravity drain piping where affected by damage stability considerations shall meet the provisions of Sec-3, [3.3.12].

2.7. Vessels Receiving Subdivision Loadlines

2.7.1. The bulkhead deck is required to apply provisions given in [2.2] of this section when it is higher than the freeboard deck for vessel receiving sub-division Load Lines.

SECTION 3 BILGE SYSTEM

Contents

3.1. General.....	434
3.2. Bilge System Sizing.....	434
3.3. Design of Bilge System	436
3.4. Oil Pollution Prevention Measures	440
3.5. Testing and Trials.....	441

3.1. General

3.1.1. Application

- a) The provisions of Section-3 applies to bilge systems serving propulsion and other machinery spaces, dry cargo spaces and spaces where accumulation of water is expected normally. As per latest IMO requirements, the additional requirements for bilge systems of specialized vessels such as oil carriers, passenger vessels, etc.
- b) All ships are to be provided with necessary pumps, suction and discharge piping and means of drainage so arranged that any compartment can be pumped out effectively, when the ship is on an even keel and/or designed trim and is either upright or has a list of not more than 5 degrees, through at least one suction, except for machinery spaces where at least two suctions are required, one of which is to be a branch bilge suction and the other is to be a direct bilge suction. Wing suctions will, generally, be necessary for this purpose, except for short narrow compartments, where a single suction may be sufficient.
- c) All passenger ships are to be provided with an efficient bilge pumping plant capable of pumping from and draining any watertight compartment which is neither a permanent oil compartment nor a permanent water compartment under all practicable conditions, after a casualty, whether the ship is upright or listed.

3.1.2. Basic Principles

- a) *Function.* A bilge system is intended to dispose of water which may collect in spaces within the vessel due to condensation, washing, leakage, fire fighting, etc. It is required to be capable of controlling flooding in the propulsion machinery space as a result of limited damage to piping systems.
- b) *Cross-flooding prevention.* The system shall be designed to circumvent the possibility of cross-flooding between spaces and between the vessel and the sea.
- c) *System availability.* Bilge pump integrity is to be assured through testing and certification to enhance system availability; at least two bilge pumps are to be provided, and bilge suction control valves are to be accessible for maintenance at all times.
- d) *Oil pollution prevention.* Provision is required to be made to process oily bilge water before discharging overboard.

3.2. Bilge System Sizing

3.2.1. Size of Bilge Suctions

The minimum internal diameter of the bilge suction pipes is required to be determined by the following equations, to the nearest 6 mm (0.25 in.) of the available commercial sizes.

- a) *Bilge main.* Following equation is to be used to determine the diameter of the main bilge line suction:

$$d = 25 + 1.68 \sqrt{L (B + D)} \text{ mm}$$

$$d = 1 + \sqrt{\frac{L (B + D)}{2500}} \text{ in.}$$

Where

d = internal diameter of the bilge main pipe; mm (in.)

L = scantling length of vessel, as defined in Part-3, Ch-1, Sec-2; m (ft); Refer also Sect [3.2.1(b)]

B = breadth of vessel, as defined in Part-3, Ch-1, Sec-2; m (ft)

D = depth to bulkhead or freeboard deck, as defined in Part-3, Ch-1, Sec-2; m (ft); Refer also [3.2.1(e)].

However, no bilge main suction pipe is to be less than 63 mm (2.5 in.) internal diameter.

- b) *Bilge system serving only engine room.* L may be reduced by the combined length of the cargo tanks or cargo holds, where the engine room bilge pumps are fitted primarily for serving the engine room and they do not serve cargo space bilges. In such cases, the cross sectional area of the main bilge line shall not be less than twice the required cross sectional area of the engine room branch bilge lines.
- c) *Direct bilge suction.* The diameter of the direct bilge suction .Refer Sect [3.3.5] (a)] shall not be less than that determined by the equation in Sect [3.2.1](a).
- d) *Bilge branch.* In accordance with the following equation, the diameter of the branch bilge suction for a compartment is to be determined. If the compartment is served by more than one branch suction, the combined area of all branch suction pipes shall not be less than the area corresponding to the diameter determined by the equations given below:

$$d_b = 25 + 2.16 \sqrt{c (B + D)} \text{ mm}$$

$$d_b = 1 + \sqrt{\frac{c (B + D)}{1500}} \text{ in.}$$

Where

d_b = internal diameter of the bilge branch pipe; mm (in.)

c = length of the compartment; m (ft)

However, no branch suction pipe needs to be more than 100 mm (4 in.) in internal diameter, nor it is to be less than 50 mm (2 in.), except that for pumping out small pockets or spaces, 38 mm (1.5 in.) internal diameter pipe may be used.

- e) *Enclosed cargo space on bulkhead deck.* For calculating the bilge main diameter of vessels having enclosed cargo spaces on the bulkhead deck or the freeboard deck, which is drained inboard by gravity as per Sect [3.2.2] and which extends for the full length of the vessel D is to be measured to the next deck above the bulkhead or freeboard deck. Where the enclosed cargo space covers a lesser length, D is to be taken as a molded depth to the freeboard deck plus lh/L , where l and h are aggregate length and height, respectively, of the enclosed cargo space.
- f) *Bilge common-main.* The diameter of each common-main bilge line may be determined by the equation for bilge branches as given in Sect [3.2.1(d)] using the combined compartment length upstream of the point where the diameter is being determined. In case of double hull construction with full depth wing tanks served by a ballast system, where the beam of the vessel is not representative of the breadth of the compartment, B, may be appropriately modified to the breadth of the compartment. However, no common-main bilge pipe needs to be more than the diameter for the bilge main given in Sect [3.2.1(a)].

3.2.2. Capacity of Bilge Pump

All ships, other than passenger ships, are to be provided with at least two independent power bilge pumps. Each pump is to be capable of giving a speed of water through the bilge main required by Sect [3.2.1(a)] of not less than 2 m (6.6 ft) per second. For ships of length 91.5 [m] and below, one of these pumps may be main engine driven. Refer Part 7B, Ch-2, (SOLAS Reg.II-1/21.2) for requirements regarding passenger ships. The minimum capacity Q of the required bilge pump may be determined from the equation given below:

$$Q = \frac{5.66 d^2}{10^3}, \text{m}^3/\text{hr}$$

$$Q = 16.1 d^2, \text{gpm}$$

Where

d = the required internal diameter, mm (in.), of the bilge main as defined in Sect [3.2.1(a)].

In case when more than two pumps are connected to the bilge system, their arrangement and aggregate capacity are not required to be less effective.

3.3. Design of Bilge System

3.3.1. General

All vessels shall be fitted with an efficient bilge pumping system. The system is required to meet the basic principles given in Sect [3.1.2], and be capable of pumping from and draining any watertight compartment other than spaces permanently used for carriage of liquids and for which other efficient means of pumping are provided. Non-watertight compartments which are likely to accumulate water, such as chain lockers, non-watertight cargo holds, etc., are also to be provided with an efficient bilge pumping system.

In lieu of a bilge pumping system, a gravity drain system, may be accepted subject to the provisions of Sec-2 of this chapter.

Bilge pumping systems are required to be capable of draining the spaces when the vessel is on even keel and either upright or listed 5 degrees on either side.

3.3.2. Bilge Pumps and Ejectors

- a) *Number of pumps.* Minimum two power driven bilge pumps are to be provided and it is required that one of it is driven by the propulsion unit. Bilge pump capacity is to be as per Sect [3.2.2].
- b) *Permissible use of other pumps.* Ballast, sanitary and general service pumps may be accepted as independent power bilge pumps, subject to that they are of required capacity, are appropriately connected to the bilge system and are not normally used for pumping oil. Pumps required for essential services are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any pumps so connected is unaffected by the other pumps being in operation at the same time.
- c) *Priming.* Where centrifugal pumps are installed, they are required to be of the self-priming type or connected to a priming system. However, pumps used for emergency bilge suction [Refer Sect [3.3.5] (b)] shall not be of the self-priming type.
- d) These pumps, together with the pipelines to which they are connected, are fitted with necessary devices to ensure that there is no risk of entry of water or oil fuel in the holds or machinery spaces. The arrangements are such that at least one of these pumps is immediately available for bilge duty, when required, even when the remaining pumps are in use for other essential duties such as firefighting.
- e) An ejector in conjunction with a sea water pump may be accepted as a substitute for independent power bilge pump. This, however, is not acceptable on passenger ships.
- f) *Test and certification.* Bilge pumps are required to be certified as per Ch-8, Sec-1/[1.4.2].

3.3.3. Strainers

Bilge lines in machinery spaces other than emergency suction shall be fitted with strainers, easily accessible from the floor plates, and are required to have straight tail pipes to the bilges. The ends of the bilge lines in other compartments are to be fitted with appropriate strainers having an open area of not less than thrice the area of the suction pipe.

3.3.4. Bilge Piping System – General

a) Bilge manifolds and valves

Bilge manifolds and valves in connection with bilge pumping are to be situated in positions which are accessible for maintenance under ordinary operating conditions at all times. All valves at the manifold controlling bilge suction from the various compartments are to be of the stop-check type. A stop valve and a non-return valve may be accepted, in place of a stop-check valve.

b) Main control valves

The bilge suction main, the ballast suction main, etc. are each to be provided with a stop valve, where a bilge pump is connected for bilge, ballast and other sea water services, so that when the pump is used for one service, the other services can be isolated.

c) Bilge piping passing through tanks

Where passing through deep tanks, unless being led through a pipe tunnel, bilge suction lines are to be of steel having a thickness at least as required by column D of Table 8.2.5 of Chapter-8. Pipes of other materials having such dimensions that properly account for corrosion and mechanical strength may be accepted. Minimum numbers of joints in these lines are to be maintained. Pipe joints are to be welded or heavy flanged (e.g., one pressure rating higher). The line within the tank is to be installed with expansion bends. Slip joints are not allowed. A non-return valve is to be fitted at the open end of the bilge line. In event of a leak in the bilge line, these requisites are intended to protect the space served by the bilge line from being flooded by liquid from the deep tank.

d) Arrangement of suction pipes

When the vessel is listed (Refer Sect [3.3.1]), for drainage, wing suction will often be necessary, except in narrow compartments at the ends of the vessel. Such arrangements are to be made such that the water in the compartment will drain to the suction pipe.

3.3.5. Requirements for Propulsion Machinery Space

a) *Direct bilge suction*

One of the required independently driven bilge pumps is required to be fitted with a suction led directly from the propulsion machinery space bilge to the suction main of the pump, so arranged that it can be operated independently of the bilge system. The size of this line shall not be less than that determined by Sect [3.2.1(c)]. Stop-check valve is to be there to control the direct bilge suction.

If watertight bulkheads split the propulsion machinery space into compartments, direct bilge suction is to be fitted from each compartment, unless the pumps available for bilge service are spread throughout these compartments. In this case, minimum one pump with a direct suction is to be fitted in each compartment.

b) *Emergency bilge suction*

An emergency bilge suction shall be fitted for the propulsion machinery space, in addition to the direct bilge suction required by (a) above. The emergency bilge suction is to be directly connected to the largest independently driven pump in the propulsion machinery space, other than the required bilge pumps. Where this pump is not proper, the second largest appropriate pump in the propulsion machinery space may be used for this service, provided that the selected pump is not one of the required bilge pumps and its capacity shall not be less than that of the required bilge pump.

The emergency bilge line is to be provided with a suction stop-check valve, which is to be so located such that the rapid operation and a suitable overboard discharge line is enabled. For the emergency bilge inlet, the distance between the open end of the suction inlet and the tank top is to be adequate to allow a full flow of water. The hand wheel of the emergency bilge suction valve is to be stationed not less than 460 mm (18 in) above the floor plates.

Besides that, the following arrangements are also to be complied with, as applicable:

- i. For internal-combustion-engine propulsion machinery spaces, the area of the emergency bilge suction pipe shall be equal to the full suction inlet of the selected pump.
 - ii. For steam propulsion machinery spaces, the main cooling water circulating pump is to be the first choice for the emergency bilge suction, and in that case, the diameter of the emergency bilge suction is to be at least two-thirds the diameter of the cooling water pump suction.
- c) Centralized or unattended operation

A high bilge water level alarm system is to be fitted, where the propulsion machinery space is intended for centralized or unattended operation (CCS/UM notation) refer Part-6, Ch-8, Sec-4/ [4.1.12]. As a minimum, bilge valve controls are to be situated above the floor grating, with regard to time likely to be required, in order to get to and operate the valves.

3.3.6. Requirements for Small Compartments

Small compartments, such as echo sounder spaces, chain lockers and decks over peak tanks, etc., may be drained by ejectors or hand pumps. Where ejectors are used for discharge, the overboard discharge arrangements are to conform to Sec-2/ [2.2].

3.3.7. Common-main Bilge Systems

A common-main bilge system normally has one or more main lines installed along the length of the vessel fitted with branch bilge suction connections to various compartments. The bilge main is required to be sited inboard of 20% of the molded beam of the vessel, where only one fore-aft bilge main is installed, measured inboard from the side of the ship, perpendicular to the centerline at the level of the summer load line. If there is at least one bilge main on each side of the vessel, then these bilge mains may be installed within 20% of the molded beam measured inboard from the side of the ship, perpendicular to the centerline at the level of the summer load line. In such cases, piping arrangements are to be such that it is feasible to effectively pump out all compartments using the main on either side of the vessel.

The control valves required in the branches from the bilge main are required to be accessible at all times for maintenance for single common-main bilge systems. This accessibility is not required for multiple common-main bilge systems arranged such that any single control valve failure will not disable the bilge pumping capability from any one space. In all cases, control valves are to be of the stop-check type with remote operators. From a manned machinery space, or from an accessible position above the freeboard deck, or from under deck walkways, remote operators may be controlled. Remote operators may be of pneumatic, hydraulic, electric or reach rod type.

3.3.8. Cargo Spaces of Combination Carriers

The arrangements are to be made for blanking off the oil and ballast lines and removing the blanks in the bilge lines when dry or bulk cargo is to be transported, for combination carriers, such as oil-or-bulk carriers. On the contrary, the bilge lines are to be blanked-off when oil or ballast is to be transported.

3.3.9. Cargo Spaces Intended to Carry Dangerous Goods

The underlying requirements apply to cargo spaces intended to transport dangerous goods as defined in Solas Ch 2

a) *Independent bilge system*

A bilge system, independent of the bilge system of the machinery space and situated outside the machinery space, is required to be provided for cargo spaces intended to carry flammable liquids with a flash point of less than 23°C or toxic liquids. The independent bilge system is to comply with the provisions of Sec-3, including the provision of at least two bilge pumps. The space containing the independent bilge pumps shall be independently ventilated, giving at least six air changes per hour. This, however, does not apply to eductors located in cargo space.

b) *Combined bilge system*

As an alternative to (a) above, the cargo spaces may be served by the bilge system of the machinery space and an alternative bilge system. The alternative bilge system is to be independent of or capable of being separated from the machinery space bilge system. The capacity of the alternative bilge system is to be at least 10 m³/h per cargo space served, but need not go beyond 25 m³/h. This alternative bilge system need not be provided with redundant pumps. Whenever flammable liquids with flash point of less than 23°C or toxic liquids are transported in the cargo spaces, the bilge lines leading into the machinery space are to be blanked off or closed off by lockable valves. In addition, a warning notice to this effect is required to be displayed at the location

c) *Gravity drain system*

The drainage is to be led directly overboard or into a closed drain tank located outside machinery spaces, if the cargo spaces are drained by gravity. The drain tank is to be vented to a secure location on the open deck. Drainage from a cargo space to the bilge well of a lower cargo space is only allowed if both spaces satisfy the similar requirements.

3.3.10. Cargo Spaces Fitted with Fixed Water-spray System

The drainage arrangements are required to be such as to check the build-up of free surfaces, where the cargo space is fitted with a fixed water-spray fire extinguishing system. If this is impossible, the unfavorable effect upon stability of the added weight and free surface of water are to be taken into account for the approval of the stability information. Refer SOLAS Ch 2

3.3.11. Bilge Suctions for Normally Unmanned Spaces

Normally, unmanned spaces situated below the waterline, such as bow thruster compartment, emergency fire pump room, etc., for which bilge pumping is required, are to be arranged such that bilge pumping can be effected from outside the space, or alternatively, a bilge alarm is to be provided.

3.3.12. Vessels Subject to Damage Stability

Bilge pipes installed within the area of assumed damage under damage stability conditions shall be considered damaged. Bilge piping will affect damage stability considerations if:

- It is installed within the extent of assumed damage in damage stability consideration, and
- The harm to such bilge piping will lead to progressive flooding of intact spaces through open ends in the bilge piping system.

Affected bilge piping is to be fitted with non-return valves in the lines in the intact spaces to keep in check progressive flooding of these spaces. The valves will not be needed if it can be shown that, even with the progressively flooded spaces taken into consideration, the vessel still conforms to the applicable damage stability criteria.

3.3.13. Cargo Spaces With Non-watertight Hatches Intended to Carry Containers

Where cargo holds are used solely for the transport of containers and for which hatch covers weather tight gaskets have been dispensed with, a bilge alarm system is to be provided.

a) *Bilge Level.*

The cargo holds are to be provided with two independent systems to detect excessive rise of bilge water in the bilges or bilge wells. The arrangements including the number of sensors and locations are to be such that accumulation of bilge water may be detected at the various angles of vessel's heel and trim. The alarm is to be given in the centralized control station.

b) *Bilge Pump.*

Where the bilge pumps are arranged for automatic operation, means are to be provided to indicate, at the centralized control station, when the pump is operating more frequently than would normally be expected, or when the pump is operating for an excessive length of time.

3.4. Oil Pollution Prevention Measures

3.4.1. General

Means shall be provided to process oil contaminated water from machinery space bilges before discharging it overboard. In general, the discharge criteria of MARPOL ANNEX 1, Regulation 15 are required to be complied with.

3.4.2. Oily Water Filtering or Separating Equipment

Oily water filtering equipment capable of processing oily mixtures to produce an effluent with oil content not going beyond 15 parts per millions (PPM) and conforming to IMO Resolution.107(49) shall be provided to allow oily water from the bilges to be processed before discharging overboard. The equipment is to be fitted with an alarm and an arrangement to automatically stop the discharge when 15 PPM cannot be maintained, for vessels of 10,000 tons gross tonnage and above.

3.4.3. Sludge Tank

A tank or tanks of adequate capacity, meeting MEPC.1/Circ.51, shall be provided to obtain oily residues such as those resulting from the oily water filtering or separating equipment and from the purification of fuel and lubricating oils. The minimum sludge tank capacity V_1 is required to be calculated by the formula given below:

$$V_1 = K_1 C D \quad \text{m}^3 \text{ (ft}^3\text{)}$$

Where,

K_1 = 0.015 for vessels where heavy fuel oil is purified for main engine use or
= 0.005 for vessels using diesel oil or heavy fuel oil which does not require purification before use.

C = daily fuel oil consumption, $\text{m}^3 \text{ (ft}^3\text{)}$

D = maximum period of voyage between ports where sludge can be discharged ashore (days). If accurate data is not available, a figure of 30 days is to be used.

For vessels fitted with incinerators or similar equipment for onboard disposal of sludge, the minimum sludge tank capacity may be reduced to 50% of V_1 or 2 m³ (72 ft³) [1 m³ (36 ft³) for vessels below 4,000 gross tonnage], whichever is greater.

The sludge tank is to be designed in such a way so that its cleaning is facilitated. Heating arrangements are to be provided to facilitate the discharge of the sludge tank, where heavy fuel oil residue is expected to be received by the sludge tank.

3.4.4. Sludge Piping System

- a) *Sludge pump.* The sludge tank shall be provided with a designated pump of a suitable type, capacity and discharge head for the discharge of the tank content to shore reception facilities.
- b) *Standard discharge connection.* To enable the discharge of sludge to shore reception facilities, the sludge piping shall be provided with a standard discharge connection, as per Table 9.3.1.
- c) *Sludge piping.* There shall be no interconnection between the sludge tank discharge piping and bilge piping other than the possible common piping, with appropriate valves, leading to the standard discharge connection. Piping to and from sludge tanks is to have no direct connection overboard other than the standard discharge connection referred to in (b) above.

Table 9.3.1: Dimensions and Details of Standard Discharge Connection Flange

	Dimension
Outside diameter	215 mm
Inner diameter	According to pipe outside diameter
Bolt circle diameter	183 mm
Slots in flange	6 holes 22 mm in diameter equidistantly placed on a bolt circle of the above diameter, slotted to the flange periphery. The slot width to be 22 mm
Flange thickness	20 mm
Bolts and nuts:	6 sets, each of 20 mm in diameter and of suitable length
Note: The flange is designed to accept pipes up to a maximum internal diameter of 125 mm and is to be of steel or other equivalent material having a flat face. This flange, together with a gasket of oil-proof material, is to be suitable for a service pressure of 6 kg/cm ²	

3.5. Testing and Trials

The bilge system is required to be tested under working conditions, Refer Ch-8, Sec 2,/[2.4.2.3]. For trials of bilge Systems, all elements are to be tested to demonstrate satisfactory pumping operation, including emergency suction and all controls. Upon completion of the trials, the bilge strainers are to be opened, cleaned and closed up in good order.

SECTION 4 BALLAST SYSTEMS

Contents

4.1. Scope 443

4.2. Ballast Pumps..... 443

4.3. Ballast Piping and Valves 443

4.1. Scope

- 4.1.1. The requirements of this section apply to ballast systems for all vessels. Refer Part 7B / Ch-3 for additional ballast system requirements for Oil Tankers.
- 4.1.2. The basic principle of these requirements are intended to provide a reliable means of pumping and draining ballast tanks through the provision of redundancy and certification of ballast pumps, and the provision of suitable remote control, where fitted.

4.2. Ballast Pumps

- 4.2.1. At least two power driven ballast pumps shall be provided, one of which may be driven by the propulsion unit. Bilge, sanitary and general service pumps may be accepted as independent power ballast pumps. Alternative means of deballasting, such as an eductor or a suitable liquid cargo pump with an appropriate temporary connection to the ballast system, may be accepted in lieu of a second ballast pump.
- 4.2.2. In accordance with the provisions of Ch-8, Sec 1, [1.4.2], Ballast pumps are required to be certified.

4.3. Ballast Piping and Valves

- 4.3.1. Provision is to be made for ballasting and de-ballasting all the ballast tanks by pipe lines which are entirely separate and distinct from pipe lines used for bilging.

Where the length of the ballast tanks exceeds 30 [m], an additional suction is to be provided at the forward end of the tanks. Where the width of the tank is unusually large, suction near the centerline in addition to wing suctions may be required.

- 4.3.2. Ballast Tank Valves

Except when ballasting, at all times, valves controlling flow to ballast tanks are to be so arranged, that they will remain closed. Where butterfly valves are used, they are to be of a type with positive holding arrangements, or equivalent, that will check the movement of the valve position due to vibration or flow of fluids.

- 4.3.3. Remote Control Valves

Remote control valves are to be arranged, where fitted, so that they will close and remain closed in the event of loss of control power. Alternatively, the remote control valves may remain in the last ordered position upon loss of power, provided that there is a readily accessible manual means to close the valves upon loss of power.

Remote control valves are required to be clearly identified as to the tanks they serve and are to be provided with position indicators at the ballast control station.

- 4.3.4. Vessels Subject to Damage Stability

Ballast pipes installed in the regions of assumed damage under damage stability consideration are required to be considered damaged. Ballast piping will affect damage stability considerations if:

- It is installed within the extent of assumed damage in damage stability consideration, and
- The damage to the ballast pipe will lead to progressive flooding of intact ballast tanks through open ends in the ballast piping system.

Affected ballast piping is required to be fitted with valves in the pipes in the intact tanks to check progressive flooding of these tanks. The valves are required to be of a positive closing type and operable from above the freeboard deck or from a manned machinery space.

Where the valves are hydraulically, electrically or pneumatically actuated, the cables or piping for this purpose shall not be installed within the extent of assumed damage, or, alternatively, the valves are to be arranged to fail in the closed position upon loss of control power.

The valves will not be required if it can be shown that, even with the progressively flooded spaces taken into consideration, the vessel still fulfills the applicable damage stability criteria.

4.3.5. Ballast Pipes Passing Through Fuel Oil Tanks

To reduce cross-contamination, where passing through fuel oil tanks, unless being led through pipe tunnel, ballast lines shall be of steel or equivalent (Refer Sec-3, [3.3.4(c)]) having a thickness at least as required by column D of Table 8.2.5 of Chapter-8. The number of joints in these lines is required to be kept to a minimum. Pipe joints are to be welded or heavy flanged (e.g., one pressure rating higher). The line within the tank is to have provision of accommodating contraction / expansion by approved means. Slip joints are not allowed.

Ballast Water Treatment Systems

Where ballast water treatment system is to be installed, it is to comply with requirements in Sections of INTLREG Guide for Ballast water treatment and same is to be verified by INTLREG surveyor

SECTION 5 TANK VENTS AND OVERFLOWS

Contents

5.1. General..... 446

5.2. Tank Vents 447

5.3. Tank Overflows 453

5.1. General

5.1.1. Application

These requirements are applicable to vents and overflows of liquid and void tanks. Tanks which contain flammable liquids, such as fuel oil and lubricating oil, are subject to additional requirements, which are provided in this subsection. For hydraulic oil, also refer Ch-8, Sec-6/, [6.2.2.2]. Vents and overflows, and inerting systems, for liquid cargo tanks, as applicable, are provided in Part 7B of INTLREG Rules.

The ventilators which are installed for ventilation of normally dry compartments, such as steering gear compartment, cargo hold, etc., are to comply with the provisions of Part-4, Ch.6, Sec-8.

Reference to oil in this Section is to be taken to mean oil which has a flash point of 60°C or above (closed cup test). The portions of vent, overflow and sounding pipes fitted above the weather deck are to be of steel. Name plates are to be affixed to the upper ends of all vent and sounding pipes.

5.1.2. Basic Requirements

- a) *Purposes of vents.* Vents are provided in all tanks served by pumps. Primarily, vents allow air or vapor from within the tank to escape when the tank is being filled, and take in air when the tank is being discharged. Vents are also required for tanks in the storage mode to allow them to 'breathe'. In general, vents shall be fitted at the highest point of the tanks so that venting can be attained effectively.

Vent pipes are to be fitted to all tanks, cofferdams, tunnels, sea chests and other compartments which are not fitted with alternative ventilation arrangements.

- b) *Purposes of overflows.* In addition to vents, tanks filled by a pumping system/ gravity may be fitted with overflows. Overflows prevent over-pressurization of a tank if it is overfilled and also provide for safe discharge or disposal of the overflowing liquid. To limit the level at which a tank may be filled, overflows may also be fitted. Overflows are to be sized depending on the capacity of the pump and the size of the filling line. Considerations are to be given to receiving the overflow.
- c) *Combining vents and overflows.* Vents may also act as overflows provided all the requirements applicable to both vents and overflows are fulfilled.
- d) *Termination of the outlet ends of vents and overflows.* Generally, vents originating from tanks containing liquids likely to evolve flammable or hazardous vapor are to have their outlets situated in the open weather. Depending on the liquid contained in the tank, overflow outlets are to be so situated that they either discharge overboard or into designated overflow tanks in order to avoid unintended flooding of internal spaces. Outlet ends of vents and overflows, where exposed to the weather, are required to be provided with means to prevent sea water from entering the tanks through these openings.
- e) *Small spaces.* Small voids which are not fitted with permanent means of pumping out bilges, or through which no pressurized piping passes, may be exempted from being fitted with vents.
- f) Vent pipes are to be fitted to all tanks, cofferdams, tunnels, sea chests and other compartments which are not fitted with alternative ventilation arrangements.
- g) The vent pipes are to be fitted at the opposite end of the tank to which the filling pipes are placed and/or at the highest part of the tank. Where the tank top is of unusual or irregular profile, special consideration will be given to the number and positions of the vent pipes.
- h) Tanks provided with anodes for cathodic protection, are to be provided with vent pipes at forward and aft ends.

- i) Vent pipes to double bottom tanks, deep tanks extending to the shell plating or tanks which can be run up from the sea and sea chests are to be led above the bulkhead deck. Air pipes for sea chests are to be fitted with shut off valve directly on sea chest.
- j) Vent pipes to oil fuel and cargo oil tanks, cofferdams, all tanks which can be pumped up, shaft tunnels and pipe tunnels are to be led above the bulkhead deck and to open air. Vent pipes from lubricating oil storage tanks may terminate in the machinery spaces, provided that the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces.
- k) The open ends of vent pipes to oil fuel and cargo oil tanks are to be situated where no danger will be incurred from issuing oil or vapour when the tank is being filled.
- l) The open ends of vent pipes to oil fuel, cargo oil and ballast tanks fitted with anodes for cathodic protection, are to be fitted with a wire gauze diaphragm of non-corrosive material which can be readily removed for cleaning. The clear area through the wire gauze is to be at least equal to the area of the vent pipe. Location and arrangement of vent pipes for fuel oil service, settling and lubricating oil tanks is to be such that a broken vent pipe will not directly lead to the risk of ingress of seawater splashes or rainwater.
- m) Vent pipes are to be self-draining under normal conditions of trim.

5.1.3. Vessels Subject to Damage Stability Requirements

Vents and overflows of vessels subject to damage stability requisites are required to be terminated above the equilibrium water line in the damaged conditions. Automatic means of closure are to be fitted to the outlets of vents whose intersection with the deck is below the equilibrium water line. Such means are also required for those vents whose outlets will be submerged in the range of residual stability beyond the equilibrium where such range is required by the applicable damage stability criteria.

5.2. Tank Vents

5.2.1. General Requirements

Generally, each tank served by a pumping system, as indicated in Sect [5.1.2] above, is to be fitted with at least two vents. However, tanks with surface area less than $B^2/16$ (where B is the breadth of the vessel as defined in Part-3, Ch-1, Sec-2, may be fitted with one vent. The vents are to be placed as far apart as possible.

As far as feasible, the vent pipe is to be situated at the highest point of the tank. This is to allow air, vapor and gas from all parts of the tank to have access to the vent pipe with the vessel at an upright position or at varying angles of heel and trim. Vent pipes are to be arranged to facilitate adequate drainage. No shut-off valve or closing device that can check the venting from a tank is to be installed in vent piping.

5.2.2. Vent Pipe Height and Wall Thickness

- a) *Exposed to weather.* Vent pipes on decks exposed to the weather are to have heights as given under:

760 mm (30 in.) for those on the freeboard deck; and

450 mm (17.5 in.) for those on the superstructure deck.

The height is to be measured from the deck to the point where water may have access below. Where these heights may meddle with the working of the vessel, a lower height may be accepted, provided INTLREG is satisfied that the closing arrangements and other circumstances to justify a lower height.

The wall thicknesses of vent pipes, where exposed to the weather, shall not be below than that given in Table 9.5.2 specified below. For vent pipes located on the fore deck, the strength and wall thickness requisites are to also conform to Part-4, Ch-6, Sec-7 and Sec-8.

Table 9.5.1.

Nominal Size, d	Min. Wall Thickness
$d \leq 65 \text{ mm (2.5 in.)}$	6.0 mm (0.24 in.)
$65 \text{ mm (2.5 in.)} < d < 150 \text{ mm (6 in.)}$	by interpolation (refer note)
$d \geq 150 \text{ mm (6 in.)}$	8.5 mm (0.33 in.)
Note: $6 + 0.029(d - 65) \text{ mm}$ or $0.24 + 0.026(d - 2.5) \text{ in.}$	

- b) *Not exposed to weather.* Vent pipes which are not exposed to the weather need not conform to the height and wall thickness required by (a). However, vent pipes passing through fuel oil or ballast tanks are required to have wall thicknesses not less than that indicated in column D of Table 8.2.5 of Chapter-8. Other vent pipes shall meet thickness requirements of column C of the same table.

5.2.3. Vent Pipe Size

- a) *Minimum size.* The minimum internal diameter of vent pipes is required to be as per Table 9.5.2.

Table 9.5.2.

Tank	Minimum Internal Diameter, mm (in.)
Water tanks	50 (2) (Refer Note)
Oil tanks	65 (2.5)
Note: Minimum diameter of vent pipes on fore deck not to be less than 65 mm.	

where water tanks refer to freshwater and sea water tanks; oil tanks refer to fuel oil, hydraulic oil, lubricating oil, and other oil tanks. Small water or oil tanks of less than 1 m³ (36 ft³) may have vent pipe of 38 mm (1.5 in.) minimum internal diameter.

- b) *Vent sizing*

The aggregate area of the vent pipe(s) provided for the tank is to be at least 125% of the effective area of the filling line, where a separate overflow is not fitted.

Where overflow pipe(s) are fitted, and the aggregate area of the overflow pipes is at least 125% of the effective area of the filling line, in such cases, vent pipes need not go beyond the minimum sizes in (a) above.

Where high capacity or high head pumps are used, calculations demonstrating the adequacy of the vent and overflow to prevent over- or under-pressurization of the ballast tanks are required to be submitted. Also refer Sect [5.3.2].

5.2.4. Termination of Vent Pipe Outlets

- a) *Termination on weather deck.* Outlets of vents from the following tanks are to be led to the weather:
- b)
- Ballast tanks
 - Fuel-oil tanks, except fuel-oil drain tanks with a volume less than 2 m³ (70.6 ft³) and which cannot be filled by a pump – refer Sec [7.2.4].
 - Thermal oil tanks

- Tanks containing liquids having flash point of 60°C (140°F) or below
- Void tanks adjacent to tanks containing liquids having a flash point of 60°C or below

Where it is not feasible to terminate vents on a weather deck as required, such as the case of open car deck of a ro-ro vessel, vents may be led overboard from a deck below the weather deck. In such a case, non-return valves of an approved type are fitted at the outlets to check ingress of water. Also refer Sect [5.3.3] of this section.

- c) *Termination on or above freeboard deck.* Vent outlets from double bottom and other structural tanks, including void tanks, whose boundaries extend to the shell of the vessel at or below the deepest load waterline, are to be led above the freeboard deck. This is so that in the event of shell damage in way of these tanks, the vent pipes will not act as a possible source of progressive flooding to otherwise intact spaces below the freeboard deck.
- d) *Termination in machinery space.* Vents from tanks other than those stated in (a) and (b) may cease within the machinery space, provided that their outlets are so situated that overflow from there will not intrude the electrical equipment, causes a hazardous consequence such as fire, or endanger personnel.

5.2.5. Protection of Vent Outlets

- a) *Protection from weather and sea water ingress.* All vents terminating in the weather are required to be fitted with return bends (gooseneck), or equivalent, and the vent outlet shall be provided with an automatic means of closure i.e., close automatically upon submergence (e.g., ball float or equivalent) conforming to Sect [5.2.7] below.
- b) *Protection for fuel oil tanks.* In addition to (a) above, vents from fuel oil tanks are to fulfill the following:
 - i) Vent outlets are required to be fitted with corrosion resistant flame-screens. Either a single screen of corrosion-resistant wire of at least 12 by 12 mesh per linear cm (30 by 30 mesh per linear inch), or two screens of at least 8 by 8 mesh per linear cm (20 by 20 mesh per linear inch) spaced not less than 13 mm (0.5 inch) nor more than 38 mm (1.5 inch) apart are acceptable. The clear area through the mesh of the flame-screen shall not be less than the required area of the vent pipe specified in Sect [5.2.3] above.
Note: Mesh count is defined as a number of openings in a linear cm (inch) counted from the center of any wire to the center of a parallel wire.
 - ii) Vent outlets are to be located where possibility of ignition of the gases issuing there from is remote.
 - iii) Vents for fuel oil service and settling tanks directly serving the propulsion and generator engines are to be so placed and arranged that in the event of a broken vent pipe, this will not directly lead to the risk of ingress of rain water or sea water splashes into the fuel oil tanks.
- c) *Protection for lubricating oil tanks.* Vents for lubricating oil tanks directly serving propulsion and generator engines, where terminated on the weather deck are required to be so sited and arranged that in the event of a broken vent pipe, this will not directly lead to the risk of ingress of rain water or sea water splashes.

5.2.6. Oil Pollution Prevention

Vents from fuel oil and other oil tanks, which, in the event of an involuntary overflow, may result in oil pollution of the marine environment, shall be fitted with overflow arrangements (Refer Sect [5.3.5]) or means of containment, such as a coaming, in way of vent outlets.

5.2.7. Vent Outlet Closing Devices

- a) *General.* Where vent outlets are required by [5.2.5(a)] to be fitted with automatic closing devices, they are to fulfill the following:
- b) *Design.*
- i) Vent outlet automatic closing devices shall be designed in such a way so that they will survive in both ambient and working conditions, and be suitable for use at inclinations up to and including $\pm 40^\circ$.
 - ii) Vent outlet automatic closing devices shall be constructed to allow inspection of the closure and the inside of the casing, as well as changing the seals.
 - iii) Efficient ball or float seating arrangements are required to be provided for the closures. Bars, cage or other devices shall be provided to prevent the ball or float from contacting the inner chamber in its normal state and made in such a way that the ball or float is not damaged when subjected to water impact due to a tank being overfilled.
 - iv) Self-draining vent outlet automatic closing devices are to be installed.
 - v) The clear area through a vent outlet closing device in the open position is required to be at least equal to the area of the inlet.
 - vi) An automatic closing device is to:
 - Prevent the free entry of water into the tanks,
 - Allow the passage of air or liquid to prevent excessive pressure or vacuum developing in the tank.
 - vii) In the case of vent outlet closing devices of the float type, suitable guides are to be provided to ascertain unhindered operation under all working conditions of heel and trim.
 - viii) The maximum allowable tolerances for wall thickness of floats should not go beyond $\pm 10\%$ of thickness. Closing device to be INTLREG approved type or certified by INTLREG. Refer (d) below.
 - ix) The outer and inner chambers of an automatic air pipe head is to be of a minimum thickness of 6 mm (0.24 inch).
- c) *Materials*
- i) Casings of vent outlet closing devices are to be of approved metallic materials sufficiently secured against corrosion.
 - ii) For galvanized steel air pipe heads, the zinc coating is required to be applied by the hot method and the thickness is to be 70 to 100 micrometers (2.756 to 3.937 mil).
 - iii) An additional harder coating should be applied for areas of the head susceptible to erosion (e.g. those parts directly subjected to ballast water impact when the tank is being pressed up, for example the inner chamber area above the air pipe, plus an overlap of 10° or more to either side). This is to be an aluminum bearing epoxy, or other equivalent coating, applied over the zinc.
 - iv) Closures and seats made of non-metallic materials shall be compatible with the media proposed to be carried in the tank and to seawater, and appropriate for operating at ambient temperatures between -25°C and 85°C (-13°F and 185°F).
- d) *Type Testing*
- i) *Testing of Vent Outlet Automatic Closing Devices.* Each type and size of vent outlet automatic closing device is required to be surveyed and type tested at the manufacturer's works or other acceptable location.

The minimum test requisites for a vent outlet automatic closing device are required to include the determination of the flow characteristics of the vent outlet closing device, the measurement of the pressure drop versus the rate of volume flow using water and with any intended flame or insect screens in place and also tightness tests during immersion/ emerging in water, whereby the automatic closing device shall be subjected to a series of tightness tests involving not less than two (2) immersion cycles under each of the following conditions:

- The automatic closing device is required to be submerged slightly below the water surface at a velocity of approximately 4 m/min (13.12 ft/min) and then returned to the original position immediately. The quantity of leakage shall be recorded.
- The automatic closing device is required to be submerged to a point slightly below the surface of the water. The submerging velocity is required to be approximately 8 m/min and the air pipe vent head is to remain submerged for not less than 5 minutes. The quantity of leakage shall be recorded.
- Each of the above tightness tests are to be conducted in the normal position as well as at an inclination of 40 degrees under the strictest conditions for the device. In cases where such strictest conditions are not clear, tests shall be carried out at an inclination of 40 degrees with the device opening facing in three different directions: upward, downward, sideways (left or right).

The maximum allowable leakage per cycle is not to go beyond 2 ml/mm (1.312×10^{-2} gal/inch) of nominal diameter of inlet pipe during any individual test.

- ii) *Discharge/Reverse Flow Test.* The air pipe head shall allow the passage of air to prevent excessive vacuum developing in the tank. A reverse flow test shall be performed. A vacuum pump or another suitable device shall be connected to the opening of the air pipe leading to the tank. The flow velocity shall be applied gradually at a constant rate until the float gets sucked and blocks the flow. The velocity at the point of blocking shall be recorded. 80% of the value recorded will be stated in the certificate. Each type and size of vent outlet automatic closing device is to be surveyed and type tested at the manufacturer's works or other acceptable location.
- iii) *Testing of Non-metallic Floats.* Impact and compression loading tests are to be done on the floats prior to and after pre-conditioning as per Table 9.5.3: Immersing in water and fuel oil is to be done for at least 48 hours.

Table 9.5.3

Test conditions	Test temperature °C (°F)		
	-25°C (-13°F)	20°C (68°F)	85°C (185°F)
Dry	Yes	Yes	Yes
After immersing in water	Yes	Yes	Yes
After immersing in fuel oil	NA	Yes	NA

Impact Test. The test may be done on a pendulum type testing machine. The floats are to be subjected to 5 impacts of 2.5 N-m (1.844 lbf-ft) each and are not required to suffer permanent deformation, cracking or surface deterioration at this impact loading.

Subsequently, the floats are required to be subjected to 5 impacts of 25 N-m (18.44 lbf-ft) each. Some localized surface damage at the impact point may happen at this impact energy level. No permanent deformation or cracking of the floats shall appear.

Compression Loading Test. Compression tests are to be done with the floats mounted on a supporting ring of a diameter and bearing area corresponding to those of the float seating with which it is intended that the float shall be used. Loads are to be applied through a concave cap of the same internal radius as the test float and bearing on an area of the same diameter as the seating, for a ball type float. Loads are to be applied through a disc of equal diameter as the float, for a disc type float.

A load of 3430 N (350 kgf, 770 lbf) shall be applied over one minute and maintained for 60 minutes. The deflection is to be measured at intervals of 10 minutes after attachment of the full load.

The record of deflection against time is to show no continuing rise in deflection and, after release of the load, there is to be no permanent deflection.

- iv) **Testing of Metallic Floats.** The above described impact tests are to be done at room temperature and in the dry condition.

Fig. 9.5.4 : Example of Normal Position

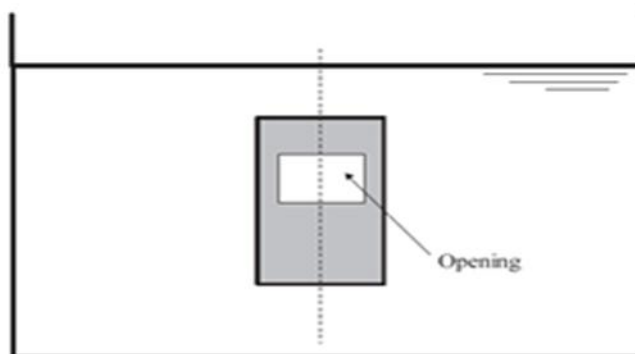


Fig.9.5.5 : Example of Inclination 40° Opening Facing upward

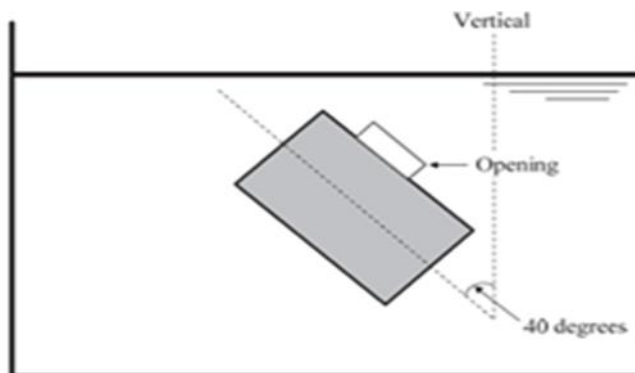
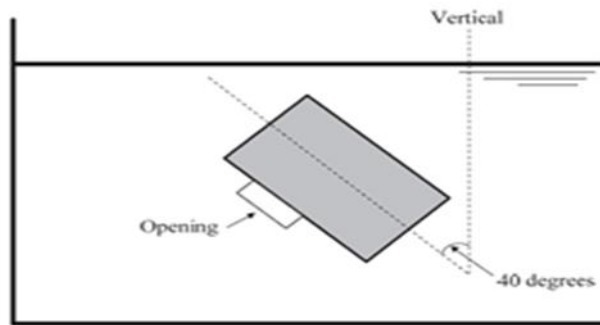
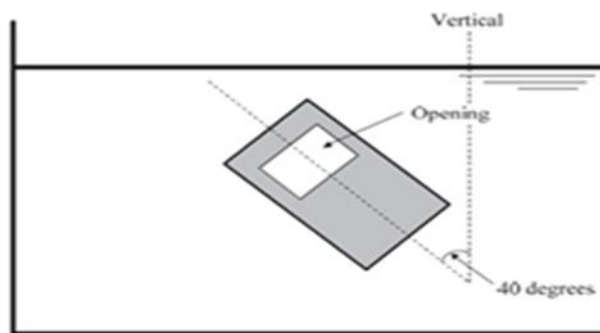


Fig. 9.5.6 : Example of Inclination of 40° Degrees Opening Facing Downward*Fig. 9.5.7 : Example of Inclination 40° Opening Facing Sideways*

5.3. Tank Overflows

5.3.1. General

- a) Generally, all tanks capable of being filled by a pumping system are to be provided with a means of overflow as specified in Sect [5.1.2.]. This may be achieved by overflowing through dedicated overflow pipes or through the tank vents, provided the size of the vents meet [5.2.3(b)]. Overflows are required to discharge outboard, i.e., on the weather deck or overboard, or into designated overflow tanks. Overflow lines shall be self-draining.
- b) All tanks which can be pumped up/ gravity fed are to be fitted with overflow pipes when the pressure head corresponding to the height of vent pipe is greater than that for which the tanks are suitable or when the sectional area of the vent pipes is less than that required by rule.
- c) Oil fuel and lubricating oil tanks which can be pumped up / gravity fed and which have openings for fittings, for example - for a float sounding system, are to be fitted with overflow pipes. The tank openings, for such fittings, are to be situated above the highest point of the overflow piping.
- d) In the case of oil fuel and lubricating oil tanks, the overflow pipe is to be led to an overflow tank of adequate capacity or to a storage tank having space reserved for overflow purposes and be in readily visible position. A sight glass is to be provided in the overflow pipe to indicate when the tanks are overflowing. Such sight glasses are to be placed only in the vertical portion of the pipes and be located in a readily visible position. Alternatively, an alarm device is to be provided to give warning either when the tanks are overflowing or when the oil reaches a predetermined level in the tanks. (Refer Sec-7/[7.3.4]).

- e) Overflow pipes from tanks, other than oil fuel, cargo oil and lubricating oil tanks, are to be led to the open or to suitable overflow tanks arranged.
- f) Where overflow from tanks, which are used for the alternative carriage of oil and water ballast, are connected to an overflow system, arrangements are to be made to prevent water ballast overflowing in to tanks containing oil.
- g) The arrangement of the vent and/or overflow system is to be such that in the event of any one of the tanks being bilged, tanks situated in other watertight compartments of the ship cannot be flooded through combined vent pipes or the overflow main.

5.3.2. Overflow Pipe Size

In general, the aggregate area of the overflow pipes shall not be less than 125% of the effective area of the filling line. The calculations demonstrating the adequacy of the overflow as well as the vent to check over- or under-pressurization of the ballast tanks are required to be submitted, where high capacity or high head pumps are used. Also refer [5.2.3(b)]. Where overflows fulfilling this requirement are fitted, tank vents need only meet the minimum size conforming to Sect [5.2.3(a)]. However, where tank vents complying with [5.2.3(b)] are fitted, separate overflows will not be required.

5.3.3. Overflows Discharging Overboard

In general, overflow pipes discharging through the vessel's sides are required to be led above the freeboard deck and shall be fitted with a non-return valve (not to be of cast iron, refer Ch-8, Sec-2, [2.5.8.2]) at the shell.

Where the overflow discharging overboard cannot be led above the freeboard deck, the opening at the shell is to be secured against sea water ingress as per the same provisions as that for overboard gravity drain from watertight spaces described in Sec-2, [2.2]. In this connection, the vertical distance of the 'inboard end' from the summer load water line may be taken as the height from the summer load water line to the level that the sea water has to rise to find its way inboard through the overboard pipe.

In accordance with the provisions of Sec-2/[2.2], where a non-return valve with a positive means of closing is required, means are to be facilitated to prevent unauthorized operation of this valve. A notice shall be posted at the valve operator warning that it may be shut by authorized personnel only.

5.3.4. Overflow Common Header

Where overflows from tanks in more than one watertight subdivision are connected to a common header below the freeboard or bulkhead deck, the arrangement is to be such as to check fore-and aft flooding from one watertight subdivision to another in the event of damage.

5.3.5. Fuel Oil Tank Overflows

Fuel oil tanks shall not be fitted with overflows discharging overboard. Fuel oil tank overflows are to be led to an overflow tank or to a storage tank with adequate excess capacity (normally 10 minutes at transfer pump capacity) to accommodate the overflow. The overflow tank shall be provided with a high level alarm, refer Sec-7/ [7.3.4].

5.3.6. Overflow Pipe Wall Thickness

In general, overflow pipes exposed to the weather are to have wall thicknesses not less than standard thickness, refer Sect [5.2.2(a)]. Overflow pipes not exposed to the weather are to meet the thickness requisites of vents in Sect [5.2.2(b)]. However, that portion of the overflow pipe subject to the provisions of Sec-2/ [2.2], as specified in Sect [5.3.3] above, is to be as per the pipe wall thicknesses in Sec-2/ [2.2].

SECTION 6 MEANS OF SOUNDING

Contents

6.1. General..... 456

6.2. Sounding Pipes 457

6.3. Gauge Glasses..... 459

6.4. Level Indicating Device 459

6.5. Remote Level Indicating Systems..... 459

6.1. General

6.1.1. Scope

These requirements are applied to the provision of a means of sounding for liquid and void tanks and for normally dry but not easily accessible compartments. However, the requirements in this sub-section do not apply to sounding arrangements of liquid cargoes, such as crude oil, liquefied gases, chemicals, etc., for which specific requirements of provided in Part 7B special type ships of INTLREG Rule.

The means of sounding covered in this subsection include sounding pipes and gauge glasses. For level-indicating devices fitted to tanks containing flammable liquid, such as fuel oil, refer Sec-7/ [7.3.6(b)]. In each case, remote tank level indicating systems are required to be submitted for consideration.

6.1.2. Basic Requirements

- a) All tanks, cofferdams, void spaces and all normally dry compartments, such as cargo holds, which have the possibility of water accumulation (e.g., adjacent to sea, pipe passing through), and which are not easily accessible, are required to be provided with a means of the sounding to determine the level of liquid inside the tanks. In general, this means is required to be a sounding pipe. A gauge glass, remote gauging system, level indicating device, etc. may also be accepted as a means of sounding.
- b) Sounding pipes are to be led to positions above the bulkhead deck which are at all times accessible. In the case of oil fuel tanks, cargo oil tanks and lubricating oil tanks, the sounding pipes are to be led to safe positions on the open deck. The sounding pipes should not terminate in any space where the risk of ignition from spillage from sounding pipe exists. Sounding pipes are not to terminate in passenger or crew spaces.
- c) Where it is impracticable to comply with (b) above, short sounding pipes may be fitted in readily accessible positions as indicated in the following:
 - i) Passenger ships:
 - Only to double bottom tanks and cofferdams in machinery spaces.
 - All short sounding pipes are to be provided with self-closing cocks.
 - ii) Cargo ships:
 - Only to tanks and cofferdams in machinery spaces and shaft tunnels.
 - Short sounding pipes to fuel oil and flammable oil tanks are to be provided with self-closing cocks.
- d) Short sounding pipes to other types of tanks and cofferdams may be fitted with screw caps attached by chain to the pipe or with shut-off cocks.
- e) If short sounding pipes are fitted to oil tanks in machinery spaces, all the following requirements are to be met:
 - i) For fuel oil and flammable oil tanks an oil level gauge complying with requirements of [6.3] of this section is to be provided in addition. (However, in case of fuel and flammable liquid tanks other than double bottom tanks and fitted with overflow arrangement, this level gauge need not be fitted).
 - ii) Short sounding pipes to oil fuel tanks, flammable oil tanks and lubricating oil tanks are not to be placed in the vicinity of boilers, preheaters, heated surfaces, electric generators or motors with commutator or collector rings or electric appliances which are not totally enclosed, unless precautions are taken such as the fitting of effective screens to prevent the oil spillage from coming into contact with source of ignition. The short sounding pipes are to be arranged in such a way that overflows or oil spray will not reach any of machinery components mentioned above.

- iii) The short sounding pipes for fuel oil and flammable oil tanks are to be fitted with self-closing cocks having cylindrical plugs with weight loaded levers permanently attached and with pedals for opening or other approved arrangements. The sounding pipes are to be provided with small diameter self-closing control cock located below cylindrical self-closing cocks for the purpose of ascertaining the presence of oil in the pipe before sounding pipe is opened. Provision must be made so as to ensure that any spillage of oil through the control cock involves no ignition hazard.
- f) Elbow sounding pipes are not to be used for deep tanks unless the elbows and pipes are situated within closed cofferdams or within tanks containing similar liquids. They may, however, be fitted to other tanks and may be used for sounding bilges, provided that it is not practicable to lead them direct to the tanks or compartments.
 - The elbows are to be of heavy construction and adequately supported;
 - In passenger ships, elbow sounding pipes are not permissible.
- g) Striking plates of adequate thickness and size are to be fitted under open ended sounding pipes. Where slotted pipes having closed ends are employed, the closing plugs are to be of substantial construction. Refer [6.2.5] below.

6.2. Sounding Pipes

6.2.1. General Installation Requirements

Sounding pipes are required to be led as straight as possible from the lowest part of tanks or spaces and shall be terminated in positions which are always accessible under all operational conditions of the vessel. Sounding pipes installed in compartments, such as the cargo holds, are to be adequately protected, where they may be exposed to mechanical damage.

6.2.2. Sounding Pipe Size

The internal diameter of the sounding pipe shall not be less than 32 mm (1.26 in.).

6.2.3. Sounding Pipe Wall Thickness

Steel sounding pipes shall have wall thickness not less than that given in the appropriate column (A, C or D) of Table 8.2.5 of Chapter-8 and in accordance with their locations of installation as follows:

- i) Within the tank to which the sounding pipe serves: column A.
- ii) Exposed to weather and outside the tank to which the sounding pipe serves: column C.
- iii) Passing through fuel oil or ballast tanks and outside the tank to which the sounding pipe serves: column D.
- iv) Passing through the bilge well and outside the tank to which the sounding pipe serves: extra heavy thickness (refer Ch-8, Sec-1/[1.2.5]).

6.2.4. Materials of Sounding Pipes

The material of sounding pipes for tanks containing flammable liquids is required to be steel or equivalent. Plastic/ Copper and Cu-Ni pipes may be used in such tanks and all other tanks subject to compliance with the following:

- i) The plastic pipe is confined to within the tank which the sounding pipe serves.
- ii) The penetration of the tank boundary shall be of steel.
- iii) The plastic pipes used are in compliance with Ch-8, Sec 3.

6.2.5. Protection of Tank Bottom Plating

Provision shall be made to protect the tank bottom plating from repeated striking by the sounding device. Such provision may be a doubler plate fitted at the tank bottom in way of the sounding pipe, or equivalent.

6.2.6. Deck of Termination and Closing Device

Sounding pipes are required to be terminated on decks on which they are always accessible under normal operating conditions so as to enable sounding of the tanks. In general, the exposed end of each sounding pipe shall be provided with a watertight closing device, permanently attached, such as a screw cap attached to the pipe with a chain.

Sounding pipes of double bottom tanks and tanks whose boundaries extend to the shell at or below the deepest load water line are, in addition, to terminate on or above the freeboard deck. This is so that in the event of shell damage in way of the tank, the opening of the sounding pipe will not cause inadvertent flooding of internal spaces. Termination below the freeboard deck is permitted, however, if the closing device fitted at the open end is a gate valve, or screw cap. For oil tanks, the closing device is to be of the quick acting valve, Refer also Sect [6.2.7] below.

6.2.7. Sounding Pipes of Fuel Oil and Lubricating Oil Tanks

Sounding pipes from fuel oil tanks shall not terminate in any spaces where a risk of ignition of spillage exists. In particular, they are not to terminate in passenger or crew spaces, in machinery spaces or in close proximity to internal combustion engines, generators, major electric equipment or surfaces with temperature in excess of 220°C (428°F). Where this is not practicable, the following are required to be complied with.

- a) *Fuel oil tanks.* Sounding pipes from fuel oil tanks may terminate in machinery spaces provided that the following are met:
 - i. The sounding pipes are to terminate in locations remote from the ignition hazards, or effective precautions, such as shielding, are taken to prevent fuel oil spillage from coming into contact with a source of ignition.
 - ii. The termination of sounding pipes is fitted with a quick-acting self-closing valve and with a small diameter self-closing test cock or equivalent located below the self-closing valve for the purpose of ascertaining that fuel oil is not present before the valve is opened. Provisions are required to be made to prevent spillage of fuel oil through the test cock from creating an ignition hazard.
 - iii. A fuel oil level gauge complying with Sec-7/[7.3.6(b)] is fitted. However, short sounding pipes may be used for tanks other than double bottom tanks without the additional closed level gauge, provided an overflow system is fitted. Refer Sec-7/, [7.3.4].
- b) *Lubricating oil tanks.* Sounding pipes from lubricating oil tanks may terminate in machinery spaces provided that the following are met:
 - i. The sounding pipes are to terminate in locations remote from the ignition hazards, or effective precautions, such as shielding, are taken to prevent oil spillage from coming into contact with a source of ignition.
 - ii. The termination of sounding pipes is fitted with a quick-acting self-closing gate valve. Alternatively, the sounding pipes may be fitted with an appropriate means of closure, such as a shutoff valve or a screw cap attached by chain to the pipe, for lubricating oil tanks that cannot be filled by a pump.

6.3. Gauge Glasses**6.3.1. Flat Glass Type**

Where gauge glasses are installed as means of level indication, flat glass type gauge glasses are required for the following tanks:

- Tanks containing flammable liquid (except as indicated in Sect [6.3.2] below for hydraulic oil and for small tanks).
- Tanks whose boundaries extend to the vessel's shell at or below the deepest load waterline.

Flat glass type gauge glasses are required to be fitted with a self-closing valve at each end and shall be adequately protected from mechanical damage.

6.3.2. Tubular Glass Type

- a) *General*. Tubular glass gauge glasses may be fitted to tanks other than those mentioned in Sect [6.3.1] above. A self-closing valve is required to be fitted at each end of the gauge glass.
- b) *Hydraulic oil tanks*. Tubular glass gauge glasses with a self-closing valve at each end may be fitted to hydraulic oil tanks provided:
 - The tanks are located outside machinery spaces of category A,
 - The tank boundaries do not extend to the shell at or below the deepest load water line, and
 - The space does not contain ignition sources such as diesel engines, major electrical equipment, hot surfaces having a temperature of 220°C (428°F) or more.
- c) *Small tanks*. Small tanks, including those containing hydraulic oil or lubricating oil located in a machinery space of category A, may be fitted with tubular glass gauge glasses without a valve at the upper end, subject to the following:
 - A self-closing valve is fitted at the lower end.
 - The tank capacity does not exceed 100 liters (26.5 gallons).
 - The gauge glass is so located or protected that any leakage there from will be contained.
 - The upper connection is as close to the tank top as possible and is to be above the maximum liquid level in the tank.
- d) *Fresh water tanks*. Structural tanks may all be fitted with tubular gauge glasses with a valve at each end or a valve at the bottom end of the glass, whose boundaries do not extend to the vessel's shell, and independent tanks for fresh water.

6.4. Level Indicating Device

The failure of the device shall not result in the release of the contents of the tank through the device, where a level-indicating device is provided for determining the level in a tank containing flammable liquid. Level switches, which penetrate below the tank top, may be used, provided they are contained in a steel enclosure or other enclosures not being capable of being destroyed by fire.

6.5. Remote Level Indicating Systems

Where fitted, plans showing the arrangements and details of the system, along with particulars of the sensing and transmitting devices, are required to be submitted for review in each case.

SECTION 7 FUEL OIL STORAGE AND TRANSFER SYSTEMS

Contents

7.1. General	461
7.2. Requirements for Installation.....	461
7.3. Fuel Oil Tanks	462
7.4. Fuel Oil System Components.....	467
7.5. Fuel Oil Transfer, Filling and Purification Systems	470
7.6. Waste Oil Systems for Incinerators	470

7.1. General**7.1.1. Scope**

In general, the provisions of Section 7 apply to fuel oil storage, transfer and processing systems. They are required to be applied appropriately together with fuel oil system requirements specific to each type of propulsion or auxiliary plant provided in Ch-8, Sec-4 (for internal combustion engines) and Ch-8, Sec-5/ [5.4] (for boilers).

7.1.2. Fuel Oil Flash Point

The provisions of this subsection apply to fuel oils having a flash point (closed cup test) above 60°C (140°F).

For vessels classed for services in specified geographical areas, fuel oil with a flash point of 60°C or below, but not less than 43°C (110°F), may only be used. The climatic conditions of such areas are to preclude the ambient temperature of spaces where such fuel oil is stored from rising to within 10°C (18°F) below its flash point. Notwithstanding this restriction, prime movers of emergency generators may use fuel oil with a flash point of not less than 43°C.

7.1.3. Requirements

The intent of the requirements of Section 7 for fuel oil systems is to minimize the possibility of fire due to fuel oil primarily by identifying and separating likely fuel leakages from ignition sources, collection and drainage of fuel leakages and proper design of fuel containment systems.

7.2. Requirements for Installation**7.2.1. Access, Ventilation and Maintenance**

All spaces where fuel oil installations, settling tanks or service tanks are located are required to be easily accessible. In order to prevent accumulation of oil vapor, such spaces are to be sufficiently ventilated. As far as possible, materials of either combustible or oil-absorbing properties shall not be used in such spaces.

7.2.2. Hot Surfaces

In order to prevent the ignition of fuel oil, all hot surfaces, e.g., steam and exhaust piping, turbochargers, exhaust gas boilers, etc. likely to reach a temperature above 220°C (428°F) during service are to be insulated with non-combustible, and preferably non-oil-absorbent, materials. Such insulation materials, if not impervious to oil, are to be encased in oil-tight steel sheathing or equivalent. The insulation assembly is to be well installed and supported having regard to its possible deterioration due to vibration.

7.2.3. Arrangement of Fuel Oil Equipment and Piping

As far as possible, fuel oil tanks, pipes, filters, heaters, etc. are required to be located far from sources of ignition, such as hot surfaces and electrical equipment. In particular, they are not to be located immediately above nor near such ignition sources. The number of pipe joints shall be kept to a minimum. Spray shields are to be fitted around flanged joints, flanged bonnets and any other flanged or threaded connections in fuel oil piping systems under pressure exceeding 1.8 bar (1.84 kgf/cm², 26 psi) which are located above or near units of high temperature, including boilers, steam pipes, exhaust manifolds, silencers or other equipment required to be insulated in accordance with Sect [7.2.2] above, and also to avoid oil spray or oil leakage into machinery air intakes or other sources of ignition.

7.2.4. Leakage Containment and Drainage System

- a) *Leakage containment.* Fuel oil system components, such as pumps, purifiers, strainers, etc., and fuel oil heaters, where leakage may normally be expected, and which require occasional dismantling for examination, are to have drip pans fitted underneath to contain the leakage.

In way of valves fitted near the bottom of fuel oil tanks located above the double bottom and in way of other tank fittings, drip pans are also to be provided, where leakage may be expected.

Free standing fuel oil tanks are required to be provided with oil tight spill trays, as required in Sect [7.3.2] of this section.

- b) *Drainage.* Drip pans, spill trays and other leakage containment facilities are to be provided with a means of drainage. Where they are led to a drain tank, protection against back flows and venting through the drain lines is to be provided as follows:
- i) The drain tank shall not form part of the fuel oil overflow system.
 - ii) The drain tank is required to be fitted with a high level alarm for propulsion machinery spaces intended for centralized operation (**CCS** notation) or unattended operation (**UM** notation).
 - iii) Where drain lines entering the tank are not fitted with non-return valves, they are required to be led to the bottom of the tank to minimize venting of the tank through the drain lines. This is not applicable to fuel oil drain tanks with a volume less than 2 m³ (70.6 ft³) and which cannot be filled up by a pump. Refer Sec-5, [5.2.4(a)], regarding termination of air vents.
 - iv) All drain lines entering the tank are required to be fitted with non-return valves at the tank so as to protect the engine room from flooding in case of bottom damage to the tank, where the drain tank is a double bottom tank.
 - v) The drain tank shall be fitted with a pumping arrangement to enable transfer of its content to the shore facility or to other waste oil tanks

7.2.5. Valve Operation

Valves related to fuel oil systems are required to be installed in readily operable and accessible positions.

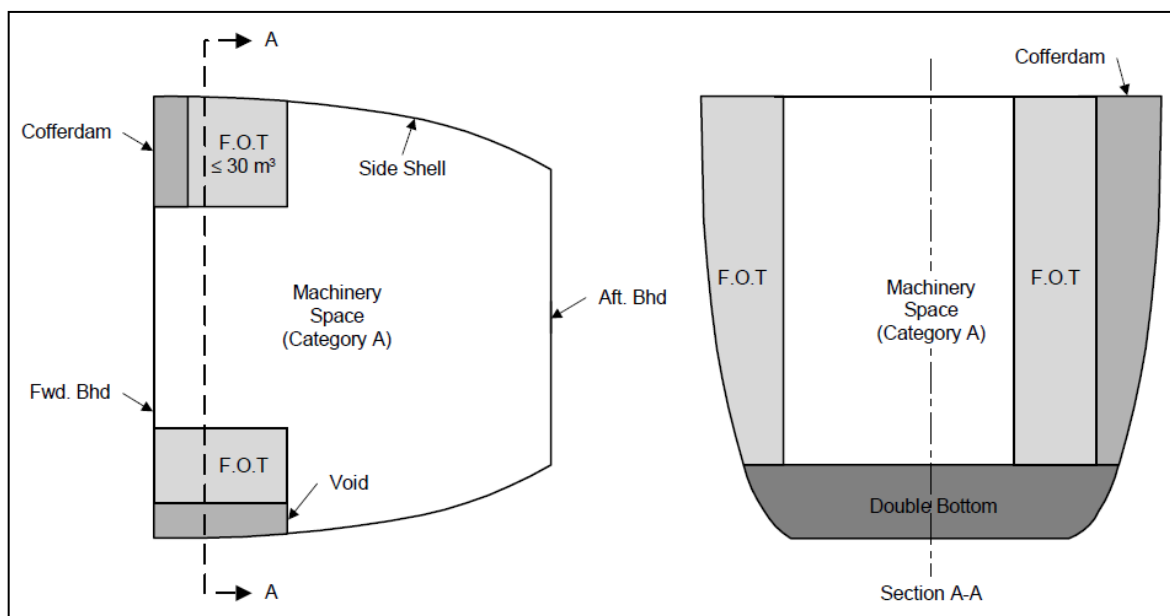
7.3. Fuel Oil Tanks

7.3.1. Arrangements of Structural Tanks

- a) *Machinery space of category A.* As far as possible, fuel oil tanks are required to be part of the vessel's structure and located away from the machinery spaces of category A. However, where it is found necessary to locate the fuel oil tanks adjacent to or inside the machinery spaces of category A, the arrangements are to reduce the area of the tank boundary common with the machinery space of category A to a minimum, and to comply with the following:
- i) Fuel tanks having boundaries common with machinery spaces of category A shall not contain fuel oils having flash point of 60°C (140°F) or less.
 - ii) At least one of their vertical sides is required to be contiguous to the machinery space boundary. The arrangements in Figure 9.7.1 are acceptable for structural tanks provided the requirements of Sec-9, [9.2] are complied with. (The side shell is not being included as a contiguous boundary of the category A machinery space.)

- iii) The bottom of the fuel oil tank is not required to be so exposed so that it will be in direct contact with flame should there be a fire in a Category A machinery space. The fuel tank is to extend to the double bottom. Alternatively, the bottom of the fuel oil tank is to be fitted with a cofferdam. To prevent accumulation of oil in the event of oil leakage from the tank, the cofferdam is to be fitted with suitable drainage arrangements.
- iv) Fuel oil tanks are required to be located in such a way so that no spillage or leakage there from can constitute a hazard by falling on heated surfaces or electrical equipment. If this is not possible, the latter are to be protected from such spillage or leakage by shields, coamings or trays as appropriate.
- v) Oil fuel tanks are to be separated from fresh water and lubricating oil tanks by means of cofferdams.
- vi) The clearance spaces between the boilers and tops of the double bottom tanks, and between the boilers and the sides of the storage tanks in which oil fuel and cargo oil is carried, are to be adequate for the free circulation of the air necessary to keep the temperature of the stored oil sufficiently below its flash point except in the case of tanks. Where water tube boilers are installed, there is to be a space of at least 760 [mm] between the tank top and the underside of the pans forming the bottom of the combustion spaces. The boilers are to be adequately lagged.
- vii) Oil fuel tanks are not to be located directly above the boilers or other highly heated surfaces.

Figure 9.7.1 Acceptable Fuel Oil Tanks Arrangements inside Category A Machinery Spaces



- b) *Drainage of water.* Means are to be provided for draining water from the bottom of the settling tanks. Similar arrangements for draining the water is required to be fitted to the fuel oil storage or the daily service tank, where there are no settling tanks installed.

Arrangements such as gutter ways or other similar means are to be provided for collecting the drains, where the drainage of water from these tanks is through open drains, valves or cocks of a self-closing type. Means are required to be provided to collect the oily discharge.

- c) *Location.* Tanks forward of the collision bulkhead are not required to be arranged for the carriage of fuel oil.
- d) *Service tanks.* For each type of fuel used onboard necessary for propulsion and vital systems, or equivalent arrangements, at least two fuel oil service tanks are required to be provided. Each service tank shall have a capacity of at least eight (8) hours at maximum continuous rating of the propulsion plant and normal operating load at sea of the generator plant.

A service tank is a fuel tank which contains only fuel of a quality ready for use, that is, fuel of a grade and quality that meets the specification required by the equipment manufacturer. A service tank is to be declared as such and is not to be used for any other purpose. Also refer Sect [7.3.6(f)].

Use of a settling tank with or without purifiers or use of purifiers alone is not acceptable as an equivalent arrangement to providing a service tank. Table 9.7.1 shows examples of acceptable arrangements.

Table 9.7.1 Alternative Arrangements for Fuel Oil Service Tanks

	Mono-fuel vessels (HFO)	Dual-fuel vessels (HFO + MDO) (Refer Note 1)	
Consumption	HFO: PE+GE+AB	HFO: PE+AB	MDO: GE
Number of Service Tanks Required	2 x 8 hr HFO	2x8 hr HFO	2x8 hr MDO
Acceptable Alternative Service Tanks	1 x 8 hr HFO (PE+GE+AB), and 1 x 8 hr MDO (PE+GE+AB)	1x8 hr HFO (PE +AB) and the greater of: 2x4 hr MDO (PE + GE+AB); or 2x8 hr MDO (GE +AB)	
Comments	Duplication of tank for MDO for initial cold start of engines/boilers is not required. However, if AB is fitted with pilot burner, another 8 hr MDO tank for this purpose is required. AB need not be accounted if exhaust gas boiler is normally used for heating HFO.		
Legend: PE = propulsion engine(s) GE = generator engine(s) HFO = heavy fuel oil AB = auxiliary boiler(s) MDO = marine diesel oil			
Note: This arrangement applies, provided the propulsion and essential systems support rapid fuel changeover and are capable of operating in all normal operating conditions at sea with both types of fuels (MDO and HFO).			

7.3.2. Arrangements of Free Standing Tanks

As far as possible, the use of free standing fuel oil tanks in the machinery spaces of category A is to be avoided, Refer the general intent in Sect [7.3.1(a)]. Where this is unavoidable, free standing fuel oil tanks in machinery spaces of category A are to be kept to a minimum and their installation is to be as follows:

- The fuel oil tanks are required to be placed in an oil tight spill tray of ample size (e.g., large enough to cover leakage points such as manhole, drain valves, gauge glass, etc.) with a drainage facility to a suitable drain tank.

- The fuel oil tanks shall not be situated where spillage or leakage there from can constitute a hazard by falling on heated surfaces. In particular they are not to be located over boilers.

7.3.3. Valves on Fuel Oil Tanks

- a) *Required valves.* Every fuel oil pipe emanating from any fuel oil tank is to be provided with a positive closing valve directly on the tank, which, if damaged, would allow fuel oil to escape from the tank. The valve shall not be of cast iron, although the use of nodular cast iron is permissible, refer Ch-8, Sec-2/[2.2.2.4] The positive closing valve is required to be provided with means of closure both locally and from a readily accessible and safe position outside of the space. In the event that the capacity of the tank is less than 500 liters (132 US gallons), this remote means of closure may be omitted.

The arrangement for remote closing may be effected by means of an additional valve on the pipe or pipes outside the tunnel or similar spaces, if the required valve is situated in a shaft tunnel or pipe tunnel or similar spaces. If such an additional valve is fitted in a machinery space, it is required to be provided with a means of closure both locally and from a readily accessible position outside of this space.

When considering two adjacent fuel oil tanks, the fuel oil suction pipe from the tank on the far side may pass through the adjacent tank, and the required positive closing valve may be located at the boundary of the adjacent tank. In such cases, the thickness of the fuel oil suction pipe passing through the adjacent fuel oil tank is to be done in accordance with Column C in Table 8.2.5 of Chapter-8 and of all welded construction.

- b) *Remote means of closure.* The remote closure of the valves may be by reach rods or by electric, hydraulic or pneumatic means. The source of power to operate these valves shall be from outside of the space in which these valves are situated. For a pneumatically operated system, the air supply may be from a source located within the same space as the valves provided that an air receiver complying with the following is located outside the space:
- Fitted with low air pressure alarm.
 - Sufficient capacity to close all connected valves twice.
 - Fitted with a non-return valve adjacent to the air receiver in the air supply line.

This remote means of closure is required to override all other means of valve control. The use of an electric, hydraulic or pneumatic system to keep the valve in the open position is not acceptable.

Materials readily rendered ineffective by heat shall not be used in the construction of the valves or the closure mechanism unless protected adequately to ensure effective closure facility in the event of fire. Electric cables are to be fire-resistant, where used, meeting the requirements of IEC Publication 60331.

The controls for the remote means of closure of the valves of the emergency generator fuel tank and the emergency fire pump fuel tank, as applicable, are required to be grouped separately from those for other fuel oil tanks.

7.3.4. Filling and Overflow

In general, filling lines are to enter at or near the top of the tank; but if this is impossible, they are required to be fitted with a non-return valve at the tank. Alternatively, the filling line shall be fitted with a remotely operable valve as required by Sect [7.3.3(a)]. Overflows from fuel oil tanks are required to be led to an overflow tank with sufficient volume to accommodate the overflows (normally 10- minutes at transfer pump capacity). A high level alarm shall be provided for the overflow tank. Overflow lines are required to be self-draining.

- 7.3.5. Vents
Vents shall be fitted to fuel oil tanks and are required to meet the requirements of Section 5 of this chapter.
- 7.3.6. Level Measurement
- a) *Sounding pipes.* Sounding pipes are required to meet the general requirements of Sec-6 of this chapter.
 - b) *Level gauges.* Level gauges may be fitted in lieu of sounding pipes, provided that the failure of, or the damage to, the level gauge will not result in the release of fuel oil. Where the gauge is located such that it is subjected to a head of oil, a valve is to be fitted to allow for its removal, Refer Ch-8, Sec-/ [2.5.7.3]. The level gauge is required to be capable of withstanding the hydrostatic pressure at the location of installation, including that due to overfilling. No level gauge shall be installed below the top of the tank, for passenger vessels.
 - c) *Gauge glasses.* Gauge glasses complying with the intent of (b) above may be fitted in lieu of sounding pipes, provided they are of flat glass type with a self-closing valve at each end and shall be adequately protected from mechanical damage. Also refer Sec-6, [6.3.1].
 - d) *Level switches.* Level switches where fitted, are required to be encased in steel, or equivalent, such that no release of fuel oil is possible in the event of their damage due to fire. Where the device is located, such that it is subjected to a head of oil, a valve is to be fitted to allow for its removal, refer Ch-8, Sec 2/ [2.5.7.3].
 - e) *High level alarm.* An alarm is to be fitted to warn of the level reaching a predetermined high level in order to prevent spillage. The high level alarm may be omitted for tanks fitted with overflow arrangements, provided a flow sight glass is fitted in the overflow pipes. Such flow sight glass is required to be fitted only on the vertical section of overflow pipe and in readily visible position.
 - f) *Additional level alarms.* Low level conditions of fuel oil settling and service tanks are to be alarmed at the centralized control station, for propulsion machinery spaces intended for centralized or unattended operation (CCS or UM notation). High level alarms are also to be provided where tanks are automatically filled. For UM notation, these tanks are to be sized for at least 24-hour operation without refilling, except that for automatically filled tanks, 8-hour operation will suffice.
- 7.3.7. Heating Arrangements in Tanks
- a) *Flash point.* Fuel oil in storage tanks shall not be heated within 10°C (18°F) below its flash point. Where fuel oil in service tanks, settling tanks and any other tanks in the supply system is heated, the arrangements are to comply with the following:
 - i) The length of the vent pipes from the tanks and/or cooling device is required to be sufficient for cooling the vapors to below 60°C, or the outlet of the vent pipes is located at least 3 m (10 ft) away from a source of ignition.
 - ii) Enclosed spaces, such as workshops, accommodation spaces, etc., are not to be located directly over the fuel tanks, except for vented cofferdams
 - iii) There are no openings from the vapor space of the fuel tanks leading into machinery spaces, except for bolted manholes.
 - iv) Electrical equipment is not to be fitted in the vapor space of the tanks, unless it is certified to be intrinsically safe.
 - b) *Fuel oil temperature control.* All heated fuel oil tanks located within machinery spaces are required to be fitted with a temperature indicator. To prevent overheating of fuel oil, in accordance with (a) above, means of temperature control are required to be provided.

- c) *Temperature of heating media.* A high temperature alarm is required to be fitted to warn of any high medium temperature, where heating is by means of a fluid heating medium (steam, thermal oil, etc.). This alarm may be omitted if the maximum temperature of the heating medium can, in no case, exceed 220°C (428°F).
- d) *Steam heating.* To guard against possible contamination of boiler feed water, where fuel oil tanks are heated by steam heating coils, steam condensate returns are to be led to an observation tank, or other approved means, to enable detection of oil leaking into the steam system.
- e) *Electric heating.* The heating elements are to be arranged to be submerged at all times during operation, where electric heating is installed, and are to be fitted with an automatic means of preventing the surface temperature of the heating element from exceeding 220°C (428°F). This automatic feature is to be independent of the fuel oil temperature control and is to be provided with manual reset.
- f) *CCS or UM notation.* For vessels whose propulsion machinery spaces are intended for centralized or unattended operation (CCS or UM notation), refer Part-6 Ch-8, Sec-4/ [4.1.11.3].

7.4. Fuel Oil System Components

7.4.1. Pipes and Fittings

- a) *Pipes.* Pipes are required to meet the general requirements of certification in Ch-8, Sec 1, [1.4.1]; materials in Ch-8, Sec 2, [2.2]; and design in Ch-8, Sec 2/ [2.3.1] subject to the following:
 - i) Pipes passing through fuel oil tanks are to be of steel except that other materials may be considered where it is demonstrated that the material is suitable for the intended service.
 - ii) Restricted use of plastic pipes will be allowed, subject to compliance with the requirements of Ch-8, Sec 3.
 - iii) For pipes, the design pressure is to be taken in accordance with Table 9.7.2.

Table 9.7.2: Design Pressure for Fuel Oil Pipes

Maximum Allowable Working Pressure (P)	Maximum Working Temperature (T)	
	T ≤ 60°C (140°F)	T > 60°C (140°F)
P ≤ 7 bar (7.15 kgf/cm ² , 101.5 psi)	3 bar (3.1 kgf/cm ² , 43 psi) or P, whichever is greater	3 bar (3.1 kgf/cm ² , 43 psi) or P, whichever is greater
P > 7 bar (7.15 kgf/cm ² , 101.5 psi)	P	14 bar (14.3 kgf/cm ² , 203 psi) or P, whichever is greater
Note: P = maximum allowable working pressure of the system, as defined in Ch.8, Sect [1.2.10] in bar (kgf/cm ² , psi)		

- b) *Pipe fittings and joints.* Pipe fittings and joints shall meet the general requirements of certification in Ch-8, Sec 1/ [1.4.1]; materials in Ch-8, Sec 2,[2.2]; and design in Ch-8, Sec 2/ [2.3.3] and Ch-8, Sec 2/[2.3.9] subject to limitations in Table 9.7.3. Fittings and joints in piping systems are also required to be compatible with the pipes to which they are attached in respect of their strength (Refer (a)-(iii) for design pressure) and are to be suitable for effective operation at the maximum allowable working pressure they will experience in service. For flanges, their pressure-temperature rating is subject to the limitations in Ch-8, Sec 2 [2.3.3.4].

- c) *Hoses.* Hoses are to comply with Ch-8, Sec 2, [2.3.4], where installed. Hose clamps are not permitted.

Table 9.7.3: Pipe Joint Limitations for Fuel Oil Piping

Types of joint	Class I	Class II	Class III
Butt welded joint	No limitation	No limitation	No limitation
Socket welded joint (Refer note 1)	Max. 80 mm (3 in.)	Max. 80 mm (3 in.)	No limitation
Slip-on welded sleeve joint (Refer note 2)	Max. 80 mm (3 in.)	Max. 80 mm (3 in.)	No limitation
Flanged joint	Types A ,B & G only. For type G, refer Pt5A-8-2/Table 8.2.8	Types A, B , C & G only. For type G, refer Pt5A-8-2/Table 8.2.8	Types A, B , C &G only. For type G, refer Pt5A-8-2/Table 8.2.8
Taper-thread joint	≤ 80 mm (3 in.) Permissible pressure/size: Refer Ch-8, Sec 2, [2.3.3.5(a)]	≤ 80 mm (3 in.) Permissible pressure/size: Refer Ch-8, Sec 2, [2.3.3.5(a)]	No limitation.
Compression couplings (Refer note 3)	≤ 60 mm (2.4 in.) OD.	≤ 60 mm (2.4 in.) OD.	No size limitation.
Molded non-metallic expansion joint	Not permitted	Not permitted	Not permitted
Molded expansion joint of composite construction	Subject to compliance with Ch-8, Sec 2, [2.3.5.1(b)]	Subject to compliance with Ch-8, Sec 2, [2.3.5.1(b)]	Subject to compliance with Ch-8, Sec 2, [2.3.5.1(b)]
Metallic bellow type expansion joint	No limitation	No limitation	No limitation
Slip-on joints	Refer Note 3	Refer Note 3	Refer Note 3
Hoses	Subject to fire resistance test: Ch-8, Sec 2, [2.3.4.3(c)]	Subject to fire resistance test: Ch-8, Sec 2, [2.3.4.3(c)]	Subject to fire resistance test: Ch-8, Sec 2, [2.3.4.3(c)]
Notes: 1. Refer Ch-8, Sec 2, [2.3.3.2] for further operational limitations. 2. Refer Ch-8, Sec 2, [2.3.3.3] for further operational limitations. 3. Refer Ch-8, Sec 2, [2.3.6] for further limitations. 4. Pipe sizes are nominal bore, except where indicated otherwise.			

7.4.2. Valves

Valves shall meet the general requisites of certification in Ch-8, Sec 1, [1.4.1]; materials in Ch-8, Sec 2, [2.2]; and design in Ch-8, Sec 2, [2.3.7] and Ch-8, Sec 2, [2.3.8]. Cast iron valves are not required to be used as shutoff valves for fuel oil tanks, as indicated in Sect [7.3.3 (a)].

Valves in piping systems are also required to be compatible with the pipes to which they are attached in respect to their strength, (Refer Sect [7.4.1] (a)iii) for design pressure) and are to be appropriate for effective operation at the maximum allowable working pressure they will experience in service. Their pressure rating is subject to the restrictions in Ch-8, Sec 2, [2.3.7.2].

7.4.3. Pumps

Fuel oil pumps are required to be fitted with stop valves at the suction and discharge sides. A relief valve shall be fitted on the discharge side, unless the pump is of the centrifugal type having a shutoff head no greater than the design pressure of the piping system. The relief valve is to discharge to the suction side of the pump or into the tank, where fitted.

Fuel oil pumps requiring certification are specified in Ch-8, Sec 1/ [1.4.2]. Also refer Ch-8, Sec 4/ [4.2] and Ch-8, Sec 5/[5.4].

7.4.4. Heaters

a) *Heater housing.* All fuel oil heaters having any of the following design parameters are required to be certified by INTLREG (for pressure vessels, Refer Chapter 10):

- Design pressure > 6.9 bar (7 kgf/cm², 100 psi) on either side;
- Design pressure > 1 bar (1 kgf/cm², 15 psi), internal volume > 0.14 m³ (5 ft³), and design temperature > 66°C (150°F) on the oil side or > 149°C (300°F) on the heating medium side;
- All fired heaters with design pressure > 1 bar (1 kgf/cm², 15 psi).

Electric oil heaters not required to be certified by the above are to have their housing design submitted for review.

- b) *Fuel oil temperature control.* All heaters shall be fitted with a fuel oil temperature indicator and a means of temperature control.
- c) *Heating media and electric heating.* The provisions of Sect [7.3.7] (c), (d) and (e) are also applicable to fuel oil heaters.
- d) *Relief valves.* Relief valves are required to be fitted on the fuel oil side of the heaters. The discharge from the relief valve is to be arranged to discharge back to the storage tank or other suitable tank of adequate capacity.
- e) *CCS or UM notation.* Refer Part-6, Ch-8, Sec-4, [4.1.11.3], for vessels whose propulsion machinery spaces are intended for centralized or unattended operation (CCS or UM notation).

7.4.5. Filters and Strainers

Filters and strainers are required to be designed to withstand the maximum working pressure of the system in which they are installed.

Means are required to be provided to minimize the possibility of a filter or strainer being opened inadvertently, where filters and strainers are fitted in parallel to enable cleaning without disrupting the oil supply.

During operation, where they are required to be opened for cleaning, they are to be fitted with means of depressurizing before being opened and venting before being put into operation. For this purpose, cocks and valves for drainage and venting are to be provided. Drain pipes and vent pipes are to be led to a safe site. Refer Sect[7.2.4] of this section, for leakage containment and drainage.

7.4.6. Sight Flow Glasses

A sight flow glass may be fitted only in the vertical sections of fuel oil overflow pipes, and provided that it is in a readily visible position.

7.5. Fuel Oil Transfer, Filling and Purification Systems

7.5.1. Fuel Oil Transfer Pumps

There are required to be at least two fuel oil transfer pumps out of which at least one of the pumps is to be independent of the main engine. Fuel oil transfer pumps are to be fitted with remote means of controls located outside the space in which they are located so that they may be ceased in the event of fire in that space.

Refer Sect [7.3.4], for filling and overflow. Also refer [7.3.6(f)] of this section, for automatic filling in propulsion machinery spaces intended for centralized or unattended operation (CCS or UM notation).

7.5.2. Segregation of Purifiers for Heated Fuel Oil

Fuel oil purifiers for heated oil shall be placed in a separate room or rooms which are enclosed by steel bulkheads extending from deck to deck and provided with self-closing doors. In addition, the room is required to be provided with the following:

- i) Fire detection system.
- ii) Independent mechanical ventilation or ventilation arrangement that can be isolated from the machinery space ventilation, of the suction type.
- iii) Fixed fire-extinguishing system capable of activation from outside the room. The extinguishing system is to be dedicated to the room but may be a part of the fixed fire extinguishing system for the machinery space.

However, for the protection of purifiers on cargo vessels of 2000 gross tonnage and above located within a machinery space of category A above 500 m³ (17,657 ft³) in volume, the above referenced fixed dedicated system is to be a fixed water-based or equivalent, local application fire-extinguishing system conforming to the provisions of SOLAS Ch 2 The system is to be capable of activation from outside the purifier room. In addition, protection is required to be provided by the fixed fire-extinguishing system covering the Category A machinery space in which the purifier room is located, Refer SOLAS Ch 2

- iv) Means of closing ventilation openings and stopping the ventilation fans, purifiers, purifier-feed pumps, etc. from a site close to where the fire extinguishing system is activated.

If it is not feasible to trace the fuel oil purifiers in a separate room, special consideration will be given with regard to location, containment of possible leakage, shielding and ventilation. In such cases, a local fixed water-based fire-extinguishing system observing the provisions of SOLAS Ch 2 is to be provided. Where, due to the restricted size of the category A machinery space (less than 500 m³ (17,657 ft³) in volume), a local fixed water-based fire-extinguishing system is not required to be provided, then an alternative type of local dedicated fixed fire-extinguishing system is to be provided for the security of the purifiers. In either case, the local fire extinguishing system is to activate automatically or manually from the centralized control station or other apt location. If automatic release is provided, additional manual release is also to be arranged.

7.6. Waste Oil Systems for Incinerators

The requisites for fuel oil storage, transfer and heating, as given in Section 7, are applicable to waste oil service tanks and related piping systems for incinerators.

SECTION 8 LUBRICATING OIL STORAGE AND TRANSFER SYSTEMS**Contents**

8.1. General and Installation Requirements.....	472
8.2. Lubricating Oil Tanks.....	473
8.3. Components of Lubricating Oil System.....	473

8.1. General and Installation Requirements

8.1.1. Application

The application of the provisions of Section 8 are to be done to storage, transfer and processing of lubricating oil. They are required to be applied appropriately along with requirements for lubricating oil systems specific to each type of propulsion or auxiliary machinery specified in Ch-8, Sec 4/ [4.3] (for internal combustion engines) and Ch-8, Sec 5/ [5.5] (for steam turbines). In addition, the requirements of Sect[7.3.7](b) through (f) and Sect [7.4.4] are applicable.

8.1.2. Basic Requirement

The requirements for the lubricating oil storage and transfer system are proposed to minimize the fire risks of lubricating oil.

8.1.3. Dedicated Piping

The lubricating oil piping, including vent and overflow piping, is to be completely separated from other piping systems. This requirement, however, does not apply to hydraulic governing and maneuvering systems for main and auxiliary engines.

8.1.4. Hot Surfaces

In order to prevent the ignition of lubricating oil, all hot surfaces, e.g., steam and exhaust piping, exhaust gas boilers, turbochargers, etc. likely to reach a temperature above 220°C (428°F) during service are to be insulated with non-combustible, and preferably non-oil-absorbent, materials. If not impervious to oil, such insulation materials are required to be encased in oil-tight steel sheathing or equivalent. The insulation assembly is to be well installed and supported with regard to its possible wear and tear due to vibration.

8.1.5. Arrangement of Lubricating Oil Equipment and Piping

- a) As far as possible, lubricating oil tanks, heaters, pipes, filters, etc. are to be placed far from sources of ignition, such as hot surfaces and electrical equipment. In particular, they are not to be sited immediately above or near such ignition sources. The number of pipe joints shall be kept to a minimum. Spray shields are to be fitted around flanged joints, flanged bonnets and any other flanged or threaded connections in lubricating oil piping systems under pressure going beyond 1.8 bar (1.84 kgf/cm², 26 psi) which are placed above or near units of high temperature, including boilers, exhaust manifolds, steam pipes, silencers or other equipment required to be insulated as per Sect [8.1.4], and also to avoid oil spray or oil leakage into machinery air intakes or other sources of ignition.
- b) The lubricating systems are to be so arranged that they will remain efficient with the ship inclined from the normal to any angle up to 15° transversely and when pitching 10° longitudinally and when rolling up to 22.5° from the vertical.
- c) Lubricating oil tanks are to be separated from other tanks containing water, fuel oil or cargo oil, by means of cofferdams.

8.1.6. Leakage Containment

Lubricating oil system components, such as pumps, purifiers, strainers, etc., which need occasional dismantling for examination, and where leakage may normally be expected, are to be provided with leakage containment and drainage arrangements, as required in Sec-7/, [7.2.4].

8.2. Lubricating Oil Tanks**8.2.1. Location**

Tanks forward of the collision bulkhead shall not be arranged for the carriage of lubricating oil. They are not to be sited where spillage or leakage there from can result in a hazard by falling on heated surfaces or electrical equipment.

8.2.2. Valves on Lubricating Oil Tanks

Normally opened valves on lubricating oil tanks are to meet the same requirements as those for fuel oil tanks given in Sec-7/[7.3.3]. To safeguard the propulsion and essential auxiliary machinery not fitted with automatic shutdown upon loss of lubricating oil, the remote means of closing the lubricating oil tank valve may be omitted and also if it's unintended activation from the remote location could result in damage to such machinery.

8.2.3. Vents

Vents are required to meet the applicable requirements in Section 5 of this chapter. Lubricating oil tank vents may cease within the machinery space provided that the open ends are situated in order to prevent the possibility of overflowing on electric equipment, engines or heated surfaces.

8.2.4. Level Measurement

- a) *Sounding pipes*. Sounding pipes are to comply with the applicable requirements in Section 6 of this chapter.
- b) *Level gauges*. Level gauges may be fitted in lieu of sounding pipes, provided that the failure of, or the damage to, the level gauge will not result in the release of lubricating oil. A valve is required to be fitted to allow for its removal, where the device is so located that it is subjected to a head of oil, refer Ch-8, Sec 2./[2.5.7.3]. The level gauge shall be capable of withstanding the hydrostatic pressure at the site of installation, including that due to overfilling. No level gauge is to be installed under the tank's top for passenger vessels.
- c) *Gauge glasses*. Gauge glasses may be fitted in lieu of sounding pipes observing the intent of (b) above, provided they are of flat glass type with a self-closing valve at each end and are sufficiently secured from mechanical damage.
- d) *Level switches*. In the event of their damage due to fire, where fitted, level switches are to be encased in steel, or equivalent, such that no release of lubricating oil can occur. Where the device is situated such that it is subjected to a head of oil, a valve is to be fitted to allow for its removal, Refer Ch-8, Sec 2/ [2.5.7.3].
- e) *Level alarms*. For propulsion machinery spaces intended for centralized or unattended operation (CCS or UM notation), lubricating oil tank low-level alarms are to be provided for:
 - Crosshead (Slow-speed) propulsion diesel engines (refer Part-6, Ch-8, Table 8.2.2);
 - Steam turbines and gears (refer Part-6, Ch-8, Table 8.2.4);
 - Gas turbines and reduction gears (refer Part-6, Ch-8, Table 8.2.5).

8.3. Components of Lubricating Oil System**8.3.1. Pipes, Fittings and Valves**

Pipes, fittings and valves are to fulfill the same requirements as those for fuel oil systems in [7.4.1] and [7.4.2], except requirement [7.4.1(a)iii].

8.3.2. Pumps

- a) Where lubricating oil for the main engine(s) is circulated under pressure, a standby lubricating oil pump shall be provided where the following conditions apply:
- i) The lubricating oil pump is independently driven and the total output of the main engine(s) exceeds 370 [kW];
 - ii) One main engine with its own pump is fitted and the output of the engine exceeds 370 [kW];
 - iii) More than one main engine each with its own lubricating oil pump is fitted and the output of each engine exceeds 370 [kW].
- b) The standby pump is to be of sufficient capacity to maintain the supply of oil for normal conditions with any one pump out of action. The pump is to be fitted and connected ready for immediate use, except that where the conditions referred to in [8.2.1(c)] apply, a complete spare pump may be accepted. In all cases satisfactory lubrication of the engines is to be ensured while starting and maneuvering.
- c) Similar provisions to those of Sections [8.2.1] and [8.2.2] are to be made where separate lubricating oil systems are employed for piston cooling, reduction gearing, oil operated couplings and controllable pitch propellers, unless approved alternative arrangements are provided. Where the oil glands for stern tubes are provided with oil circulating pump, and the continuous running of this pump is necessary during normal operation, then a standby pump for this purpose is to be provided.
- d) Independently driven rotary type pumps are to be fitted with non- return valves on the discharge side of the pumps
- e) A relief valve in close circuit is to be fitted on the pump discharge if the pump is capable of developing a pressure exceeding the design pressure of the system, the relief valve is to effectively limit the pump discharge pressure to the design pressure of the system
- f) Lubricating oil pumps requiring certification are specified in Ch-8, Sec 1/ [1.4.2]. Refer also Ch-8, Sec 4/ [4.3] and Ch-8, Sec 5/ [5.5].

8.3.3. Filters and Strainers

Filters and strainers are to fulfill the same requirements as for those for fuel oil systems in Sec-7, [7.4.5].

8.3.4. Coolers

INTLREG is required to certify lubricating oil coolers having either of the following design parameters:

- Design pressure > 6.9 bar (7 kgf/cm², 100 psi) on either side;
- Design pressure > 1 bar (1 kgf/cm², 15 psi), internal volume > 0.14 m³ (5 ft³), and design temperature > 90°C (200°F) on the lubricating oil side.

8.3.5. Sight-flow Glasses

In the vertical sections of lubricating oil overflow pipes, only a sight flow glass may be fitted, provided that it is in an easily visible position.

SECTION 9 ADDITIONAL MEASURES FOR OIL POLLUTION PREVENTION

Contents

9.1. General.....	476
9.2. Requirements for Tank Protection.....	476
9.3. Class Notation – POT.....	477

9.1. General

- 9.1.1. The provisions of Section 9 provide the arrangement of fuel oil tanks for compliance with MARPOL 73/78, as amended. In addition to the requirements of Section 7 of this chapter, they are to be applied and are applicable to all types of vessels classed with INTLREG.
- 9.1.2. *Submission of Plans:* Plans showing agreement with the applicable requirements in [9.2] below shall be submitted for review.

9.2. Requirements for Tank Protection

- 9.2.1. The requisites in this section apply to vessels having an aggregate fuel oil capacity of 600 m³ (21,190 ft³) and above. However, the requirements need not be applied to individual fuel oil tanks with a capacity not greater than 30 m³ (1060 ft³), provided that the aggregate capacity of such excluded tanks is not greater than 600 m³ (21,190 ft³). Further, individual fuel oil tanks shall not have capacity greater than 2,500 m³ (88,290 ft³).
- 9.2.2. Fuel oil tanks of any volume are not required to be used for ballast water.
- 9.2.3. The protective locations for the tanks as mentioned in Sect [9.2.1] above are to be based on two approaches given below:
- Deterministic Approach
 - Probabilistic Approach
- 9.2.4. *Deterministic Approach:* All applicable tanks are to be situated away from the vessel's bottom or side shell plating for a distance as specified in (i), (ii) or (iii). Small suction wells may extend below fuel oil tanks bottoms, if they are as small as possible, and the distance between the vessel's bottom plate and the suction well bottom is not reduced by more than half of the distance required by (i) below.

- For vessels having an aggregate oil fuel capacity of 600 m³ (21,190 ft³) and above, all tanks are required to be arranged above vessel's molded line of bottom shell plating at least of the distance h as specified below:

$$h = \frac{B}{20} \text{ (meter)} \quad \text{or} \quad h = 2.0 \text{ (meter) (6.6 ft), whichever is smaller}$$

Where;

B is the breadth of the vessel, as defined in Part-3, Ch-1, Sec-2, in m (ft).

this in no case to be less than 0.76 m (2.5 ft).

- For vessels having an aggregate oil fuel capacity greater than or equal to 600 m³ (21190 ft³) but less than 5000 m³ (176570 ft³), tanks are required to be arranged inboard of the molded line of side plating not less than the distance w is as specified below:

$$w = 0.4 + \frac{2.4 C}{20000} \text{ m} \qquad w = 1.31 + \frac{7.87 C}{706290} \text{ ft}$$

Where;

C = vessel's total volume of oil fuel in m³ (ft³) at 98% tank filling;

w = at least 1.0 m (3.3 ft)

for individual tanks smaller than 500 m³ (17,657 ft³) w is to be at least 0.76 m (2.5 ft)

- For vessels having an aggregate oil fuel capacity of 5000 m³ (176570 ft³) and above, tanks are required to be arranged inboard of the molded line of side plating not less than the distance w is as specified below:

$$w = 0.5 + \frac{C}{20000} \text{ m} \qquad w = 1.64 + \frac{C}{706290} \text{ ft}$$

or $w = 2.0 \text{ m} \qquad w = 6.6 \text{ ft,}$

whichever is smaller

Where;

C is the vessel's total volume of oil fuel in m^3 (ft^3) at 98% tank filling.
The minimum value of $w = 1.0 \text{ m}$ (3.3 ft).

- 9.2.5. *Probabilistic Approach:* As an alternative to the deterministic approach of Sect [9.2.4] above, arrangements fulfilling the accidental oil fuel outflow performance standard of Regulation 12A, Annex I, MARPOL 73/78, as amended, would be acceptable.

9.3. Class Notation – POT

- 9.3.1. In addition to the requisites for fuel oil tank protection as specified in [9.2.1] utilizing the deterministic approach of [9.2.2(a)], where lubricating oil tanks are also arranged in the same manner as required by the deterministic approach [9.2.2(a)] for fuel oil tanks, vessels are required to be eligible for the optional Class notation, **POT**– Protection of Fuel and Lubricating Oil Tanks.

The exemptions stated below are applicable to lubrication oil tanks:

- i) In application of equation in Sect 9.2.4 – (ii) or (iii), total volume of lubricating oil tanks need not be accounted for C (vessel's total volume of oil fuel in m^3 (ft^3) at 98% tank filling).
- ii) Tanks used as main engine lubricating oil drain tanks need not be located in a protected location away from the vessel's side or bottom plates.

CHAPTER 10 BOILERS AND PRESSURE VESSELS

CONTENTS

SECTION 1 GENERAL REQUIREMENTS.....	479
SECTION 2 MATERIALS.....	486
SECTION 3 DESIGN	488
SECTION 4 FABRICATION, TESTING AND CERTIFICATION.....	524
SECTION 5 BOILER ACCESSORIES.....	526
SECTION 6 BOILER CONTROL	534
SECTION 7 THERMAL OIL HEATERS	539
SECTION 8 INCINERATORS	542
SECTION 9 PRESSURE VESSEL AND HEAT EXCHANGER ACCESSORIES.....	544
SECTION 10 INSTALLATION AND SHIPBOARD TRIALS.....	546

SECTION 1 GENERAL REQUIREMENTS

Contents

1.1. Scope	480
1.2. General Definitions	481
1.3. Recognized Codes or Standards	481
1.4. Grouping of Boilers and Pressure Vessels	481
1.5. Certification	482
1.6. Special Cases	483
1.7. Documents to be Submitted	484

1.1. Scope

- 1.1.1. The boilers, pressure vessels, fired and unfired heaters, and heat exchangers of the categories given below are to be subjected to the provisions of this section, no matter of which system they are a part of:
- (i) Boilers and steam generators with design pressure over 3.5 bar (3.6 kgf/cm², 50 psi).
 - (ii) Independent pressure vessel tanks for the carriage of liquefied gases, defined in Part 7 B, Chapter-3.
 - (iii) Fired heaters for oil with design pressure over 1 bar (1 kgf/cm², 15 psi).
 - (iv) Accumulators, regardless of their diameters, Refer Ch-8, Sec-6/[6.2.3.4].
 - (v) Other pressure vessels and heat exchangers of 150 mm (6 in.) diameter and over, having design pressure, temperature and volume as defined in Table 10.1.1. Pressure vessels and heat exchangers under 150 mm (6 in.) in diameter are not required to comply with the provisions of this section. Acceptance of them will be based on manufacturer's guarantee of physical properties and suitability for the intended service, provided the installation is carried out to the satisfaction of the Surveyor.
 - (vi) Fired heaters and boilers which are not included above along with the fired inert gas generators and incinerators are subject to the provisions of Section 8 only.

Table 10.1.1: Pressure Vessels Covered

		Pressure				Temperature			Volume	
		bar	kgf/cm ²	psi		°C	°F		m ³	ft ³
a)	Pressure vessels and heat exchangers for toxic and corrosive substances (Refer Ch-1, sec-1, [1.5.5])	> 1.0	> 1.0	> 15	-	all	all	-	all	all
b)	Pressure vessels, heat exchangers and heaters other than (a)	> 6.9	> 7.0	> 100	-	all	all	-	all	all
c)	Pressure vessels, heat exchangers and heaters other than (a) and (b)	> 1.0	> 1.0	> 15	and	>149 (Refer note1)	>300 (Refer note1)	and	> 0.14	> 5
						>66 (Refer note2)	>150 (Refer note2)			
						>90 (Refer note3)	>200 (Refer note3)			

Notes:

1. Applicable to gas or vapor, steam and to liquids other than fuel oil, lubricating oil, hydraulic oil and thermal oil.
2. Applicable to fuel oil only.
3. Applicable to lubricating oil, hydraulic oil and thermal oil.

1.2. General Definitions**1.2.1. Design Pressure**

While designing the boiler or pressure vessel, the gauge pressure that is used is actually the design pressure and it is at least the most severe condition of coincidental pressure and temperature that is expected under normal operation conditions. For pressure vessels with more than one chamber, design pressure of the inner chamber is to be the maximum difference between the outer and inner chambers.

1.2.2. Maximum Allowable Working Pressure

The maximum permissible pressure at the top of the boiler or pressure vessel in its normal operating condition is its Maximum Allowable Working Pressure (MAWP) and it is taken at the designated coincidental temperature specified for that pressure. It is the least of the values found for MAWP for any pressure-bearing parts, adjusted for the difference in static head that may exist between the concerned part and the top of the pressure vessel or boiler. Design pressure is always greater than MAWP.

1.2.3. Design Temperature

The design temperature is the maximum temperature used in design and is not to be less than the mean metal temperature (through the thickness) that is attained under operating conditions. The minimum metal temperature used in design is to be the lowest expected in service, except when Rules of the recognized code or standard permit lower temperatures.

1.3. Recognized Codes or Standards

1.3.3. The design, construction and testing of all the pressure vessels and boilers is required to be in line with the Section 3 of this chapter and is to be certified by [1.1] of this section. Alternatively, they may conform to a recognized code or standard. Some of the International and National standards that are recognized for the purpose of this section are given below:

Pressure vessels and heat exchangers:

- ASME Boiler and Pressure Vessel Code Section VIII Div. 1; or Section VIII Div. 2
- Standards of Tubular Exchanger Manufacturers Association
- British Standard BS 5500 Specification for unfired fusion welded pressure vessels
- Japanese Industrial Standard JIS B8270 et al for Pressure vessels

Boilers:

- ASME Boiler and Pressure Vessel Code Section I
- British Standard BS 1113 Design and manufacture of water tube steam generating plant (including superheaters, reheaters and steel tube economizers)
- British Standard BS 2790 Specifications for the design and manufacture of shell boilers of welded construction

Other national standards or codes will only be considered, provided they are no less effective.

1.4. Grouping of Boilers and Pressure Vessels

Grouping of pressure vessels and boilers as in Table 10.1.2 is done for the purpose of specifying the extent of inspection and testing during the certification process.

1.5. Certification

All pressure vessels and boilers within the scope of [1.1] are required to be certified by INTLREG. Pressure vessels that are mass produced, including seamless extruded cylinders and fluid power cylinders, may be certified by other means as given in [1.6] below. Table 10.1.3 lists significant elements of the certification process for each group of pressure vessels and boilers. Columns 1, 2 and 3 in Table 10.3.2 are to be complied with for all pressure vessels and boilers, regardless of the chosen standard or code of conformance. Fabrication and inspection details in Columns 4 in Table 10.3.2(Refer Part-2, Ch-3,Sect 4) are to be in compliance also, except that considerations will be given to alternative provisions in the chosen standard or code of compliance.

Table 10.1.2: Grouping of Boilers and Pressure Vessels

Grp	Type		Pressure				Temperature			Volume			Thickness	
			bar	kgf/cm ²	psi		°C	°F		m ³	t ³		mm	in.
I	a)	Boilers and steam generators	> 3.5	> 3.6	> 50	–	all	all	–	all	all	–	all	all
	b)	Pressure vessels and heat exchangers, other than d) and e) (Refer note 6)	> 41.4	> 42.2	> 600	or	>371 (Refer note1)	>700 (Refer note1)	a n d	all	all	or	>38	>1.5
							>204 (Refer note2)	>400 (Refer note2)						
	c)	Fired heaters for oil	> 41.4	> 42.2	> 600	–	all	All	–	all	all	–	all	all
	d)	Liquefied gas pressure vessel cargo tanks (Refer note 6)	≥ 2.1	≥ 2.1	≥ 30	–	all	All	–	all	all	–	all	all
II	e)	Pressure vessels and heat exchangers for toxic or corrosive substances (Refer note 6)	>1.0	>1.0	> 15	–	all	All	–	all	all	–	all	all
	a)	Fired heater for oil	≤41.4 and >1.0	≤42.2 and >1.0	≤600 and >15	–	all	All	–	all	all	–	all	all
	b)	Pressure vessels and heat exchangers, other than Group I b (Refer note 6)	≤41.4 and >6.9	≤42.2 and >7	≤600 and >100	a n d	≤371 (Refer note1)	≤700 (Refer note1)	a n d	all	all	and	≤ 38	≤ 1.5
							≤204 (Refer note2)	≤400 (Refer note2)						
	c)	Pressure vessels and heat exchangers, other than Group II b (Refer note 6)	≤ 6.9 and > 1.0	≤ 7 and > 1.0	≤ 100 and > 15	a n d	>149 (Refer note3)	>300 (Refer note3)	a n d	> 0.14	> 5	and	≤ 38	≤ 1.5
							>66 (Refer note4)	>150 (Refer note4)						
							>90 (Refer note5)	>200 (Refer note5)						
Notes: 1. Steam, gas or vapor, other than toxic or corrosive substances. 2. Liquids, other than toxic and corrosive substances. 3. Steam, gas or vapor, and liquids excluding fuel oil, lubricating oil and thermal oil; other than toxic or corrosive substances. 4. Fuel oil. 5. Lubricating oil and thermal oil.														

6. Internal diameter $\geq$ 150 mm (6 in.). Vessels with smaller diameter are outside the scope of this section.

Table 10.1.3: Certification Details

	1	2	3	4			
	Design approval	Survey during fabrication	Material test witnessed by Surveyor	Full radiography	Post-weld heat treatment	Production test plate	Charpy V-notch test
Group I	x	x	x	x	x	x	as required
Group II	x	x	-	-	-	-	as required

1.6. Special Cases

1.6.1. Independent Cargo Pressure Vessels

Besides the provisions of this section, pressure vessels independent of the vessel's hull and intended for the carriage of liquefied gases as cargo are to comply with provisions of Part 7–B, Chapter-3 also.

If such vessels are intended for carriage of cargoes other than liquefied gases, such as bulk cement, which require compressed air for loading and discharging, these are subject to the provisions of this section only if the operating pressure and volume of the vessels exceed that indicated in Table 10.1.1 item c.

1.6.2. Mass-produced Pressure Vessels and Boilers

Mass-produced pressure vessels, boilers and heat exchangers may be certified on the basis of the INTLREG Type Approval Program (Refer Ch-1, Table 1.2.5 and Part-1, Ch-1, Sec-2/[2.2]), provided their designs are approved by INTLREG in each case.

Accepting Group II pressure vessels and heat exchangers is considered on the basis of certification given by an independent agency in line with this section, and the certificate of compliance being submitted to the Surveyor for verification. Each such unit is required to have a permanently affixed nameplate traceable to the certificate. If there is doubt pertaining to the integrity of the unit, further design evaluation and testing may be required.

1.6.3. Pressure Vessels Included in Self-contained Equipment

Pressure vessels and heat exchangers, which are part of an independently manufactured and assembled unit (for example, a self-contained air conditioning or ship's stores refrigeration unit, etc.), are not subject to the provisions of this Chapter, provided the independently assembled unit is not a part of the ship's piping system discussed in Chapter-9 of this part

1.6.4. Seamless Pressure Vessels for Gases

Mass-produced pressurized cylinders intended for carriage of industrial gases viz. oxygen, carbon dioxide, acetylene, etc., and which are of extruded seamless construction, are to be designed, manufactured and tested as per a recognized standard for this type of pressure vessel. These are accepted on the basis of their compliance with the standard verified by either INTLREG or an agency that is recognized by a national authority (in the country of manufacture) and having jurisdiction over the safety of such vessels. Yet, in each case, the certificate of compliance that is traceable to the cylinder's serial number is to be presented to the attending Surveyor for verification.

1.6.5. Fluid Power Cylinders

Hydraulic cylinders for steering gears, regardless of their diameter, are to meet requirements given in Ch-6, Sec-4 & Sect 9 and other hydraulic and pneumatic cylinders, regardless of their diameter are required to meet specifications given in Ch-8, Sec-6/ [6.2.3.5].

1.7. Documents to be Submitted

1.7.1. Boilers

General arrangement

Design data: heating surface, design and working pressure and temperature, evaporative capacity, superheater header and tube mean wall temperatures, estimated pressure drop through the superheaters, safety relief valve settings and capacities, draft requirements at design conditions, number, capacity of forced draft fans, air flow through the combustion chamber, boiler furnace and boiler uptake spaces, including measures taken to assure effective purging in all of the spaces.

Materials of all pressurized parts and their welded attachments

Sectional assembly

Details of areas of refractory material in the combustion chamber and boiler furnace spaces,

Seating arrangements

Water wall details

Steam and water drums, and header details

Steam and superheater tubing including the maximum expected mean wall temperature of the tube wall, and the tube support arrangements

Economizer arrangement, header details, and element details

Typical weld joint designs

Casing arrangement

Post-weld heat treatment and nondestructive examination

Boiler mountings including safety valves and relieving capacities, blow-off arrangements water gauges and try cocks, etc.

Reheat section (when fitted)

Integral piping

Forced draft system

Fuel oil burning arrangements including burners and registers

Boiler instrumentation, monitoring and control systems

1.7.2. Pressure Vessels and Heat Exchangers

General arrangements

Design data: design pressures and temperatures, degree of radiographic examination, fluid name, corrosion allowance, hydrostatic test pressure, heat treatment (or lack of it), setting of safety relief valve

Material specifications including heat treatment and mechanical properties

Shell and head details, and shell to head joint details

Nozzles, openings, manways, etc., and their attachment details; flanges and covers, as applicable

Tubes, tube sheets, heads, shell flanges, covers, baffles, tube to tubesheet joint details, packings, as applicable

Support structures, seating, etc.

1.7.3. Thermal Oil Heaters

In addition to the arrangements and details and construction details of pressure parts as required for steam boilers and heat exchangers, as appropriate, the following are required to be submitted:

Thermal oil characteristics, including flash point; thermal oil deterioration testing routines and facilities

Thermal oil plant design parameters: thermal oil circulation rate; circulating pump head/capacity; designed maximum oil film temperature

Schematic of thermal oil piping system

Fire extinguishing fixtures for the furnace space

Arrangement and details of appurtenances; relief valve capacities

Instrumentation, monitoring and control systems

1.7.4. Calculations

Calculations in accordance with a recognized standard or code.

Calculations, showing that a minimum of air changes of the combustion chamber, boiler furnace and boiler uptake spaces will be achieved during automatic purging operations, with details of the forced draft fans and arrangements of air flow from fan intake to flue outlet, are to be submitted for consideration.

Calculations, are to be submitted showing that the ventilation of machinery spaces containing boilers is adequate for the air consumers within the space with an unimpaired air supply, in accordance with the equipment manufacturer's recommendations, under operating conditions as defined.

1.7.5. Fabrication

Welding procedure specifications and procedure qualification records; nondestructive examination plan; post-weld heat treatment procedure, where applicable. Welder qualification records are required to be submitted to the Surveyor.

SECTION 2 MATERIALS

Contents

2.1. Permissible Materials 487

2.2. Permissible Welding Consumables 487

2.3. Materials Certification and Tests 487

2.1. Permissible Materials**2.1.1. General**

Pressure parts of pressure vessels and boilers are to be made from materials that conform to specifications permitted by the applicable pressure vessel or boiler code. The material specifications for such vessels given in Part-2, Ch-2, Sec-1 may be used in connection with the provisions of Section 3. For non-pressure parts, materials to be used shall be of weldable grade (to be verified by welding procedure qualification), if such parts are to be welded to pressure parts.

2.1.2. Materials for High Temperature Service

Where pressure parts are subjected to service temperatures higher than room temperature, the materials used in making them are to have such mechanical and metallurgical properties that they render adequate strength to those parts for operating under stress at such temperatures. Material specifications shall specify mechanical properties at elevated temperatures, or alternatively, the application of the materials is to be restricted by allowable stresses at higher temperatures as specified in the applicable pressure vessel or boiler standard. The use of materials specified in Part-2, Ch-2, Sec-1 is to be in line with the allowable stresses specified in Section 3.

2.1.3. Materials for Low Temperature Service

The pressure parts subjected to low service temperatures are to be made from such materials which have appropriate notch toughness properties. Permissible materials, allowable operating temperatures, the tests that need to be done and the corresponding toughness criteria are to be as specified in the applicable pressure vessel standard.

2.2. Permissible Welding Consumables

Welding consumables are to be in compliance with the recognized standards and shall be tested, certified and listed by INTLREG for meeting the standard that may be used in all cases. Refer to Part-2, Ch-5, Sec-8[8.5.6].

Unlisted welding consumables, which are otherwise specified by the manufacturer as conforming to a standard, may be used in Group II pressure vessels. These shall have qualified the welding procedures intended to be used in the fabrication of the pressure vessel or boilers, or are to be of a make acceptable to the Surveyor. For Group I pressure vessels and boilers, such consumables are to be further represented by production test pieces taken from representative butt welds to prove the mechanical properties of the metal.

2.3. Materials Certification and Tests

Materials, including welding consumables, used in the construction of pressure vessels and boilers are to be certified by the material manufacturers as meeting the material specifications. Certified mill test reports, traceable to the material concerned, are to be submitted to the Surveyor for information and verification purposes, in all cases.

In addition, as and where indicated in Table 10.1.3 Sect [1.5] above, materials used in the fabrication of main pressure parts, namely, steam and water drums, headers, shell flange, shell and heads, tubes, tube sheets, etc. shall have their materials tested in the Surveyor's presence to verify their compliance with the related material specifications and for the welding consumables, verification of the mechanical strength is to be accomplished by means of testing of production test pieces.

SECTION 3 DESIGN

Contents

3.1. General	489
3.2. Cylindrical Shell under Internal Pressure	489
3.3. Unstayed Heads	503
3.4. Openings and Reinforcements	513
3.5. Boiler Tubes	521
3.6. Welded Joints and Tests	523

3.1. General**3.1.1. Application**

As per the requirements of [1.1], all boilers, steam generators, fired heaters, pressure vessels and heat exchangers are certified. They are based on ASME Boiler and Pressure Vessel Code Section I and Section VIII Div. 1. Alternatively, a recognized code or standards given in Sec-1, [1.3] may be used. All such designs are to be submitted for approval before fabrication is commenced.

3.1.2. Loads Other than Pressure

All pressure vessels and boilers designed in line with the provisions of this Section are to take into account the hydrostatic head when determining the minimum thickness. Although it is not mentioned in the design rules of this Section, there are additional stresses imposed by effects other than pressure or static head and these increase the average stress by more than 10% of the allowable working stress, so they are also to be taken into account. These effects are the static and dynamic weight of the unit and its content, piping and support structure, external loads from connecting equipment, thermal stress, fluctuating pressure or temperature conditions, and loads incurred during hydrostatic testing.

3.1.3. Deformation Testing

Where these Rules are not feasible for the purpose of testing due to shape of a proposed pressure vessel, submission may be made for approval of maximum allowable working pressure determined from a hydrostatic deformation test done on a full-sized sample. Consideration will be given to maximum allowable working pressure determined with the help of empirical equations and hydrostatic deformation test data in compliance with a recognized standard.

3.1.4. Plate and Pipe Thickness Tolerance

Plate and pipes ordered are not to be thinner than design thickness. Vessels made of plate furnished with mill under tolerance of not more than the value of 0.25 mm (0.01 in.) or 6% of the ordered thickness may be used at the full design pressure for the thickness ordered.

3.2. Cylindrical Shell under Internal Pressure**3.2.1. General Equations**

Seamless and fusion-welded shells are to be as given in the following equations. The equations to be used are subject to Sect [3.2.2] below for boiler shells and Sect [3.2.3] for pressure vessel shells.

$$\text{Equation 1: } W = \frac{f S E (T - C)}{R + (1 - y)(T - C)} \text{ or } T = \frac{W R}{f S E - (1 - y) W} + C$$

$$\text{Equation 2: } W = \frac{f S E \{(R_o - C)^2 - R^2\}}{(R_o - C)^2 + R^2}$$

$$\text{Equation 3: } W = \frac{2 f S E (T - C)}{D - 2 y (T - C)} \text{ or } T = \frac{W D}{f S E + 2 y W} + C \quad \dots \dots \text{ for } W \geq 6.9 \text{ bar}$$

Where;

- f = factor for units of measure = 10 (100, 1) for SI (MKS, US) units respectively
- W = maximum allowable working pressure; bar (kgf/cm², psi)
For Equation-3, W is not to be taken less than 6.9 (7, 100) respectively for any condition of service or steel material
- S = maximum allowable working stress at the design temperature material, to be obtained from Table 10.3.3; in N/mm² (kgf/mm², psi)
- E = efficiency of longitudinal joint or ligaments between tube holes or efficiency of other closely spaced openings, whichever is least; is dimensionless; Refer [3.2.2.4], [3.2.2.5] and [3.2.3.4].
- T = minimum thickness of shell, mm (in.)
- R = inside radius of the weakest course of the shell; mm (in.)
- R_o = outside radius of the above shell under consideration; mm (in.)
- D = outside diameter of header or drum, mm (in.)
- C = corrosion allowance, Refer [3.2.2.6] and [3.2.3.2]; mm (in.)
- y = coefficient having values as in Table 10.3.1 below (interpolation of values between temperatures may be done):

Table 10.3.1

	≤ 482°C 900°F	510°C 950°F	538°C 1000°F	566°C 1050°F	593°C 1100°F	≥ 621°C 1150°F
Ferritic steel	0.4	0.5	0.7	0.7	0.7	0.7
Austenitic steel	0.4	0.4	0.4	0.4	0.4	0.7

3.2.2. Boiler Shells

3.2.2.1. Thickness Less than One-half the Inside Radius

Where the thickness is less than one-half the inside radius, drums and headers are to be as per Equation (1) or (3).

3.2.2.2. Thickness Greater than One-half the Inside Radius

The maximum allowable working pressure for parts of boilers of cylindrical cross section designed to work at temperatures up to that of saturated steam at critical pressure (374.1°C, 705.4°F) is to be determined with help of Equation (2).

3.2.2.3. Minimum Thickness

The minimum thickness of any boiler plate under pressures is to be 6.4 mm (0.25 in.), or its minimum wall is to be 6.4 mm (0.25 in.) when pipe over 127 mm (5 in.) OD is used in place of plate for the shell of cylindrical components under pressure.

3.2.2.4. Weld Seam Efficiency

The value of *E* is to be used for calculations for the corresponding part of the shell is as follows.

- *Seamless shells*: *E* = 1.00
- *Welded shells*: circumferential and longitudinal weld seams of boiler shells are to be accomplished by double-welded butt type, or equivalent, and using radiography are to be examined for their full length, *E* = 1.00

3.2.2.5. Ligament Efficiency

- a) *Longitudinal ligament.* When the longitudinal axis and tube holes are parallel such that the pitch of the tube on every row is equal, as in Figure 10.3.1 (a), E is to be given by following equation:

$$E = \frac{p - d}{p}$$

When pitch of the tube holes on any one row is unequal, as in Figure 10.3.1 (b) and (c), E is to be given by following equation:

$$E = \frac{p_1 - nd}{p_1}$$

where

p, p_1 = pitch of tubes; mm (in.)

n = number of tube holes in pitch p_1

d = diameter of tube holes, mm (in.)

- b) *Diagonal ligament efficiency.* Where the tube holes are as shown in Figure 10.3.1 (d), the efficiency of such ligaments is to be determined using Figure 10.3.2. When efficiency determined from (a) is more than the diagonal efficiency, it is to be used in computing the minimum shell thickness.
- c) *Unsymmetrical ligament efficiency.* When tubes or holes are unsymmetrical spaced, the average ligament efficiency is not to be less than that given by the requirements given below, which are applicable to ligaments between tube holes and not to single openings. In some cases, this procedure may give lower efficiencies than those for symmetrical groups which extend to a distance greater than the inside diameter of the shell as covered under (a) and (b). When it occurs, efficiencies computed under (a) and (b) are to be used.
- (i) For a length equal to the inner diameter of drum for the position which gives the minimum efficiency, the efficiency is not to be less than that on which the maximum allowable pressure is based. When diameter of the drum exceeds 1525 mm (60 in.), length is to be taken as 1525 mm (60 in.) as this requirement is applied.
 - (ii) For a length equal to the inner radius of drum for the position which gives the minimum efficiency, the efficiency shall not be less than 80% of that on which the maximum allowable pressure is based. When the radius of the drum exceeds 762 mm (30 in.), length is to be taken as 762 mm (30 in.) as this requirement is applied.
 - (iii) For holes which are placed longitudinally along a drum but which do not fall in a straight line, the above Rules for calculating efficiency are to hold, except that the equivalent longitudinal width of a diagonal ligament is to be used. To attain equivalent width, longitudinal pitch of two holes having a diagonal ligament is to be multiplied by the efficiency of the diagonal ligament as shown in Figure 10.3.3.
- d) *Circumferential ligament efficiency.* The efficiency of circumferential ligaments is to be determined just as that of the longitudinal ligaments in (a) and is to be equal to at least 1/2 the efficiency of the latter.

3.2.2.6. Corrosion Allowance, C

If corrosion or erosion is expected, a corrosion allowance is to be added. The value of corrosion allowance is to be specified in the plans submitted to INTLREG.

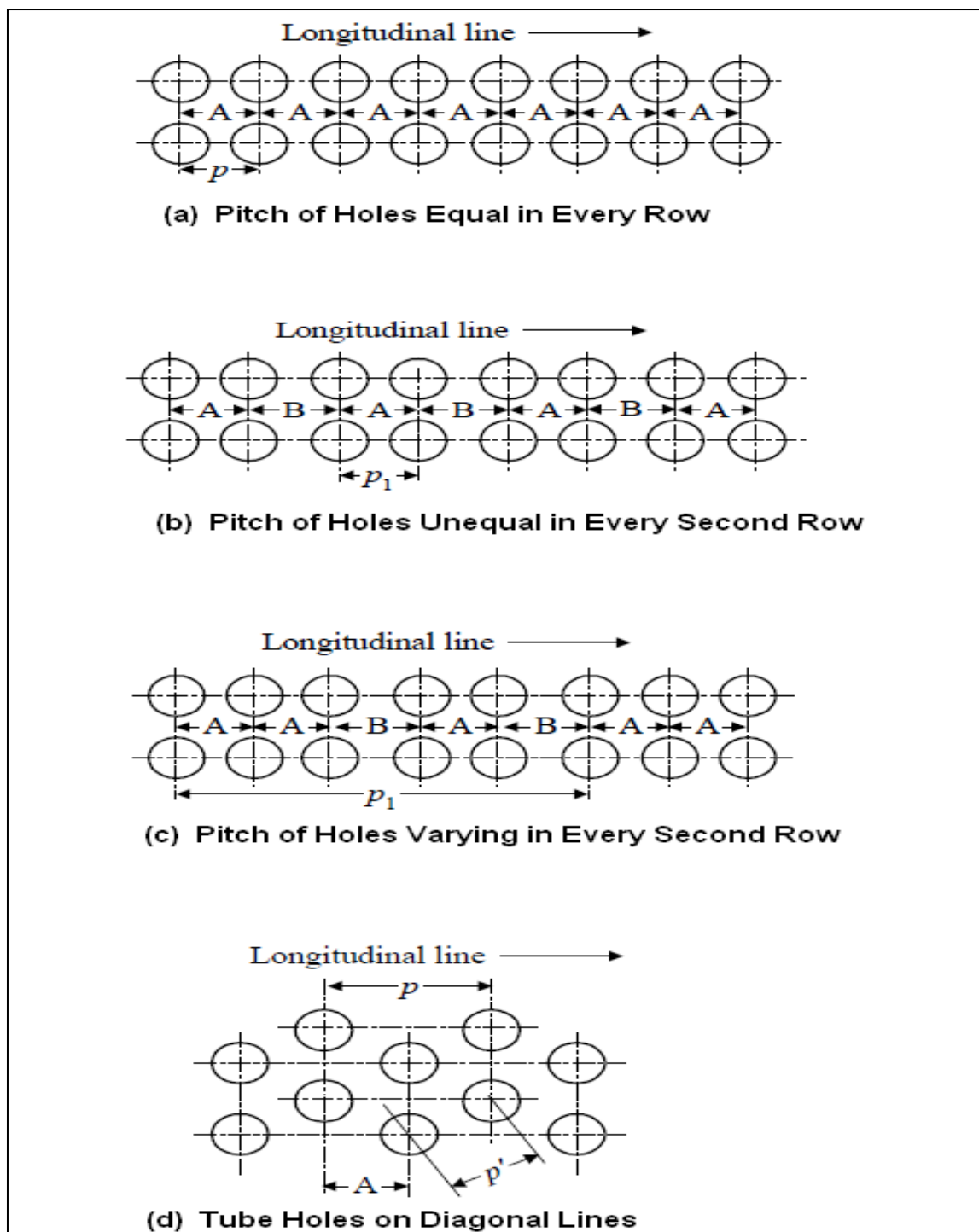


Figure 10.3.1: Examples of Tube Spacing

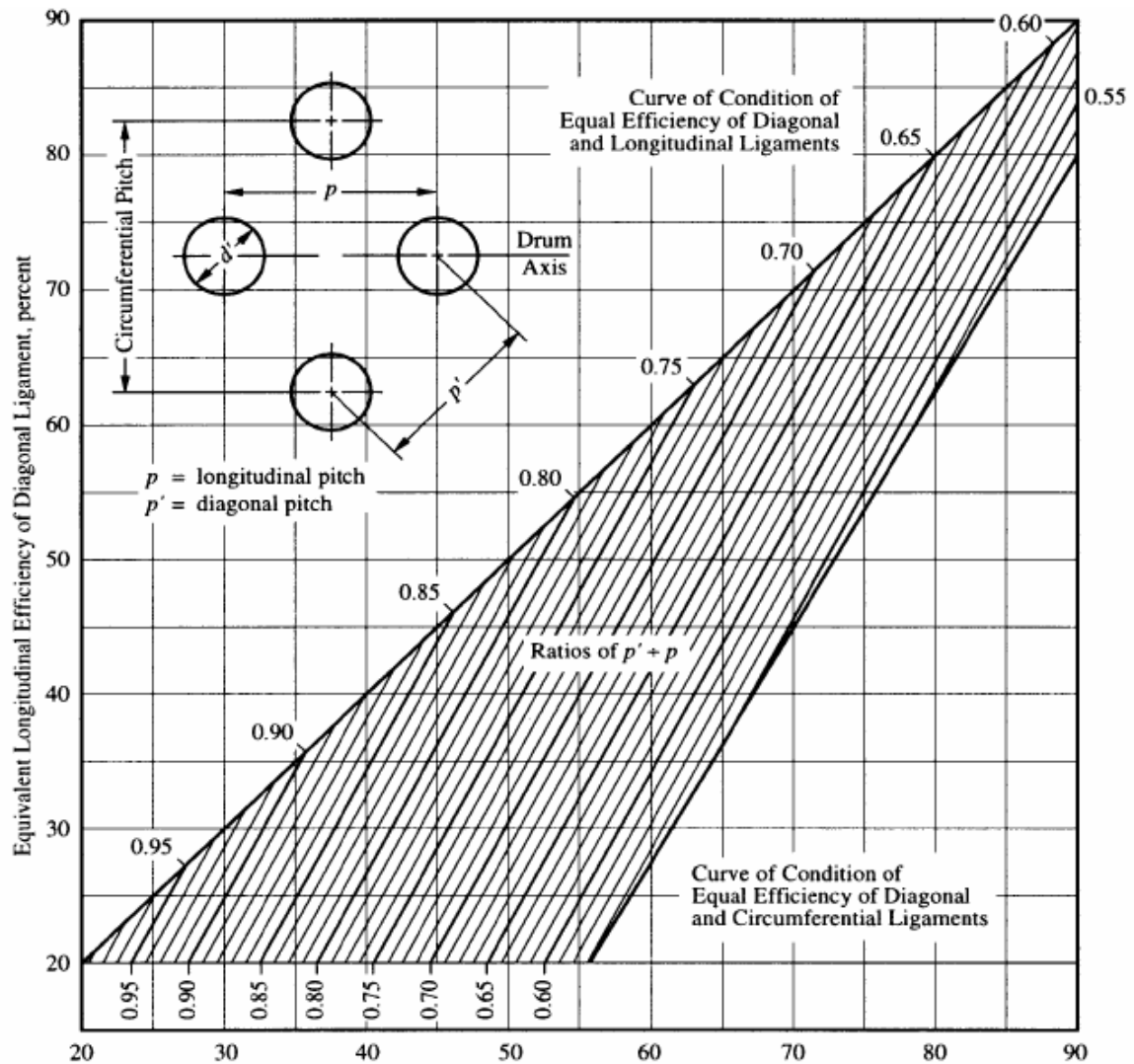


Figure 10.3.2: Diagram for Determination of Diagonal Efficiency

$$\left[\text{Longitudinal Efficiency (\%)} = \frac{p - d}{p} \times 100 \right]$$

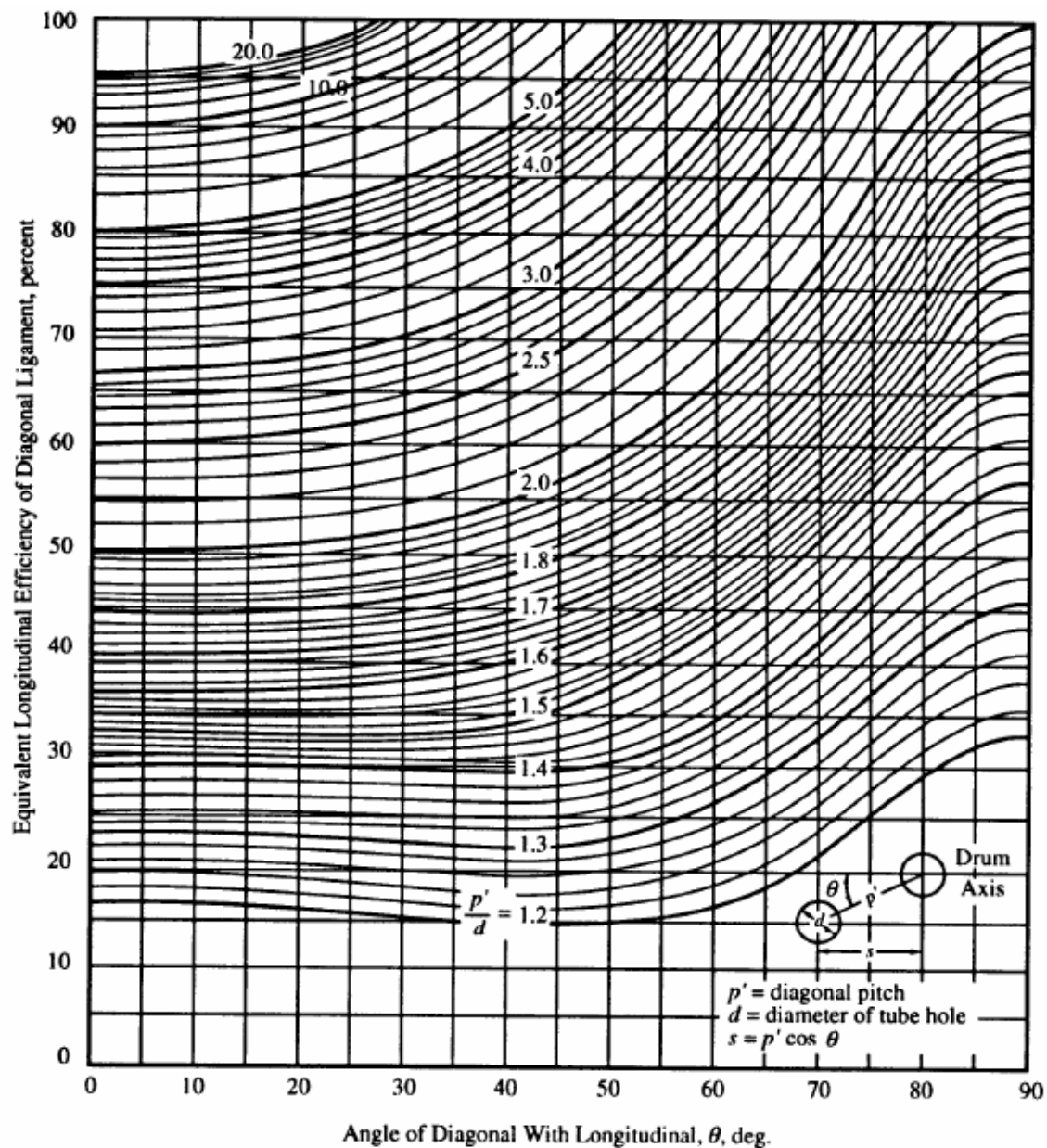


Figure 10.3.3: Diagram for Determining Efficiency of Diagonal Ligaments in Order to Obtain Equivalent Longitudinal Efficiency

3.2.3. Pressure Vessel Shells

3.2.3.1. Maximum Allowable Working Pressure

The maximum allowable working pressure is to be determined using Equation (1) in Sect [3.2.1] when W does not exceed $3.85SE$ (SI units), $38.5SE$ (MKS units), or $0.385SE$ (US units) or when the thickness does not exceed $1/2$ of the inner radius. Where the thickness of the shell exceeds $1/2$ of the inner radius, or when W exceeds $3.85SE$ (SI units) pressure vessels designed for pressures above 207 bar (210 kgf/cm², 3000 psi), Equation (2) in Sect [3.2.1] is to be used.

3.2.3.2. Corrosion Allowance

A corrosion allowance, C , of not less than $1/6^{\text{th}}$ of the calculated thickness is to be used in finding the thickness of pressure vessels intended for air, steam or water or any combination thereof when they are designed with S values taken from Table 10.3.3 and the minimum required thickness is less than 6.4 mm (0.25 in.), except that the sum of the calculated thickness and corrosion allowance need not exceed 6.4 mm (0.25 in.). This corrosion allowance is to be provided on the surface in contact with the substance. For following cases, a corrosion allowance may be omitted:

- When seamless vessel parts are designed with $E = 0.85$, or
- When 0.8 of the S values taken from Table 10.3.3 are used in the design or,
- When values of E in column (c) of Table 10.3.2 are used in the design

3.2.3.3. Minimum Thickness

Thickness of plates shall not less than 2.4 mm ($3/32$ in.) after forming and without allowance for corrosion.

3.2.3.4. Weld Joint Efficiency

Efficiencies for welded, unfired pressure vessels are to be determined from Table 10.3.2. For Group I pressure vessels, circumferential and longitudinal weld seams of shell are to be accomplished by double-welded butt type, or equivalent, and are to be examined for their full length by radiography, in which $E = 1.00$.

Table 10.3.2: Joint Efficiencies for Welded Joints

Type of Joint	Limitation	Degree of Radiography			
		(a) Full (Refer note 1)	(b) Spot (Refer note 1)	(c) None (Refer note 2)	
(a) Butt joints as attained by double welding or by other means which will obtain the same quality of deposited weld metal on the inside and outside weld surfaces. Welds using metal backing strips which remain in place are excluded	None	1.00	0.85 (4)	0.7	
(b) Single welded butt joint with backing strip other than those included above	None, except 15.9 mm (0.625 in.) maximum thickness in circumferential butt welds having one plate offset as shown in Part 2, Ch-3, Figure 3.3.1.	0.90	0.8	0.65	
(c) Single-welded butt joint without use of backing strip	Circumferential joints only, not over 15.9 mm (0.625 in.) thick and not over 610 mm (24 in.) outside diameter.			0.6	
(d) Double full-fillet lap joint	Longitudinal joints not over 9.5 mm (0.375 in.) thick. Circumferential joints not over 15.9 mm (0.625 in.) thick.			0.55	
(e) Single full-fillet lap joints with plug welds	Circumferential joints for attachment of heads, not over 610 mm (24 in.) outside diameter to shell not over 12.7 mm (0.5 in.) thick (3).			0.5	
(f) Single full-fillet lap joints without plug welds	i) For the attachment of heads convex to pressure to shell not over 15.9 mm (0.625 in.) required thickness, only with use of fillet weld on the inside of shell. Or ii) For attachment of heads having pressure on either side to shells not over 610 mm (24 in.) inside diameter and not over 6.4 mm (0.25 in.) required thickness with fillet weld on outside of head flange only.			0.45	
Notes: 1. Full and spot radiograph requirements covered in Part 2, Ch-3, Sec-2/ [2.12]. 2. The maximum allowable joint efficiencies shown in this column are the weld-joint efficiencies multiplied by 0.8 (and rounded off to the nearest 0.05) to effect the basic reduction in allowable stress required by the Rules for welded vessels that are not spot examined. This value may only be used provided that a maximum allowable unit working stress not exceeding 0.8 of the appropriate S value in Table 10.3.3 (a) is used in all other design calculations except for stress S for unstayed flat heads and covers in [3.3.4], and stresses used in flange designs. 3. Joints attaching hemispherical heads to shells are excluded. 4. Seamless vessel sections and heads with circumferential butt joints, excluding hemispherical heads, that are spot radiographed are to be designed for circumferential stress using the appropriate S value in Table 10.3.3 (a). Where seamless vessel sections and heads with circumferential butt joints are not spot radiographed, they are to be designed for circumferential stress using stress value not to exceed 0.85 of the appropriate S value in Table 10.3.3 (a). This stress reduction is not applicable to Trand Trm in reinforcement calculations.					

INTLREG Rules for Building and Classing Steel Vessels

Table 10.3.3 (a) (SI units): Maximum Allowable Stress Values for Ferrous Materials – N/mm²

Stress values shown in *italics* are permissible, but use of these materials at these temperatures is not current practice.

The stress values in this table may be interpolated to determine values for intermediate temperatures.

Stress values for other materials may be the same as given in the ASME Boiler and Pressure Vessel Code.

INTLRE G Grade	ASTM Grade	Nominal Comp.	Min. Tensile strength	Note	Metal temperature (°C) not exceeding															
					-29 to 149	204	260	316	343	371	399	427	454	482	510	538	566	593	621	649
Plate steels – Part 2, Ch-2, Sec-2																				
MA	A285 Gr.A	C	310	1,4	88.9	88.9	88.9	84.8	82	79.3	73.8	57.2	45.5	34.5						
MB	A285 Gr.B	C	345	1,4	98.6	98.6	98.6	95.1	91.7	86.2	75.8	64.8	50.3	34.5						
MC	A285 Gr.C	C	379	1,4	108.2	108.2	108.2	105.5	102	98.6	89.6	74.5	60	40.7						
MD	A515 Gr.55	C Si	379	1	108.2	108.2	108.2	105.5	102	98.6	89.6	74.5	60	40.7	27.6	17.2				
ME	A515 Gr.60	C	414	1	117.9	117.9	117.9	113.1	108.9	105.5	89.6	74.5	60	40.7	27.6	17.2				
MF	A515 Gr.65	C	448	1	128.2	128.2	128.2	123.4	119.3	115.1	95.8	78.6	60	40.7	27.6	17.2				
MG	A515 Gr.70	C	483	1	137.9	137.9	137.9	133.8	129.6	124.8	102	82.7	64.1	46.2	27.6	17.2				
H	A204 Gr.A	C-1/2 Mo	448	2	128.2	128.2	128.2	128.2	128.2	128.2	128.2	126.9	123.4	94.5	56.5	33.1				
I	A204 Gr.B	C-1/2 Mo	483	2	137.9	137.9	137.9	137.9	137.9	137.9	137.9	137.2	133.1	94.5	56.5	33.1				
J	A204 Gr. C	C-1/2 Mo	517	2	147.5	147.5	147.5	147.5	147.5	147.5	147.5	147.5	142.7	95.5	56.5	33.1				
K	A516 Gr.55	C	379	1	108.2	108.2	108.2	105.5	102	98.6	89.6	74.5	60	40.7	27.6	17.2				
L	A516 Gr. 60	C	414	1	117.9	117.9	117.9	113.1	108.9	105.5	89.6	74.5	60	40.7	27.6	17.2				
M	A516 Gr. 65	C	448	1	128.2	128.2	128.2	123.4	119.3	115.1	95.8	78.6	60	40.7	27.6	17.2				
N	A516 Gr. 70	C	483	1	137.9	137.9	137.9	133.8	129.6	124.8	102	82.7	64.1	46.2	27.6	17.2				
Forged steel drum – Part 2, Ch-2, Sec-5																				
A	A266 Cl-1		414	1	117.9	117.9	112.4	105.5	102	98.6	89.6	74.5	60	40.7	27.6	17.2				
B	A266 Cl-2		483	1	137.9	137.9	135.1	126.9	122.7	118.6	102	82.7	64.1	46.2	27.6	17.2				

Castings – Part 2, Ch-2, Sec-7 and Sec-10																			
3	A216.WC A	C	414	1,7	117.9	117.9	112.4	105.5	102	98.6	89.6	74.5	60	40.7	27.6	17.2			
4	A216 WCB	C	483	1,7	137.9	137.9	135.1	126.9	122.7	118.6	102	82.7	64.1	46.2	27.6	17.2			
60-14-18	A395	Nodular iron	414	7	82.7														
Tubes – Part 2, Ch-2, Sec-15																			
D	A178 Gr.A	C-Mn	324	1,3,5 ,6	92.4	92.4	92.4	91.7	88.3	85.5	73.8	62.1	49	34.5	17.9	9			
F	A178 Gr.C	C-Mn	414	1,3,5	117.9	117.9	117.9	117.9	117.9	107.6	89.6	74.5	60	34.5	23.4	14.5			
G	A226	C-Mn	324	1,5,6	92.4	92.4	92.4	91.7	88.3	85.5	73.8	62.1	49	34.5	20.7	10.3			
H	A192	C-Mn	324	1,6	92.4	92.4	92.4	91.7	88.3	85.5	73.8	62.1	49	34.5	31	17.2			
J	A210 Gr.A-1	C-Mn	414	1	117.9	117.9	117.9	117.9	117.9	107.6	89.6	74.5	60	40.7	27.6	17.2			
K	A209 Gr.T1	C-Mn-1/2 Mo	379	2	108.2	108.2	108.2	108.2	108.2	108.2	106.2	102.7	100	94.5	56.5	33.1			
L	A209 Gr.T1a	C-Mn-1/2 Mo	414	2	117.9	117.9	117.9	117.9	117.9	115.8	113.1	109.6	106.2	94.5	56.5	33.1			
M	A209 Gr.T1b	C-Mn-1/2 Mo	365	2	104.1	104.1	104.1	104.1	103.4	101.4	98.6	96.5	93.1	89.6	56.5	33.1			
N	A213 Gr.T11	1-1/4 Cr - 1/2 Mo	414		123.4	123.4	123.4	108.2	106.2	104.1	102	99.3	96.5	93.8	64.1	43.4	30	19.3	13.1
O	A213 Gr.T12	1 Cr - 1/2 Mo	414		113.8	113.8	113.8	112.4	110.3	108.9	106.9	105.5	102.7	100	77.9	77.2	31	19.3	12.4
P	A213 Gr.T22	2-1/4 Cr - 1 Mo	414		114.5	114.5	114.5	114.5	114.5	114.5	114.5	114.5	114.5	93.8	74.5	55.2	39.3	26.2	16.5
Notes 1) Upon prolonged exposure to temperatures above 425°C, the carbide phase of carbon steel may be converted to graphite. 2) Upon exposure to temperatures above about 470°C, the carbide phase of carbon-molybdenum steel may be converted to graphite. 3) Only killed steel is to be used above 482°C. 4) Flange quality in this specification not permitted above 454°C. 5) Above 371°C these stress values include a joint efficiency factor of 0.85. When material to this specification is used for pipe, multiply the stress values up to and including 371°C by a factor of 0.85. 6) Tensile value is expected minimum. 7) To these values a quality factor of 0.80 is to be applied unless nondestructive testing (NDT) is carried out beyond that required by material specification. Refer UG 24 of ASME Code, Section VIII, Division 1.																			

INTLREG Rules for Building and Classing Steel Vessels

Table 10.3.3 (b) (MKS units): Maximum Allowable Stress Values for Ferrous Materials – kgf/mm²

Stress values shown in *italics* are permissible, but use of these materials at these temperatures is not current practice.

The stress values in this table may be interpolated to determine values for intermediate temperatures.

Stress values for other materials may be the same as given in the ASME Boiler and Pressure Vessel Code.

INTLRE G Grade	ASTM Grade	Nominal Comp.	Min. Tensile strength	Note	Metal temperature (°C) not exceeding															
					-29 to 149	204	260	316	343	371	399	427	454	482	510	538	566	593	621	649
Plate steels – Part 2, Ch-2, Sec-2																				
MA	A285 Gr.A	C	31.6	1,4	9.07	9.07	9.07	8.65	8.37	8.09	7.52	5.84	4.64	3.52						
MB	A285 Gr.B	C	35.2	1,4	10.05	10.05	10.05	9.70	9.35	8.79	7.73	6.61	5.13	3.52						
MC	A285 Gr.C	C	38.7	1,4	11.04	11.04	11.04	10.76	10.41	10.05	9.14	7.59	6.12	4.15						
MD	A515 Gr.55	C Si	38.7	1	11.04	11.04	11.04	10.76	10.41	10.05	9.14	7.59	6.12	4.15	2.81	1.76				
ME	A515 Gr.60	C	42.2	1	12.02	12.02	12.02	11.53	11.11	10.76	9.14	7.59	6.12	4.15	2.81	1.76				
MF	A515 Gr.65	C	45.7	1	13.08	13.08	13.08	12.58	12.16	11.74	9.77	8.01	6.12	4.15	2.81	1.76				
MG	A515 Gr.70	C	49.2	1	14.06	14.06	14.06	13.64	13.22	12.73	10.41	8.44	6.54	4.71	2.81	1.76				
H	A204 Gr.A	C-1/2 Mo	45.7	2	13.08	13.08	13.08	13.08	13.08	13.08	13.08	12.94	12.59	9.63	5.77	3.37				
I	A204 Gr.B	C-1/2 Mo	49.2	2	14.06	14.06	14.06	14.06	14.06	14.06	14.06	13.99	13.57	9.63	5.77	3.37				
J	A204 Gr. C	C-1/2 Mo	52.7	2	15.05	15.05	15.05	15.05	15.05	15.05	15.05	15.05	14.55	9.36	5.77	2.27				
K	A516 Gr.55	C	38.7	1	11.04	11.04	11.04	10.76	10.41	10.05	9.14	7.59	6.12	4.15	2.81	1.76				
L	A516 Gr. 60	C	42.2	1	12.02	12.02	12.02	11.53	11.11	10.76	9.14	7.59	6.12	4.15	2.81	1.76				
M	A516 Gr. 65	C	45.7	1	13.08	13.08	13.08	12.58	12.16	11.74	9.77	8.01	6.12	4.15	2.81	1.76				
N	A516 Gr. 70	C	49.2	1	14.06	14.06	14.06	13.64	13.22	12.73	10.41	8.44	6.54	4.71	2.81	1.76				
Forged steel drum – Part 2, Ch-2, Sec-5																				
A	A266 Cl-1		42.2	1	12.02	12.02	11.46	10.76	10.41	10.05	9.14	7.59	6.12	4.15	2.81	1.76				
B	A266 Cl-2		49.2	1	14.06	14.06	13.78	12.94	12.51	12.09	10.41	8.44	6.54	4.71	2.81	1.76				

PART 5A
CHAPTER 10

INTLREG Rules for Building and Classing Steel Vessels

Castings – Part 2, Ch-2, Sec-7 and Sec-10																			
3	A216.WC A	C	42.2	1,7	12.02	12.02	11.46	10.76	10.41	10.05	9.14	7.59	6.12	4.15	2.81	1.76			
4	A216 WCB	C	49.2	1,7	14.06	14.06	13.78	12.94	12.51	12.09	10.41	8.44	6.54	4.71	2.81	1.76			
60-14-18	A395	Nodular iron	42.2	7	8.44														
Tubes – Part 2, Ch-2, Sec-15																			
D	A178 Gr.A	C-Mn	33.0	1,3,5,6	9.42	9.42	9.42	9.35	9.00	8.72	7.52	6.34	4.99	3.52	1.83	0.91			
F	A178 Gr.C	C-Mn	42.2	1,3,5	12.02	12.02	12.02	12.02	12.02	10.96	9.14	7.59	6.12	3.16	2.39	1.48			
G	A226	C-Mn	33.0	1,5,6	9.42	9.42	9.42	9.35	9.00	8.72	7.52	6.33	4.99	3.52	2.11	1.05			
H	A192	C-Mn	33.0	1,6	9.42	9.42	9.42	9.35	9.00	8.72	7.52	6.33	4.99	3.52	3.16	1.76			
J	A210 Gr.A-1	C-Mn	42.2	1	12.02	12.02	12.02	12.02	12.02	10.97	9.14	7.59	6.12	4.15	2.81	1.76			
K	A209 Gr.T1	C-Mn-1/2 Mo	38.7	2	11.04	11.04	11.04	11.04	11.04	11.04	10.83	10.46	10.19	9.63	5.77	3.37			
L	A209 Gr.T1a	C-Mn-1/2 Mo	42.2	2	12.02	12.02	12.02	12.02	12.02	11.81	11.53	11.18	10.83	9.63	5.77	3.37			
M	A209 Gr.T1b	C-Mn-1/2 Mo	37.3	2	10.62	10.62	10.62	10.62	10.55	10.36	10.05	9.82	9.49	9.14	5.77	3.37			
N	A213 Gr.T11	1-1/4 Cr - 1/2	42.2		12.02	11.81	11.39	11.04	10.83	10.62	10.41	10.12	9.84	9.56	6.54	4.43	2.95	1.97	1.34
O	A213 Gr.T12	Mo	42.2		11.60	11.60	11.60	11.46	11.25	11.11	10.90	10.76	10.48	10.19	7.94	5.06	3.16	1.97	1.27
P	A213 Gr.T22	1 Cr - 1/2 Mo	42.2		11.67	11.67	11.67	11.67	11.67	11.67	11.67	11.67	11.67	9.56	7.59	5.62	4.00	2.67	1.69
Notes 1) Upon prolonged exposure to temperatures above 425°C, the carbide phase of carbon steel may be converted to graphite. 2) Upon exposure to temperatures above about 470°C, the carbide phase of carbon-molybdenum steel may be converted to graphite. 3) Only killed steel is to be used above 482°C. 4) Flange quality in this specification not permitted above 454°C. 5) Above 371°C these stress values include a joint efficiency factor of 0.85. When material to this specification is used for pipe, multiply the stress values up to and including 371°C by a factor of 0.85. 6) Tensile value is expected minimum. 7) To these values a quality factor of 0.80 is to be applied unless nondestructive testing (NDT) is carried out beyond that required by material specification. Refer UG 24 of ASME Code, Section VIII, Division 1.																			

INTLREG Rules for Building and Classing Steel Vessels

Table 10.3.3 (c) (US units): Maximum Allowable Stress Values for Ferrous Materials – ksi

Stress values shown in *italics* are permissible, but use of these materials at these temperatures is not current practice.

The stress values in this table may be interpolated to determine values for intermediate temperatures.

Stress values for other materials may be the same as given in the ASME Boiler and Pressure Vessel Code.

Stress values for other materials may be the same as given in the ASME Boiler and Pressure Vessel Code.																				
INTLRE G Grade	ASTM Grade	Nominal Comp.	Min. Tensile strength	Note	Metal temperature (°C) not exceeding															
					-20 300	to 400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200
Plate steels – Part 2, Ch-2, Sec-2																				
MA	A285 Gr.A	C	45	1,4	12.9	12.9	12.9	12.3	11.9	11.5	10.7	8.3	6.6	5.0		2.5				
MB	A285 Gr.B	C	50	1,4	14.3	14.3	14.3	13.8	13.3	12.5	11.0	9.4	7.3	5.0		2.5				
MC	A285 Gr.C	C	55	1,4	15.7	15.7	15.7	15.3	14.8	14.3	13.0	10.8	8.7	5.9		2.5				
MD	A515 Gr.55	C Si	55	1	15.7	15.7	15.7	15.3	14.8	14.3	13.0	10.8	8.7	5.9	4.0	2.5				
ME	A515 Gr.60	C	60	1	17.1	17.1	17.1	16.4	15.8	15.3	13.0	10.8	8.7	5.9	4.0	4.8				
MF	A515 Gr.65	C	65	1	18.6	18.6	18.6	17.9	17.3	16.7	13.9	11.4	8.7	5.9	4.0	4.8				
MG	A515 Gr.70	C	70	1	20.0	20.0	20.0	19.4	18.8	18.1	14.8	12.0	9.3	6.7	4.0	4.8				
H	A204 Gr.A	C-1/2 Mo	65	2	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.4	17.9	13.7	8.2	2.5				
I	A204 Gr.B	C-1/2 Mo	70	2	20.0	20.0	20.0	20.0	20.0	20.0	20.0	19.9	19.3	13.7	8.2	2.5				
J	A204 Gr. C	C-1/2 Mo	75	2	21.4	21.4	21.4	21.4	21.4	21.4	21.4	21.4	20.7	13.7	8.2	2.5				
K	A516 Gr.55	C	55	1	15.7	15.7	15.7	15.3	14.8	14.3	13.0	10.8	8.7	5.9	4.0	2.5				
L	A516 Gr. 60	C	60	1	17.1	17.1	17.1	16.4	15.8	15.3	13.0	10.8	8.7	5.9	4.0	2.5				
M	A516 Gr. 65	C	65	1	18.6	18.6	18.6	17.9	17.3	16.7	13.9	11.4	8.7	5.9	4.0	2.5				
N	A516 Gr. 70	C	70	1	20.0	20.0	20.0	19.4	18.8	18.1	14.8	12.0	9.3	6.7	4.0	2.5				
Forged steel drum – Part 2, Ch-2, Sec-5																				
A	A266 Cl-1		60	1	17.1	17.1	16.3	15.3	14.8	14.3	13.0	10.8	8.7	5.9	4.0	2.5				
B	A266 Cl-2		70	1	20.0	20.0	19.6	18.4	17.8	17.2	14.8	12.0	9.3	6.7	4.0	2.5				
Castings – Part 2, Ch-2, Sec-7 and Sec-10																				

PART 5A
CHAPTER 10

INTLREG Rules for Building and Classing Steel Vessels

3	A216.WC A	C	60	1,7	17.1	17.1	16.3	15.3	14.8	14.3	13.0	10.8	8.7	5.9	4.0	2.5				
4	A216 WCB	C	70	1,7	20.0	20.0	19.6	18.4	17.8	17.2	14.8	12.0	9.3	6.7	4.0	2.5				
60-14- 18	A395	Nodular iron	60	7	12.0															
Tubes – Part 2, Ch-2, Sec-15																				
D	A178 Gr.A	C-Mn	47	1,3,5,6	13.4	13.4	13.4	13.3	12.8	12.4	10.7	9.0	7.1	5.0	2.6	1.3				
F	A178 Gr.C	C-Mn	60	1,3,5	17.1	17.1	17.1	17.1	17.1	15.6	13.0	10.8	8.7	5.0	3.4	2.1				
G	A226	C-Mn	47	1,5,6	13.4	13.4	13.4	13.3	12.8	12.4	10.7	9.0	7.1	5.0	3.0	1.5				
H	A192	C-Mn	47	1,6	13.4	13.4	13.4	13.3	12.8	12.4	10.7	9.0	7.1	5.0	4.5	2.5				
J	A210 Gr.A-1	C-Mn	60	1	17.1	17.1	17.1	17.1	17.1	15.6	13.0	10.8	8.7	5.9	4.0	2.5				
K	A209 Gr.T1	C-Mn-1/2 Mo	55	2	15.7	15.7	15.7	15.7	15.7	15.7	15.4	14.9	14.5	13.7	8.2	4.8				
L	A209 Gr.T1a	C-Mn-1/2 Mo	60	2	17.1	17.1	17.1	17.1	17.1	16.8	16.4	15.9	15.4	13.7	8.2	4.8				
M	A209 Gr.T1b	C-Mn-1/2 Mo	53	2	15.1	15.1	15.1	15.1	15.0	14.7	14.3	14.0	13.5	13.0	8.2	4.8				
N	A213 Gr.T11	1-1/4 Cr - 1/2 Mo	60		17.1	16.8	16.2	15.7	15.4	15.1	14.8	14.4	14.0	13.6	9.3	6.3	4.2	2.8	1.9	1.2
O	A213 Gr.T12	1 Cr - 1/2 Mo	60		16.5	16.5	16.5	16.3	16.0	15.8	15.5	15.3	14.9	14.5	11.3	7.2	4.5	2.8	1.8	1.1
P	A213 Gr.T22	2-1/4 Cr - 1 Mo	60		16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	13.6	10.8	8.0	5.7	3.8	2.4	1.4
Notes																				
1) Upon prolonged exposure to temperatures above 800°F, the carbide phase of carbon steel may be converted to graphite.																				
2) Upon exposure to temperatures above about 875°F, the carbide phase of carbon-molybdenum steel may be converted to graphite.																				
3) Only killed steel is to be used above 900°F.																				
4) Flange quality in this specification not permitted above 850°F.																				
5) Above 700°F these stress values include a joint efficiency factor of 0.85. When material to this specification is used for pipe, multiply the stress values up to and including 700°F by a factor of 0.85.																				
6) Tensile value is expected minimum.																				
7) To these values a quality factor of 0.80 is to be applied unless nondestructive testing (NDT) is carried out beyond that required by material specification. Refer UG 24 of ASME Code, Section VIII, Division 1.																				

3.3. Unstayed Heads**3.3.1. Tori spherically and Hemi spherically Dished Heads****3.3.1.1. Minimum Thickness**

The minimum thickness for heads without manholes or hand holes and having the pressure on the concave side is required to be determined by the equation given below. Refer Figure 10.3.4 (u) & (v). For heads having pressure on the convex side, Refer Sect [3.3.1.7].

$$T = \frac{W R M}{2 f S E - 0.2 W} + C$$

$$M = 0.25 \left(3 + \sqrt{\frac{R}{r}} \right)$$

= 1.00 for hemispherically dished heads

Where;

W = maximum working pressure; bar (kgf/cm², psi)

T = minimum thickness of the head; mm (in.)

R = radius to which the head is dished, measured on the concave side, Refer Sect [3.3.1.2] below; mm (in.)

r = knuckle radius of head, Refer Sect [3.3.1.3]; mm (in.)

S = maximum allowable working stress, Refer Sect [3.3.1.4]; N/mm² (kgf/mm², psi)

E = lowest efficiency of any joint in the head, Refer Sect [3.3.1.5]

C = corrosion allowance, Refer Sect [3.3.1.6]; mm (in.)

f = factor = 10 (100, 1) for SI (MKS, US) units, respectively

3.3.1.2. Dish Radius

The radius to which a head is dished shall not be greater than outer diameter of the flanged portion of the head.

3.3.1.3. Knuckle Radius

The inner radius of the flange formed on any head for its attachment to the shell plate is to be

- Not less than thrice (3) the thickness of the head, and
- In the case of dished heads, not less than 6% of the outer diameter of the flanged portion of the head.

3.3.1.4. Maximum Allowable Working Stress

The Maximum Allowable Working Stress (MAWS) may be taken from Table 10.3.3, except that in the case of pressure vessels where spot radiography is not done. The maximum allowable unit working stress shall not exceed 0.85 of the appropriate S value in Table 10.3.3.

3.3.1.5. Joint Efficiency

For boilers and Group I pressure vessels, weld seams in the heads are required to be of double-welded butt type and are to be fully radiographed, thus, $E = 1$. For seamless heads, use $E = 1.00$. For Group II pressure vessels, E values as given in Table 10.3.2 is to be used.

Head to shell seams are to be considered circumferential seams of shell and are to be dealt with as in Sect [3.2.2.4] for boiler and Sect [3.2.3.4] for Group I pressure vessels. However, for hemispherical heads without a skirt, where attachment of the head to shell is at the equator, it is to be included in estimating the joint efficiency of the head.

3.3.1.6. Corrosion Allowance

The values of the corrosion allowance are to be as given in Sect [3.2.2.6] for boilers and Sect [3.2.3.2] for pressure vessels.

3.3.1.7. Heads Having Pressure on the Convex Side

The minimum thickness of a dished head having pressure on the convex side shall not be less than the thickness calculated by the equation in [3.3.1.1] using $1.67 \times W$, where W is the maximum working pressure on the convex side.

3.3.2. Ellipsoidal Heads

3.3.2.1. Heads with Pressure on the Concave Side

In accordance with the following equation given below, the minimum thickness of a dished head of an ellipsoidal form having pressure on the concave side is to be done:

$$T = \frac{W D K}{2 f S E - 0.2 W} + C$$
$$K = \frac{1}{6} \left[2 + \left(\frac{D}{2h} \right)^2 \right]$$

Where;

D = inside diameter of the head skirt; mm (in.) (Refer Figure 10.3.4-t)

h = inside depth of the head not including the skirt; mm (in.) (Refer Figure 10.3.4-t)

T , W , S , E , C and f are as defined in Sect [3.3.1].

3.3.2.2. Heads with Pressure on the Convex Side

The minimum thickness of a dished head having pressure on the convex side shall not be less than the thickness calculated by the equation in Sect [3.3.2.1] above using $1.67 \times W$, where W is the maximum working pressure on the convex side.

3.3.3. Heads with Access Openings

3.3.3.1. Tori spherically- and Hemi spherically-dished Heads

When a dished head has a manhole or other access opening exceeding 152 mm (6 in.) in any dimension and which is not reinforced as per [3.4] of this section, the head thickness determined using Sect [3.2.1] of this section, is $M = 1.77$, and is required to be increased by 15%, but in no case by less than 3.2 mm (0.125 in.).

3.3.3.2. Ellipsoidal Heads

If a flanged-in manhole is positioned in an ellipsoidal head, the thickness is required to be the same as for a spherically dished head with a dish radius equal to 0.8 of the inner diameter of the shell and with added thickness for the manhole as stated in Sect [3.3.3.1] above.

3.3.3.3. Manhole Flange Depth

A flanged-in manhole opening in a dished head is required to be flanged to a depth of not less than thrice the required thickness of the head for plate up to 38 mm (1.5 in.) in thickness. The depth is to be the required thickness of the plate plus 76 mm (3 in.), for plate exceeding 38 mm (1.5 in.). The flange depth is required to be measured from outside the opening along the major axis.

3.3.3.4. Reinforced Access Openings

When an access opening is reinforced as stated in Sect [3.4.2] of this section, the head thickness may be same as for a blank head.

3.3.4. Unstayed Flat Heads

3.3.4.1. General

The minimum thickness for unstayed flat heads is to conform to the provisions of [3.3.4].

These provisions are applicable to both circular and noncircular heads and covers. Some acceptable types of flat heads and covers are shown in Figure 10.3.4. In this figure, dimensions of the component parts and of the welds are exclusive of extra metal required by corrosion allowance.

3.3.4.2. Definitions of Symbols Used

B = total bolt load, as further defined hereunder; N (kgf, lbf)

C = corrosion allowance, Refer Sect [3.2.2.6] for boilers and Sect [3.2.3.2] for pressure vessels

D = long span of noncircular heads or covers measured perpendicular to short span; m (in.)

d = diameter, or short span, measured as given in Figure 10.3.4, mm (in.)

f = factor = 10 (100, 1) for SI (MKS, US) units, respectively

h_g = gasket moment arm, equal to the radial distance from the center line of the bolts to the line of the gasket reaction, as shown in Figure 10.3.4-j & k; mm (in.)

K = factor depending on the method of attachment of the head; on the shell, pipe or header dimensions; and on other items given in Sect [3.3.4.3 (d)], dimensionless

L = perimeter of noncircular bolted head measured along the centers of the bolt holes; mm (in.)

l = length of flange of flanged heads, measured from the tangent line of knuckle, as given in Figure 10.3.4-a, c-1 & c-2; mm (in.)

$m = t_r/t_s$

S = maximum allowable stress value from Table 10.3.3; N/mm² (kgf/mm², psi)

r = inside corner radius on the head formed by flanging or forging; mm (in.)

t = minimum required thickness of flat head or cover; mm (in.)

t_e = minimum distance from beveled end of drum, pipe or header, before welding, to outer face of head, as indicated in Figure 10.3.4-i; mm (in.)

t_r = actual thickness of the flange on a forged head, at the large end, as indicated in Figure 10.3.4-b-1, mm (in.)

t_h = actual thickness of flat head or cover; mm (in.)

t_i = throat dimension of the closure weld, as given in Figure 10.3.4-r; mm (in.)

t_r = required thickness of seamless shell, pipe or header, for pressure; mm (in.)

t_s = actual thickness of shell, pipe or header; mm (in.)

t_w = thickness through the weld joining the edge of a head to the inside of a drum, pipe or header, as given in Figure 10.3.4-g; mm (in.)

W = maximum allowable working pressure; bar (kgf/cm², psi)

Z = factor for noncircular heads and covers that depends on the ratio of short span to long span, as given in Figure 10.3.4-c.

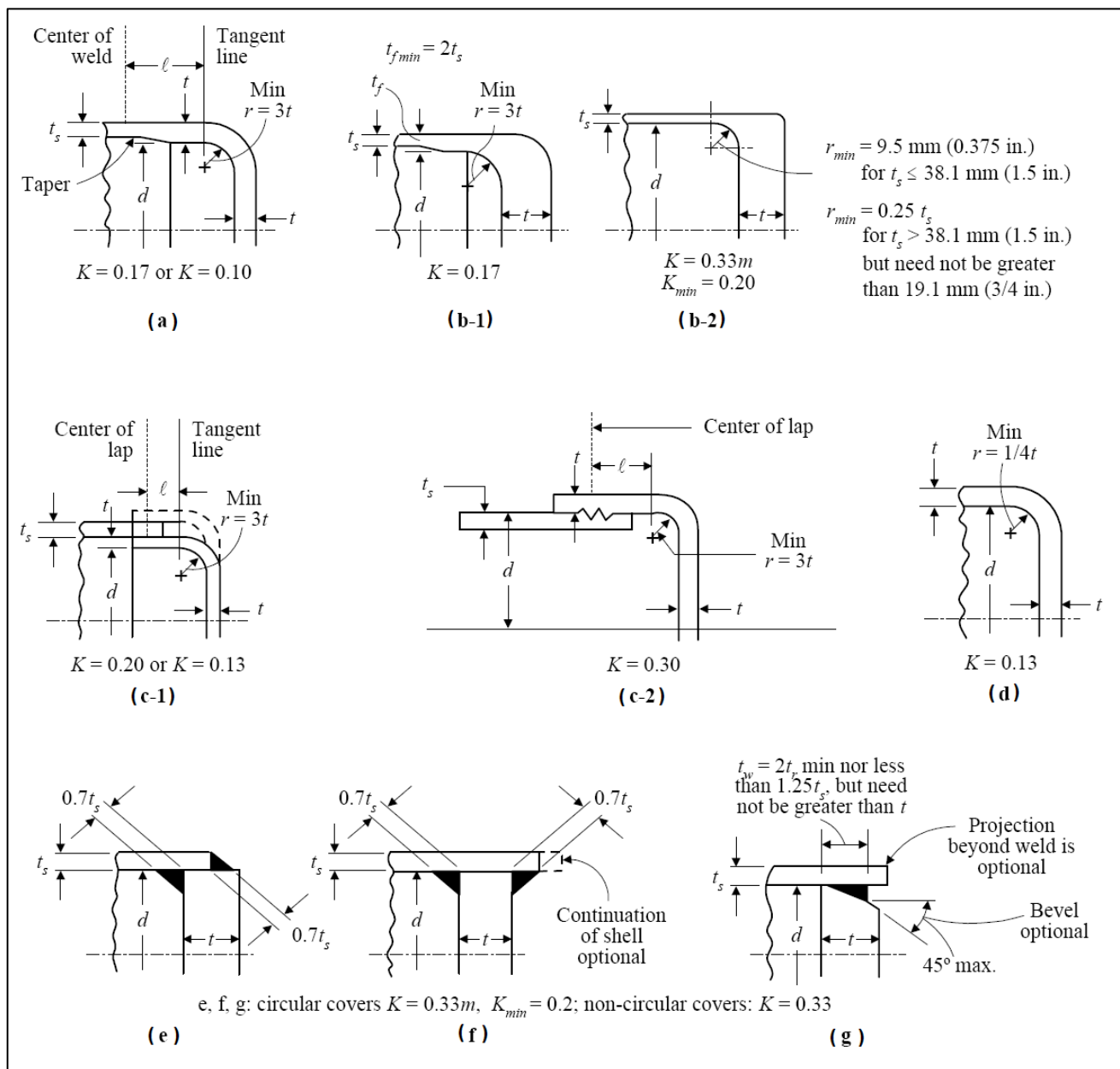


Figure 10.3.4: Acceptable Types of Unstayed Heads and Covers

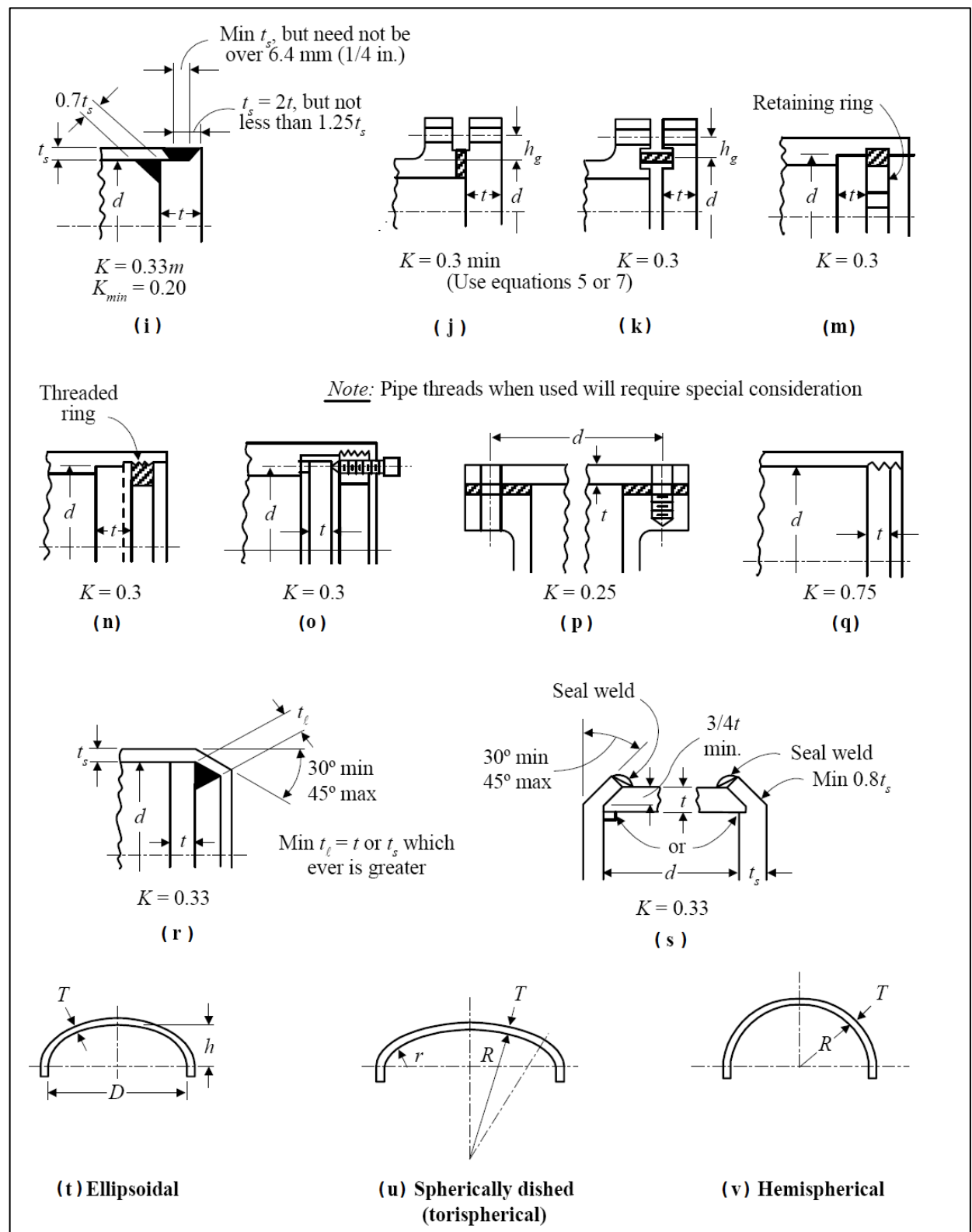


Figure 10.3.4: (continued) Acceptable Types of Unstayed Heads and Covers

3.3.4.3. Equations for Minimum Thickness

To evaluate t minimum required thickness for flat unstayed heads, blind flanges, and covers, following provisions are to be used. The equations in (b) through (d) below allow for only pressure and bolt loading. Greater thickness may be indispensable, provided deflection cause leakage at threaded or gasketed joints.

- a) *Standard blind flanges*. Circular blind flanges of ferrous materials conforming to ANSI B16.5 will be acceptable for the pressure-temperature ratings as specified in the Standard. These flanges are shown in Figure 10.3.4-j & k. Blind flanges conforming to other compatible recognized national or international standards may be submitted for approval.
- b) *Circular heads*. The minimum required thickness of flat unstayed circular heads, covers and blind flanges is to be computed with the help of equation given below:

$$\text{Equation (4):} \quad t = d \sqrt{\frac{K W}{f S}} + C$$

except when the cover, head or blind flange is attached by bolts that causes an edge moment (Refer Figure 10.3.4-j & k), in which case the thickness is to be computed with the help of equation given below:

$$\text{Equation (5):} \quad t = d \sqrt{\frac{K W}{f S} + \frac{1.9 B h_g}{S d^3}} + C$$

While using Equation 5, thickness t is required to be calculated for both design conditions and initial tightening, and the greater of the two values is to be used. The value for S at room temperature shall be used, and B is to be the average of the required bolt load and the load available from the bolt area actually used, for initial tightening conditions. For design conditions, the value for S at design temperature shall be used, and B is to be the sum of bolt loads required to resist the end-pressure load and to maintain gasket's tightness.

- c) *Noncircular heads*. Flat unstayed heads, covers or blind flanges may be square, elliptical, rectangular, obround, segmental or otherwise noncircular. Their required thickness is to be calculated with the help of equation given below:

$$\text{Equation (6):} \quad t = d \sqrt{\frac{Z K W}{f S}} + C$$

$$Z = 3.4 - 2.4 \frac{d}{D} \quad \text{with } Z \leq 2.5$$

except where the noncircular heads, covers, or blind flanges are attached by bolts causing a bolt edge moment (Refer Figure 10.3.4-j & k), where the required thickness is required to be calculated with the help of equation given below:

$$\text{Equation (7):} \quad t = d \sqrt{\frac{Z K W}{f S} + \frac{6 B h_g}{S L d^2}} + C$$

While using Equation 7, the thickness t is to be calculated for both initial tightening and design conditions, as prescribed for Equation 5.

d) *K values*. For the types of construction shown in Figure 10.3.4, the *K* values to be used in Equations 4, 5, 6, and 7 are as follows.

- i) Figure 10.3.4-a: $K = 0.17$ for flanged noncircular and circular heads, forged integral with or butt-welded to the shell, pipe or header. The inside corner radius shall not be less than thrice the required head thickness, with no special requirement with respect to the flange length. Welding is required to meet all of the requirements for circumferential joints as given in Part-2, Ch-3, Sec-3 & Sec 4

$K = 0.10$ for circular heads, when the flange length for heads of the above design is not less than that given in the following equation and the taper is no greater than 1:3:

Equation (8):
$$l = \left(1.1 - \frac{0.8 t_s^2}{t_h^2} \right) \sqrt{d t_h}$$

- ii) Figure 10.3.4-b-1: $K = 0.17$ for noncircular and circular heads, forged integral with or butt-welded to the shell, pipe or header. The corner radius on the inside shall not be less than thrice the flange thickness and welding meets all the requirements for circumferential joints as given in Part-2, Ch-3, Sec-3.
- iii) Figure 10.3.4-b-2: $K = 0.33m$ but not less than 0.20 for forged noncircular and circular heads integral with or butt welded to the vessel, where the flange thickness is not less than the shell thickness and the corner radius on the inside is not less than:

$$r_{\min} = 9.5 \text{ mm (0.375 in.) for } t_s \leq 38.1 \text{ mm (1.5 in.)}$$

$$r_{\min} = 0.25 t_s \text{ for } t_s > 38.1 \text{ mm (1.5 in.) but need not be } > 19.1 \text{ mm (0.75 in.)}$$

The welding is to conform to the requirements for circumferential joints given in Part-2, Ch-3, Sec-3.

- iv) Figure 10.3.4-c-1: $K = 0.13$ for circular heads lap-welded or brazed to the shell with the corner radius not less than $3t$ and l not less than required by Equation 8 and where the welds fulfill the requirements of Part-2, Ch-3, Sec-3 & Sect 4

$K = 0.20$ for noncircular and circular lap-welded or brazed construction as above, but with no special requirement with respect to l .

- v) Figure 10.3.4-c-2: $K = 0.30$ for circular flanged plates screwed over the end of the shell, pipe or header, with the inside corner radius not less than $3t$, in which the design of the threaded joint against failure by shear, tension or compression, resulting from the end force due to pressure, is based on a factor of safety of at least four (4), and the threaded parts are at least as strong as the threads for standard piping of the same diameter. If desired, seal welding may be used.
- vi) Figure 10.3.4-d: $K = 0.13$ for integral flat circular heads when the dimension d does not exceed 610 mm (24 in.), the ratio of thickness of the head to the dimension d is not less than 0.05 nor greater than 0.25, the head thickness t_h , is not less than the shell thickness t_s , the inner corner radius is not less than $0.25t$, and the construction is obtained by special techniques of upsetting and spinning the end of the shell, pipe or header, such as employed in closing header ends.

- vii) Figure 10.3.4-e, *f* & *g*: $K = 0.33m$ but not less than 0.2 for circular plates, welded to the inside of a drum, pipe or header, and otherwise meeting the requirements for the respective types of fusion-welded boiler drums, including stress relieving when required for the drum, but neglecting radiographic examination. If m is smaller than 1, the shell thickness t_s is to extend to a length of at least $2\sqrt{dt}$ from the inside face of the head. The throat thickness of the fillet welds in Figure 10.3.4-e & *f* is to be at least $0.7t_s$. The size of the weld t_w in Figure 10.3.4-g is not to be less than twice the required thickness of a seamless shell nor less than 1.25 times the nominal shell thickness, but need not be greater than the head thickness. The weld is to be deposited in a welding groove with the root of the weld at the inner face of the head as shown in the figure. For any of the weld joints shown in the figure, radiographic examination is not required.

$K = 0.33$ for noncircular plates, welded to the inside of a drum, pipe or header, and otherwise meeting the requirements for the respective types of fusion-welded boiler drums, including stress-relieving when required for the drum, but omitting radiographic examination. The throat thickness of the fillet welds in Figure 10.3.4-e & *f* is required to be at least $0.7t_s$. The size of the weld t_w in Figure 10.3.4-g is not to be less than twice the required thickness of a seamless shell nor less than 1.25 times the nominal shell thickness, but need not be greater than the head thickness. The weld is to be deposited in a welding groove with the root of the weld at the inner face of the head as shown in the figure. For any of the weld joints shown in the figure, radiographic examination is not required.

- viii) Figure 10.3.4-i: $K = 0.33m$ but not less than 0.2 for circular plates welded to the end of the drum, pipe or header, when an inside weld with minimum throat thickness of $0.7t_s$ is used, and when the beveled end of the drum, pipe or header is located at a distance not less than $2t_n$ nor less than $1.25t_s$ from the outer face of the head. The width at the bottom of the welding groove is to be at least equal to t_s , but need not be over 6.4 mm (0.25 in.). For any of the weld joints shown in the figure, radiographic examination is not required.
- ix) Figure 10.3.4-j & *k*: $K = 0.3$ for noncircular and circular heads and covers bolted to the shell, flange or side plate, as shown in the figures. Note that Equation 5 or 7 is to be used because of the extra moment applied to the cover by the bolting. When the cover plate is grooved for a peripheral gasket, as shown in Figure 10.3.4-k, the net cover-plate thickness under the groove or between the groove and the outer edge of the cover plate shall not be less than:

$$d \sqrt{\frac{1.9 B h_g}{S d^3}} \text{ for circular heads and covers,}$$

nor less than

$$d \sqrt{\frac{6 B h_g}{S L d^2}} \text{ for non-circular heads and covers,}$$

- x) Figure 10.3.4-m, *n* & *o*: $K = 0.3$ for a circular plate inserted into the end of a shell, pipe or header, and held in place by a positive mechanical locking arrangement, and when all possible means of failure either by shear, tension, compression or radial deformation, including flaring, resulting from pressure and differential thermal expansion, are resisted with a factor of safety of at least four (4). Seal welding may be used, if required.

- xi) Figure 10.3.4-p: $K = 0.25$ for noncircular and circular covers bolted with a full-face gasket to shells, side plates or flanges.
- xii) Figure 10.3.4-q: $K = 0.75$ for circular plates screwed into the end of a shell, pipe or header, having an inner diameter d not exceeding 305 mm (12 in.); or for heads having an integral flange screwed over the end of a shell, pipe or header, having an inner diameter d not exceeding 305 mm (12 in.); and when the design of the threaded joint against failure by shear, tension, compression or radial deformation, including flaring, resulting from pressure and differential thermal expansion, is based on a factor of safety of at least four (4). A tapered pipe thread will require special consideration. Seal welding may be used, if required.
- xiii) Figure 10.3.4-r: $K = 0.33$ for circular plates having a dimension d not exceeding 457 mm (18 in.), inserted into the shell, pipe or header, and welded as shown, and otherwise meeting the requirements for fusion-welded boiler drums, including stress-relieving but neglecting radiographic examination. The end of the shell, pipe or header, is to be crimped over at least 30° but not more than 45° . It is to be done cold only when this operation will not harm the metal. The throat of the weld is not to be less than flat head thickness or the shell, pipe or header, whichever is greater. For any of the weld joints shown in the figure, radiographic examination is not required.
- xiv) Figure 10.3.4-s: $K = 0.33$ for circular beveled plates with a diameter d not exceeding 457 mm (18 in.), inserted into a shell, pipe or header, the end of which is crimped over at least 30° but not more than 45° , and when the undercutting for seating leaves at least 80% of the shell thickness. The beveling shall not be less than 75% of the head thickness. The crimping is to be done when the entire circumference of the cylinder is uniformly heated to the proper forging temperature for the material used. For this construction, the ratio t_s/d is not to be less than the ratio:

$$\frac{W}{10 S} \left(\frac{W}{100 S}, \frac{W}{S} \right)$$

for SI (MKS, US) units, respectively, nor less than 0.05.

The maximum allowable working pressure, W , for this construction should not exceed:

$$\frac{50.8 S}{d} \left(\frac{508 S}{d}, \frac{S}{5d} \right)$$

for SI (MKS, US) units respectively.

For any of the weld joints shown in the figure, radiographic examination is not required.

3.3.5. Stayed Flat Heads

3.3.5.1. General

Flat plates such as heads or parts thereof, furnace plates, wrapper sheets, side sheets, combustion chamber plates, tube plates, etc., along with curved plates with pressure on the convex side which are not self-supporting are the surfaces which require to be stayed. In stayed surface construction, no plates less than 7.9 mm (5/16 in.) in thickness are to be used.

3.3.5.2. Plates Supported by Stay Bars

In accordance with the following equation, the required minimum thickness of plates supported by stay bars is required to be determined:

$$T = p \sqrt{\frac{K W}{f S}}$$

Where;

T = minimum thickness of the plate; mm (in.)

p = maximum pitch measured between the centers of stays in different rows, which may be horizontal and vertical, or radial and circumferential; mm (in.)

W = maximum working pressure; bar (kgf/cm², psi)

f = factor = 10 (100, 1) for SI (MKS, US) units, respectively

S = maximum allowable working stress; N/mm² (kgf/mm², psi)

K = factor that depends on the kind of service to which plate is subjected and its method of construction, as given below:

i) For plates exposed to products of combustion:

K	=	0.23	for plates under 11.1 mm (7/16 in.)
	=	0.22	for plates 11.1 mm (7/16 in.) and over
	=	0.21	for plates under 11.1 mm (7/16 in.) reinforced by doubling strips, the width of the doubling strip to be not less than 2/3 of the maximum pitch of the stays and the thickness is to be not less than 2/3 of the thickness of the plate
	=	0.20	for plates 11.1 mm (7/16 in.) and over reinforced by doubling strips, the width of the doubling strip to be not less than 2/3 of the maximum pitch of the stays and the thickness is to be not less than 2/3 of the thickness of the plate

ii) For plates not exposed to products of combustion:

K	=	0.20	for plates under 11.1 mm (7/16 in.)
	=	0.19	for plates 11.1 mm (7/16 in.) and over
	=	0.18	for plates under 11.1 mm (7/16 in.) reinforced by doubling strips, the width of the doubling strip to be not less than 2/3 of the maximum pitch of the stays and the thickness is to be not less than 2/3 of the thickness of the plate
	=	0.17	for plates 11.1 mm (7/16 in.) and over reinforced by doubling strips, the width of the doubling strip to be not less than 2/3 of the maximum pitch of the stays and the thickness is to be not less than 2/3 of the thickness of the plate

3.3.5.3. Plates Supported by Stay Tubes

The required minimum thickness of plates supported by stay tubes is to be determined with the help of equation given below:

$$T = p \sqrt{\frac{K W}{f S} \left(p^2 - \frac{\pi}{4} d_o^2 \right)}$$

Where;

d_o = outside diameter of the tube; mm (in.)

T, p, K, W, f and S are as defined above.

3.3.5.4. Tube Plates Subjected to Compressive Stresses

For flat tube plates with the ligaments subjected to compressive stresses, such as tube plates of combustion chambers with the tops supported by girders, the required minimum thickness of plates is to be determined with the help of equation given below:

$$T = \frac{LPW}{2 f S (P - d)}$$

Where;

L = total length of the combustion chamber over the tube plate and back sheet, mm (in.)

P = least horizontal pitch of tubes, mm (in.)

d = inside diameter of plain tube, mm (in.)

T, W, S and f are as defined above.

3.3.5.5. Stays

The required minimum cross sectional area of stays is to be determined with the help of equation given below:

$$A_r = \frac{1.1 A W}{f S}$$

Where;

A_r = required cross sectional area of stay, mm² (in²)

A = area supported by the stay, mm² (in²)

W = maximum working pressure, bar (kgf/cm², psi)

f = factor = 10 (100, 1) for SI (MKS, US) units, respectively

S = maximum allowable working stress, N/mm² (kgf/mm², psi)

3.4. Openings and Reinforcements

3.4.1. General

3.4.1.1. Application

The following is applicable to all openings in shells, headers or heads, except those provided in Sect [3.4.1.2] below. The reinforcement requirements apply to openings not exceeding the following dimensions.

- For shells 1525 mm (60 in.) diameter or less, 1/2 the shell diameter but not over 508 mm (20 in.).
- For shells over 1525 mm (60 in.) diameter, 1/3 the shell diameter but not over 1016 mm (40 in.).

For specific approval, reinforcement of larger openings is to be submitted.

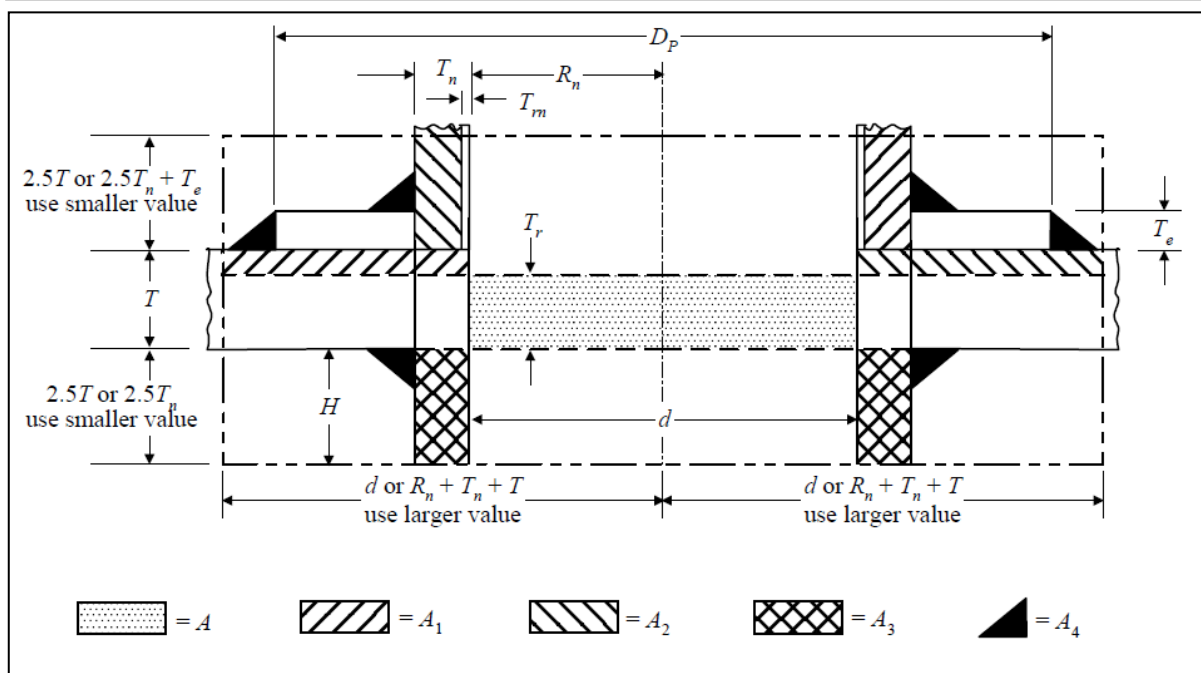


Figure 10.3.5: Example of Reinforced Opening

Without Reinforcing Element (refer Fig. 10.3.5)

$$A = d \times Tr \times F$$

$$A1 = (ET - FTr)(d - Rn)2 = (ET - FTr)d$$

or

$$= (ET - FTr)(Rn + Tn + T - Rn)2 = (ET - FTr)(Tn + T)2$$

$$A2 = (Tn - Trn)2.5T \times 2 = (Tn - Trn)5T$$

or

$$= (Tn - Trn)2.5Tn \times 2 = (Tn - Trn)Trn5Tn$$

$$A3 = (Tn)2H$$

A4= Area of welds

If $A1 + A2 + A3 + A4 \geq A$

If $A1 + A2 + A3 + A4 < A$

With Reinforcing Element (refer Fig. 10.3.5)

A1, A2, A3, A4 are same as for without reinforcing element.

2.5Tn is measured from the top surface of the reinforcing element.

A2 becomes the smaller of $(Tn - Trn)5T$ or $(Tn - Trn)(5Tn - 2Te)$.

Area of reinforcing element = $(Dp - d - 2Tn)Te = A5$

If $A1 + A2 + A3 + A4 + A5 \geq A$ opening is adequately reinforced.

3.4.1.2. Openings in Definite Pattern

Openings in a definite pattern such as tube holes may be designed as for the requirements of Sect [3.2.2.5], provided the largest hole in the group does not exceed that allowed by the equations given below.

$$d = 8.08 \times \sqrt[3]{DT(1 - K)} \text{ mm}$$

or

$$d = 2.75 \times \sqrt[3]{DT(1 - K)} \text{ in}$$

subject to the following:

- i) $d \leq 203 \text{ mm (8 in.)}$
- ii) $K = \frac{W D}{1.6 f S T}$ when design with 0.8 of S value from Table 10.3.3
- iii) $K = \frac{W D}{1.82 f S T}$ when design with actual S values from Table 10.3.3
- iv) if $DT > 129,000 \text{ mm}^2 \text{ (200 in}^2\text{)}$, use $DT = 129,000 \text{ mm}^2 \text{ (200 in}^2\text{)}$

When;

d = maximum allowable diameter of opening; mm (in.)

T = thickness of plate; mm (in.)

S = maximum allowable working stress from Table 10.3.3; N/mm² (kgf/mm², psi)

D = outside diameter of shell; mm (in.)

W = maximum working pressure; bar (kgf/cm², psi)

f = factor = 10 (100, 1) for SI (MKS, US) units, respectively

Also refer to [3.4.6.3] for reinforcement between tube holes.

3.4.1.3. Calculations

Calculations demonstrating conformation to Sect [3.4.2] below are to be made for all openings, except:

- i) Where there are single openings in the headers or shell with the diameter of the opening less than that allowed by the equation in [Sect 3.4.1.2] above, or
- ii) Where single openings of not larger than 50 mm (2 in.) nominal pipe size are made in headers or shells having an inner diameter not less than four times diameter of the opening.

Tube holes arranged in a definite pattern are also to conform to Sect [3.4.2] below when the tube hole diameter is greater than that allowed by the equation in Sect [3.4.1.2] above.

3.4.1.4. Openings in or Adjacent to Welds

Any opening allowed in these Rules may be positioned in a welded joint that has been stress relieved and radiographed.

3.4.2. Reinforcement Requirements

3.4.2.1. Shells and Formed Heads

Reinforcement is to be provided in such an amount and distribution that the area requirements for reinforcement are fulfilled for all planes through the center of the opening and normal to the vessel surface. In any given plane, total cross-sectional area of reinforcement is not to be less than attained with the help of equation given below:

$$A = F \times d \times T_r$$

Where;

A = required reinforcement (Refer Figure 10.3.6); mm² (in²)

F = a correction factor which compensates for the pressure variation in stresses on different planes with respect to the vessel axis. A value of 1.0 is to be used provided the chosen plane housing the opening (or the nozzle) axis concurs with the longitudinal axis of the vessel. Otherwise, values of F are to be as given in Figure 10.3.6.

d = diameter of the finished opening in the given plane; mm (in.)

T_r = the minimum required thickness, exclusive of the corrosion allowance, C , of a seamless shell, header, formed head or flat head, as calculated by formulas given in Sections [3.2.1], [3.3.1], [3.3.2], or [3.3.4] of this section as appropriate, using $E = 1$; mm (in.), except for following:

- for dished heads when the opening and its reinforcement are completely within the spherical portion, T_r is the thickness exclusive of the corrosion allowance required by the equation given in [3.3.1] using $M = 1$; and
- for elliptical heads as defined in Sect [3.3.2] when the opening and its reinforcement are positioned entirely within a circle, the center of which coincides with the center of the head and the diameter of which is 0.8 of the inside shell diameter, T_r is the thickness, exclusive of the corrosion allowance required by the equation given in Sect [3.3.1] using $M = 1$ and $R = 0.9$ of the inside diameter of the shell

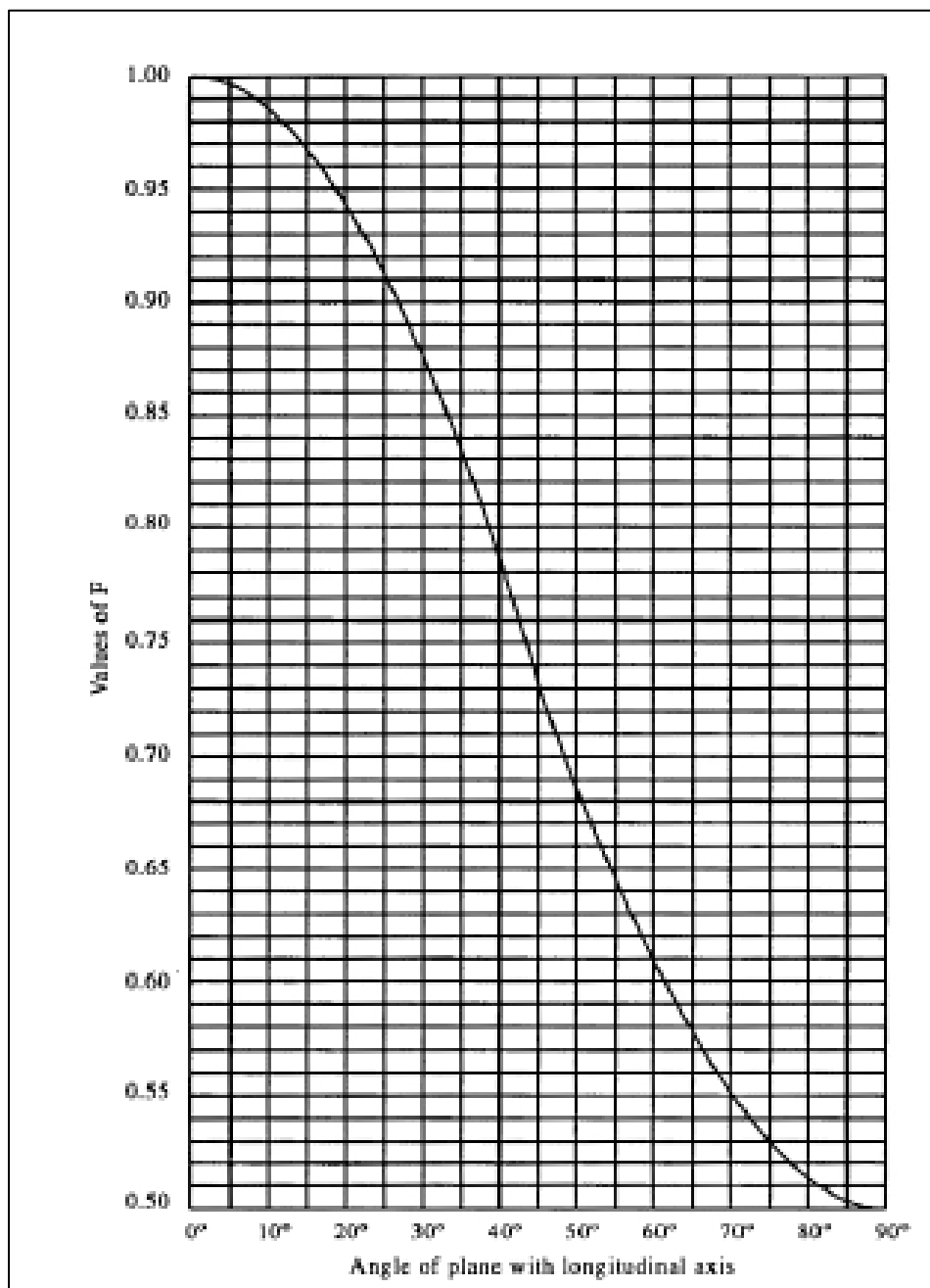


Figure 10.3.6: Chart for Determining Value of F

3.4.2.2. Flat Heads

Flat heads with an opening of a diameter that does not exceed 1/2 of the head diameter, or shortest span, should have a total cross-sectional area of reinforcement i.e. not less than that given by:

$$A = 0.5 \times d \times T$$

Where;

A = required reinforcement; mm² (in²)

d = diameter of the finished opening in the given plane; mm (in.)

T = minimum required thickness of plate, exclusive of corrosion allowance, as determined from Sect [3.3.4]; mm (in.)

Alternatively, the flat heads thickness may be increased to provide the required reinforcement using $2K$ in Equations 4 and 6 given in [3.3.4.3] though the value of $2K$ to be used in the equations need not exceed 0.75. For the types of construction mentioned in Figure 10.3.4-j & k, the quantity under the square-root of Equations 5 and 7 given in sect [3.3.4.3] is to be doubled. Flat heads that have an opening with a diameter that exceeds 1/2 of the head diameter, or shortest span, are required to be designed as a flange as per bolted flange-connection practice.

3.4.3. Reinforcement Limits

Within the reinforcement limits as specified below, metal in the vessel and nozzle walls, exclusive of corrosion allowance, over and above the thickness required to resist pressure may be considered as reinforcement.

3.4.3.1. Limits Along Wall

The limits of reinforcement measured along the vessel wall are required to be at a distance on each side of the axis of the opening (or nozzle) equal to the greater of the following requisites:

- i) The radius of the finished opening plus the vessel wall thickness plus the nozzle wall thickness
- ii) The diameter of finished opening.

3.4.3.2. Limits Normal to Wall

The limits of reinforcement measured normal to the pressure vessel wall should be parallel to the contour of the vessel surface and at a distance from each surface equal to the smaller of the following requisites:

- i) 2.5 times the shell thickness
- ii) 2.5 times the nozzle wall thickness, plus the thickness of any added reinforcement exclusive of the weld metal on the side of shell under consideration

3.4.4. Metal Having Reinforcement Value

3.4.4.1. Reinforcement Available in Vessel Wall

Within the reinforcement limits given in Sect [3.4.3], metal in the vessel wall, exclusive of corrosion allowance, over and above the thickness required to resist pressure may be considered as reinforcement. The cross-sectional area of the vessel wall i.e. available as reinforcement is the larger of the A_1 values as given in the following equations.

$$A_1 = (ET - FT_r)d$$

$$A_1 = 2(ET - FT_r)(T + T_n)$$

Where;

A_1 = area in the excess thickness in the vessel wall available for reinforcement;
mm² (in²)

E = weld joint efficiency, to be taken as:

- The longitudinal weld joint efficiency when any part of the opening passes through a longitudinal weld joint; or
- 1.0 when the opening is made in the seamless plate or when the opening passes through a circumferential joint in a shell (exclusive of head to shell joints)

T = thickness of the vessel wall, less corrosion allowance; mm (in.)

T_r = the minimum required thickness of a seamless shell or head as defined in [3.4.2.1]

T_n = thickness of the nozzle wall, exclusive of corrosion allowance; mm (in.)

d = diameter of the finished opening (or internal diameter of the nozzle) less corrosion allowance, in the plane under consideration; mm (in.)

F = a factor, as defined in Sect [3.4.2.1]

3.4.4.2. Reinforcement Available in Nozzles

- a) *Nozzles extending outside the vessel.* The nozzle wall, exclusive of corrosion allowance, over and above the thickness required to resist pressure, and in that part of the nozzle extending outside the pressure vessel wall, may be considered as reinforcement within the reinforcement limits as given in Sect [3.4.3]. The maximum area on the nozzle wall available as reinforcement is the smaller of the values of A_2 given by the following equations.

$$A_2 = (T_n - T_m)5T$$

$$A_2 = (T_n - T_m)(5T_n + 2T_e)$$

Where;

A_2 = area of excess thickness in the nozzle wall available for reinforcement;
mm² (in²)

T_m = the minimum required thickness of a seamless nozzle wall, excluding corrosion allowance, found by the equation used for T_r for shell; mm (in.)

T = thickness of vessel wall, less corrosion allowance; mm (in.)

T_e = thickness of reinforcing element; mm (in.)

T_n = thickness of nozzle wall, exclusive of the corrosion allowance; mm (in.); which is not to be less than the smallest of the following:

- Thickness of standard-wall pipe; or
- The required minimum thickness of the seamless shell or head;
- The required minimum thickness of a pipe based on 41.4 bar (42.2 kgf/cm², 600 psi) internal pressure.

- b) *Nozzles extending inside the vessel.* All metal except corrosion allowance in the nozzle wall that extends inside the pressure vessel and within the reinforcement limits specified in [3.4.3] may be included as reinforcement.

3.4.4.3. Added reinforcement

Metal in attachment welds, provided they are within the reinforcement limits, and metal added as reinforcement may be included as reinforcement.

3.4.5. Strength of Reinforcement

3.4.5.1. Material Strength

Generally, material used for reinforcement is to have an allowable stress value greater than or equal to that of the material in the vessel wall. Where material of lower strength is used, available area for reinforcement is to be proportionally reduced by the ratio of the allowable stresses. However, no credit is to be taken for the additional strength of any reinforcement with a higher allowable stress than the vessel wall. Deposited weld metal i.e. used as the reinforcement is assumed to have an allowable stress value equal to weaker of the materials connected by the weld.

3.4.5.2. Required Strength of Nozzle Attachment Weld

In the plane normal to the vessel wall and that passes through center of the opening, strength of the weld that attaches the nozzle and reinforcement element to the vessel wall is to be equal to the smallest from among the following:

$$V = d \times T_r \times S$$

$$V = [d_u T_r - (2d - d_u)(T - T_r) + A_s] S$$

$$V = [d_u T_r - 2 T (T - T_r) + A_s] S$$

Where;

V = required strength (through load-carrying paths; Refer e.g. given in, Figure 10.3.7 to be provided by weldment or by the combination of weldment and nozzle wall to resist shear from pressure loading; N (kgf, lbf)

d_u = diameter of the unfinished opening prior to nozzle installation; mm (in.)

S = allowable stress of the vessel wall material from Table 10.3.3; N/mm² (kgf/mm², psi) d, T_r , T are as defined in Sect [3.4.4.1].

A_s = total stud hole cross-section area where stud holes are tapped into the vessel wall; mm² (in²)

3.4.5.3. Calculating the Strength of Attachment Weld

Adequate welding is to be deposited to develop the strength (through load-carrying paths, Refer Figure 10.3.7) of the reinforcing parts through shear or tension in the weld and nozzle wall, as applicable. The combined strength of the weld or nozzle wall or both, as applicable, is to be calculated and shall not be less than the value of V specified in Sect [3.4.5.2] above. The weld shear areas to be used in the calculation are to be as per the following provisions:

- i) The groove welds strength is to be based on half of the area subjected to shear, as applicable, and that is calculated with help of the minimum weld depth dimension at the line of load-carrying path in the direction under our consideration. The diameter of the weld is to be taken as the inside diameter of the weld when calculating path number 3 (Refer Figure 10.3.7), or the mean diameter of the weld while calculating path number 1 or 2 (Refer Figure 10.3.7).
- ii) The fillet weld strength is to be based on half of the area subject to shear, computed on the inside diameter of the weld while calculating path number 3, or the mean diameter of the weld when calculating path number 1 or 2, by using weld leg dimension in the direction under consideration.

The allowable stress values for fillet welds and groove and for shear in nozzle necks, in stress value percentages for the vessel material, are as given below:

Nozzle wall shear	70%
Groove weld tension	74%
Groove weld shear	60%
Fillet weld shear	49%

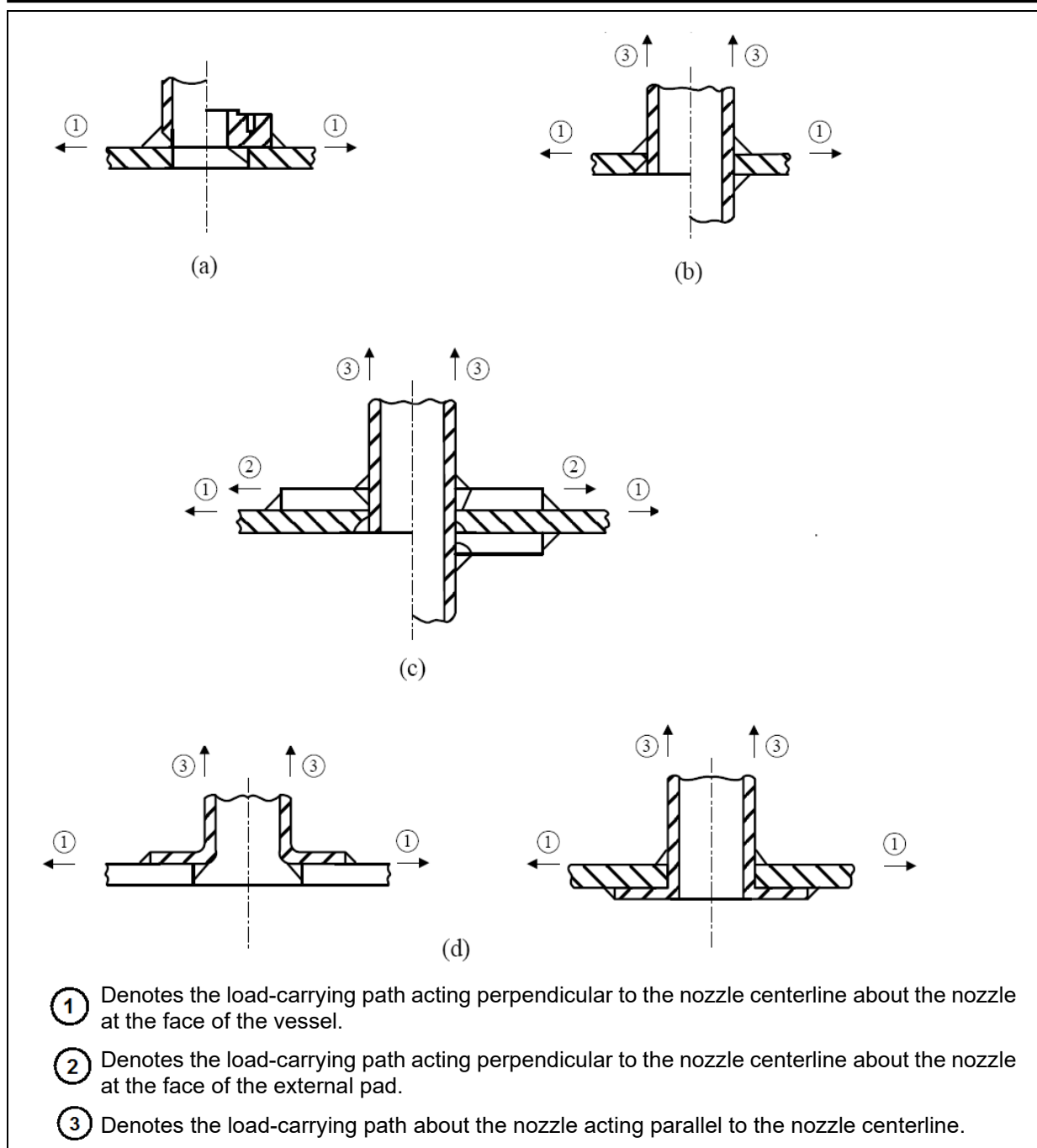


Figure 10.3.7: Load-carrying Paths in Welded Nozzle Attachments

3.4.6.Reinforcement of Multiple Openings

3.4.6.1. Spacing of Openings

The distance between centers of two adjacent openings is not to be less than $1\frac{1}{3}$ times their average diameter.

3.4.6.2. Reinforcement Overlapping

When adjacent openings are spaced in such a manner that their limits of reinforcement overlap, opening is to be reinforced as per Sect [3.4.2] with a reinforcement should have an area equal to the combined area of the reinforcement required for the separate openings. No portion of the cross section is to apply to more than one opening or be evaluated more than once in a combined area.

3.4.6.3. Reinforcement of Holes Arranged in a Definite Pattern

When a series of holes in a definite pattern is there in a shell, the net cross-sectional area between any two finished openings within the limits of the actual shell wall, except the reinforcing part not fused to the shell wall, is to be equal to at least $0.7F$ of the cross-sectional area obtained by multiplying the center-to-center distance of the openings by T_r , the required thickness of a seamless shell, where the factor F is taken from Figure 10.3.6 for the plane under consideration.

Illustration of these requirements is shown in Figure 10.3.8.

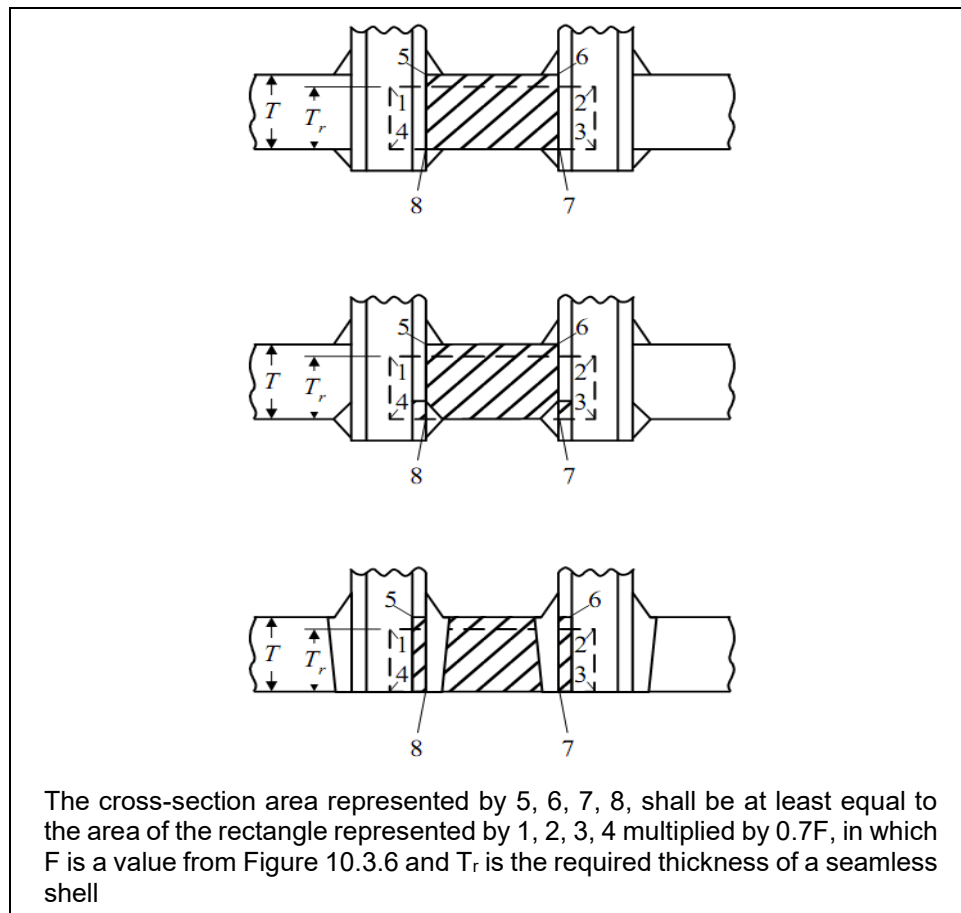


Figure 10.3.8: Illustration of Rules Given in [3.4.6.3] of this section

3.5. Boiler Tubes

3.5.1. Materials

Tubes for super heaters, water-tube boilers and other parts of a boiler are required to be of electric-resistance-welded tubing or seamless steel, where subjected to internal pressure.

3.5.2. Maximum Allowable Working Pressure

The maximum allowable working pressure and the minimum required thickness are to be as per the equations given below:

$$W = f S \left[\frac{2T - 0.01D - 2e}{D - (T - 0.005D - e)} \right]$$

$$T = \frac{W D}{2 f S + W} + 0.005 D + e$$

Where;

D = outside diameter of tube; mm (in.)

W = maximum working pressure; bar (kgf/cm², psi)

T = minimum thickness of tube wall; mm (in.)

S = maximum allowable working stress; N/mm² (kgf/mm², psi); at not less than the maximum expected mean wall temperature, m , of the tube wall, which in no case is taken less than 371°C (700°F) for tubes absorbing heat. For tubes not absorbing heat, the wall temperature may be taken as the temperature of the fluid within the tube, but not less than the saturation temperature. Table 10.3.3 gives appropriate values of S

m = sum of outside and inside surface temperatures divided by 2

e = 1 mm (0.04 in.) over a length at least equal to the length of the seat plus 25 mm (1 in.) for tubes expanded into tube seats, Refer [3.5.3] below.

= 0 for tubes strength-welded to headers and drums

f = factor for units of measure, 10 (100, 1) for SI (MKS, US) units, respectively.

3.5.3. Tube-end Thickness

The thickness of the ends of tubes strength-welded to headers or drums need not be made greater than the run of tube as determined from Sect [3.5.2] above. However, the thickness of tubes shall not be less than the minimum thickness required by Sect [3.5.2] above for each diameter for which a working pressure is tabulated, where expanded into headers or drums. The minimum thickness of tubes or nipples for expanding into tube seats may be calculated from Sect [3.5.2] above with e equal to zero, if the thickness at the tube ends to be expanded is made minimum of:

- i) 2.40 mm (0.095 in.) for tubes 32 mm (1.25 in.) outside diameter.
- ii) 2.67 mm (0.105 in.) for tubes more than 32 mm (1.25 in.) outside diameter and up to 51 mm (2 in.) outside diameter inclusive.
- iii) 3.05 mm (0.120 in.) for tubes more than 51 mm (2 in.) outside diameter and up to 76 mm (3 in.) outside diameter inclusive.
- iv) 3.43 mm (0.135 in.) for tubes more than 76 mm (3 in.) outside diameter and up to 102 mm (4 in.) outside diameter inclusive.
- v) 3.81 mm (0.150 in.) for tubes more than 102 mm (4 in.) outside diameter and up to 127 mm (5 in.) outside diameter inclusive.

3.5.4. Tube-end Projection

The ends of the tubes and nipples used in water-tube boilers project through the tube plate or header, at not less than 6.4 mm (0.25 in.) nor at more than 19 mm (0.75 in.). They get expanded in the plate and then either becomes bell-mouthed or beaded. Where tubes are to be attached to tube sheets via welding, its details are to be submitted for approval.

3.6. Welded Joints and Tests**3.6.1. Joint Designs**

Welded joints are to be designed as specified in Part-2, Ch-3, Sec-3, [3.3]

3.6.2. Joint and Dimensional Tolerances

Joint and dimensional tolerances are to be as specified in Part-2, Ch-4, Sec-4, [4.14].

3.6.3. Weld Tests

Welding procedure and welder/welding operator qualification tests are to be as specified in Part-2, Ch-3, Sec-4[4.6] Sect 3[3.2].

3.6.4. Radiography and Other Nondestructive Examination

Radiography of butt-welded seams is to be as specified in Part-2, Ch-3, Sec-2/ [2.12].

3.6.5. Preheat and Post weld Heat Treatment

Preheat and post weld heat treatments are to be as specified in Part-2, Ch-3, Sec-2/ [2.6] through [2.11].

3.6.6. Hydrostatic Tests**3.6.6.1. Boilers**

All completed boilers (after all required nondestructive examination and after post weld heat treatment) are required to be subjected to a hydrostatic test at not less than 1.5 times the design pressure or the maximum allowable pressure (the pressure to be stamped on the nameplate is to be used) in the Surveyor's presence. The pressure gauge used in the test is to have a maximum scale of about two times the test pressure, but in no case it is to be less than 1.5 times the test pressure. After the hydrostatic test, the test pressure may be reduced to the design or the maximum allowable working pressure, and the Surveyor inspects all joints and connections.

3.6.6.2. Pressure Vessels

All completed pressure vessels (after required non-destructive examination and post weld heat treatment are complete) are to be subjected to a hydrostatic test at not less than 1.3 times the design pressure or the maximum allowable pressure (the pressure to be stamped on the nameplate is to be used) in the Surveyor's presence. The pressure gauge used in the test shall have a maximum scale of about two times the test pressure, but in no case that is to be less than 1.3 times the test pressure. After the hydrostatic test, the test pressure may be reduced to the design or the maximum allowable working pressure, and the Surveyor inspects all joints and connections.

SECTION 4 FABRICATION, TESTING AND CERTIFICATION

Contents

4.1. Material Tests 525

4.2. Welded Fabrication..... 525

4.3. Dimensional Tolerances 525

4.4. Non-destructive Examination 525

4.5. Preheat and Postweld Heat Treatment 525

4.6. Hydrostatic Tests 525

4.7. Manufacturer’s Documentation 525

4.1. Material Tests

Material tests are to be done in line with Sec-2, [2.3].

4.2. Welded Fabrication

Welding of pressure parts and non-pressure parts to pressure parts is to be executed using qualified welding procedures and by qualified welders. The qualification of welding procedures is to be done as per provisions of Part-2, Ch-3, Sec-4 or the applicable pressure vessel or boiler standard or code. Welding procedure specifications and qualification records are to be presented for review purpose as given in Sec-1/ [1.7.5]. There is provision that Surveyor can witness the qualification test, and may also request additional qualification tests if there are enough reasons to doubt the qualified procedure. The qualification of welders is to be as per the applicable code and the attending Surveyor's satisfaction.

4.3. Dimensional Tolerances

Parts which are to be welded are to be aligned within the tolerances specified in Part-2, Ch-4, Sec-4/[4.14] or the applicable standard or code. Surveyor examines the fitting of the main seams prior to welding. The formed heads are to conform to the theoretical shape and the out-of-roundness of the finished shells are to be within specified dimensional tolerances and that is to be verified to the Surveyor's satisfaction.

4.4. Non-destructive Examination

Radiographic examinations are to be as specified in Part-2, Ch-3, Sec-2/ [2.12] or the applicable standard or code. All Group I pressure vessels and boilers are to have their butt seams fully radiographed. Refer to Sec-1/[1.5]. Group II pressure vessels are to be radiographed to the extent, as required by the designed joint-efficiency. The radiography standard and acceptance criteria and the extent of other non-destructive examination, such as dye penetrant, ultra-sonic, or magnetic particle, are to be in line with the chosen standard or code. For review by the Surveyor, radiographic films are to be submitted.

4.5. Preheat and Postweld Heat Treatment

Preheat and postweld heat treatments are to be in line with specifications given from Part-2, Ch-3, Sec-2, [2.6.] to [2.11] or the applicable standard or code. All Group I pressure vessels and boilers are to be postweld heat treated. Refer to Sec-1/ [1.5]. Besides, post weld heat treatment is to be done where required and as per the applicable pressure vessel or boiler code or standard. Its procedural details are to be submitted to the Surveyor for review before the heat treatment is given.

4.6. Hydrostatic Tests**4.6.1. Boilers**

The attending Surveyor is to witness hydrostatic tests on all boilers. It is to be taken care of that the test pressure is not less than 1.5 times the maximum allowable working pressure or pressures specified by the standard or code of compliance.

4.6.2. Pressure Vessels

The attending Surveyor is to witness hydrostatic tests on all pressure vessels. The test pressure shall not be less than 1.3 times the maximum allowable working pressure or at such pressures as specified by the standard or code of compliance. The cases where hydrostatic tests are not feasible, alternative pressure test methods, such as a pneumatic pressure test, may be considered, subject to such test procedures being submitted for consideration.

4.7. Manufacturer's Documentation

For final review by the attending Surveyor, all the required documentation of fabrication records is submitted by the manufacturer. It includes but is not restricted to material certificates, welder qualification records, welding procedure qualification records, heat treatment reports, non-destructive examination reports and dimensional check reports, as applicable.

SECTION 5 BOILER ACCESSORIES

Contents

5.1. Safety Valves.....	527
5.2. Permissible Valve Connections on Boilers.....	529
5.3. Steam and Feed Valves	530
5.4. Instrument Connections for Boilers	530
5.5. Miscellaneous Connections.....	531
5.6. Inspection of Openings.....	532
5.7. Dampers	532
5.8. Guidance for Spare Parts	532
5.9. Additional Requirements for Shell Type Exhaust Gas Economizers	532

5.1. Safety Valves**5.1.1. General**

- a) *Boiler.* Each steam generator and boiler (including exhaust gas boiler) is to be fitted with at least one safety valve and where the water-heating surface is more than 46.5 m² (500 ft²), two or more safety valves are to be provided. As far as feasible, the valves are to be of equal size and their aggregate relieving capacity shall not be less than the evaporating capacity of the boiler under extreme operating conditions. However, in none of the cases, the inlet diameter of any safety valve for propulsion boiler and superheaters used to generate steam for main propulsion and other machinery to be less than 38 mm (1.5 in.) nor more than 102 mm (4 in.). The inlet diameter of the safety valve must not be less than 19 mm (3/4 in.) nor more than 102 mm (4 in.), for auxiliary boilers and exhaust gas economizers.
- b) *Superheater.* Whether or not the superheater can be isolated from the boiler, it is to be fitted with at least one safety valve on the outlet. Also refer to Sect [5.1.2](b).
- c) *Economizers.* These, where fitted with a bypass arrangement, is to be provided with a sentinel relief valve, unless that arrangement is capable of preventing buildup of pressure inside it when it is bypassed.

5.1.2. Minimum Relieving Capacity

- a) *Boiler.* The relieving capacity of safety valves located on a boiler that is determined on the basis of the water-wall heating surface and boiler heating surface along with the fuel-burning equipment, shall not be less than that given in the Table 10.5.1. Where the boiler manufacturer's certification pertaining to the evaporative capacity of the boiler under extreme operating conditions indicates a higher capacity, it is to be used.

Table 10.5.1:

Minimum mass of steam per hour per heating surface area of oil-fired boilers, kg/h/m² (lb/h/ft²)		
Boiler Type	Boiler Heating Surface	Waterwall Surface
Fire-tube	39.1 (8)	68.3 (14)
Water-tube	48.8 (10)	78.1 (16)

- b) *Boilers with integral superheaters.* Where there is no intervening valve between the superheater and the boiler and a superheater is fitted as an integral part of a boiler, the relieving capacity of the superheater safety valve, based on the reduced pressure, may be included in determining the total relieving capacity of the safety valves for the whole boiler. In such a case, the relieving capacity of the superheater safety valve is not to be credited for more than 25% of the total capacity required. Under any relieving condition, the safety valves are to be so set that enough steam pass through the superheater to prevent its overheating. For this purpose, specially designed full-flow superheater valves that are pilot-operated from the steam drum may be used.
- c) *Exhaust gas boiler.* Manufacturer is to determine the minimum required relieving capacity of the safety valve. The relieving capacity is to take into consideration whether auxiliary firing is intended in combination with exhaust gas heating or only as an alternative to exhaust gas heating. In the latter case, the relieving capacity is to be based on the higher of the two.
- d) *Pressure rise during relieving.* The total capacity of safety valves installed in each boiler is to be such that all steam that can be generated by the boiler is expelled without allowing the pressure to rise by more than 6% above the maximum allowable working pressure. Refer to Sect [5.1.8].

5.1.3. Pressure Settings

- a) *Boiler drum.* One safety valve located on the boiler drum is to be at least set at or below the maximum allowable working pressure. If there are more safety valves installed on the boiler drum, the highest setting of the safety valves is not to go exceed by more than 3% of the maximum allowable working pressure. For all the drum safety valves, the range of pressure settings is not to exceed 10% of the highest pressure to which any safety valve is set.

In none of the cases, the relief pressure is to be greater than the design pressure of the steam piping or that of the machinery connected to the boiler plus the pressure drop in the steam piping.

- b) *Super heater.* The super heater safety valve is to be so set that it relieves at a pressure not greater than the design pressure of the steam piping or machinery connected to the super heater plus pressure drop in the steam piping. In none of the cases, super heater safety valves are set at a pressure greater than its design pressure.

With respect to the super heater, safety valves located on the boiler drum are to be set at a pressure not less than that at which super heater-valve are set at, plus 0.34 bar (0.35 kgf/cm², 5 psi), and approx. the normal-load pressure drop through the super heater. Also refer to (a).

5.1.4. Easing Gear

Each super heater and boiler , safety valve is to be fitted with proficient mechanical mechanism with help of which the valve disc may be positively lifted from its seat. This is to be ensured that mechanism is so arranged that the valves may be safely operated either by hand or any approved power arrangement from the boiler room or machinery space platforms.

5.1.5. Connection to Boiler

Boiler and safety valves are to be directly connected, except that they may be mounted on a common fitting; refer to [5.2]. However, there is no need to mount them on the same fitting as that for the main or auxiliary steam outlet. Also, this does not apply to super heater safety valves, which may be mounted on the super heater steam outlet fitting.

5.1.6. Escape Pipe

The minimum escape pipe area is to be at least equal to the combined outlet area of all the safety valves discharging into it. Moreover, it is to be so routed that the condensate is not accumulated and so supported that its body is not subjected to undue load or moment.

5.1.7. Drain Pipe

The drain pipes leading to the bilges or an appropriate tank are to be fitted on all the safety valve chests but no valve or cock is to be fitted in the drain pipe itself.

5.1.8. Pressure Accumulation Test

By means of pressure accumulation tests, safety valves are to be tested after they are set under steam in the presence of the Surveyor. The boiler pressure is not to rise over 6% above the maximum allowable working pressure when the steam stop valve is closed under full firing condition for 15 minutes in case of fire tube boilers and 7 minutes in case of water tube boilers.

During the test, surplus feed water is not to be supplied and only that is necessary to maintain a safe working water level is supplied. The popping point of each safety valve is not to go beyond 3% above its set pressure.

Where such accumulation tests are not feasible due to superheater design, an application to exclude such tests may be approved, provided the following are complied with:

- All safety valves are to be set in the Surveyor's presence with due consideration given to back pressure in the safety valve steam escape pipe.
- Similarly, all the capacity tests on each valve type are to be done in the presence of the Surveyor.
- The valve manufacturer furnishes a certificate for each safety valve of the boiler stating its capacity at the maximum allowable working pressure and temperature.
- Similarly, boiler manufacturer furnishes a certificate stating the maximum evaporation of the boiler.

5.1.9. Changes in Safety Valve Setting

Where, for any reason, there are changes in the safety valve settings, for example, the maximum allowable working pressure is lower than that for which the boiler and safety valves were originally designed then, the valve's relieving capacity which are operating under lower pressure is to be checked against the evaporating capacity of the boiler. Also, the manufacturer has to guarantee that the valve capacity is adequate for the new conditions and that is submitted for approval. Alternatively, it is to be demonstrated in Surveyor's presence by conducting a pressure accumulation test, specified in Sect [5.1.8] above, that the valve's relieving capacity is adequate.

5.2. Permissible Valve Connections on Boilers

5.2.1. Connection Method

All the valves with nominal diameter of more than 30 mm (1.25 in.) are to be attached to the boiler with welded or flanged joints. Where shell plate thickness is over 12.7 mm (0.5 in.), or where it has been reinforced by welded pads, valves of 30 mm (1.25 in.) nominal diameter and under may be attached by small, extra-heavy screwed nipples.

The stud holes are not to pierce the whole thickness of the shell plate for studded connections and the depth of the thread is also to be at least equal to 1.5 times the stud diameter.

5.2.2. Valve Materials

All valves either directly attached to a boiler or by means of a distance piece, are to be cast steel or forged, except where the pressure does not exceed 24.1 bar (24.6 kgf/cm², 350 psi) and the steam temperature does not exceed 232°C (450°F), nodular cast iron Grade 60-40-18 (refer Part-2, Ch-2, Sec-10,) may be used. Valves may be made of Type 1 bronze conforming to Part-2, Ch-4, Sec-6, [6.1], where temperature does not exceed 208°C (406°F) and the temperature limit may be 288°C (550°F), where high temperature bronze is used.

5.2.3. Valve Design

Valve design is to comply with a recognized national standard, and be permanently marked as per the requirements of the standard. For other valves that do not comply with a recognized national standard are to be approved in each case and refer to Ch-8, Sec-2/[2.3.9] for such valves.

5.3. Steam and Feed Valves

5.3.1. General

Stop valves directly connected to the boilers in all steam and feed water connections. The distance piece between the boiler and the valve is permissible if it is short, as possible. The stop valves are to be arranged so as to close against boiler pressure but the stop valves on feed water connections may close against feed water pressure. To close the screw down valves, when facing the top of the stem, move the hand in clockwise direction.

5.3.2. Steam Stop Valves

Each steam outlet from a propulsion or auxiliary boiler is to be fitted with at least one steam stop valve. However, where a super heater is fitted, it is to be located at it to insure a flow of steam through at all times. Exceptionally an alternative arrangement may be considered in case where the total superheat temperature is low. Each steam stop valve exceeding 150 mm (6 in.) nominal diameter is required to be fitted with a by-pass valve for plant warm-up.

Where two or more boilers are connected, non-return type of steam stop valve is to be fitted. Besides that, the steam outlet connecting pipe from each boiler is fitted with additional shut off valve located in series and downstream of the required steam stop valve.

5.3.3. Feed Valves

- a) *Temperature differential.* For boilers with a design pressure of 27.6 bar (28 kgf /cm², 400 psi) or more, a sleeve or a suitable device is to be fitted to the feed-water connection to the drum to reduce the adverse effects of metal temperature differential between the shell or head of the drum and the feed pipe.

While discharging the feed water into a boiler, care must be taken that it does not directly invade the surfaces exposed to hot gases or fire.

- b) *Feed stop valve.* On each feed water line attached directly to the boiler, a feed stop valve is to be fitted. If an economizer is a part of the boiler, the feed water stop valve may be attached directly on that also. It is considered that the valve is located near an operating platform, provided that the pipe between the valve and the economizer is a seamless steel pipe with all welded joints.

Refer to Ch-8, Sec-5, [5.3] for feed water system requirements.

- c) *Feed stop check valve.* A feed stop check valve is to be fitted, or as close thereto as feasible, in addition to and adjacent to the stop valve in (b). If a by-pass is also fitted, a feed water regulator may also be interposed between the stop valve and the stop check valve.
- d) *Feed water line between economizer and boiler.* If economizers are fitted in a boiler, it is to be provided with a check valve located in the feed water line between the economizer and the boiler drum. It is to be located as close as possible to the boiler drum feed water inlet nozzle. When a by-pass arrangement is provided for the economizer, the stop check type check valve is to be used.

5.4. Instrument Connections for Boilers

5.4.1. Water Gauges

- a) *Number of gauges.* At least two approved independent means of indicating the water level, one of which is to be a direct reading gauge glass is to be given to each boiler. On boilers with drums more than 4 m in length and with drum axis athwart ships and double-ended fire-tube boilers, these water-level indicators are to be fitted on or near both the ends.
- b) *Gauge details.* Water gauges are to be fitted with shutoff valves, top and bottom, and drain valves. Shutoff valves are to be of through-flow construction and well equipped

to clearly indicate whether they are open or closed. Shutoff valves for water columns are to be attached directly to the boilers, and the pipes leading to the columns are not to pass through smoke boxes or uptakes unless they are entirely enclosed in open-ended tubes of appropriate size to allow free air circulation around the pipes. Glass water gauges are required to be so located that the lowest visible level in the glass is either not lower than 51 mm (2 in.) above the lowest permissible water level specified in (c) below.

- c) *Lowest permissible water level.* The lowest permissible water level referred to in (b) is to be as given below:
- Water tube boilers: the lowest permissible water level is to be just above [usually 25 mm (1 in.) above] the top row of tubes when cold; the manufacturer is required to submit a lowest permissible level for consideration for boilers with tubes not submerged when cold. In all the cases, the lowest permissible level is to be submitted with the boiler design in each case for approval.
 - Internally fired fire-tube boilers with combustion chambers integral with the boiler: 51 mm (2 in.) above the highest part of the combustion chamber.
 - Vertical fire-tube boilers: half the length of the tubes above the lower tube sheet.
 - Vertical submerged-tube boilers: 25 mm (1 in.) above the upper tube sheet.
- d) *Marking of furnace top.* The highest part of the effective heating surface like the furnace crown of a vertical boiler and the combustion chamber sited in a horizontal boiler is to be distinctively marked in a position adjacent to the water gauge glass.

5.4.2. Pressure Gauges

A steam pressure gauge that indicates pressure precisely up to at least 1.5 times the pressure at which the safety valves are set is given to each boiler. At the end of each double-ended boiler, one such gauge is to be there and it is located in such a way that it is easily visible and the highest permissible working pressure is specially marked.

5.5. Miscellaneous Connections

5.5.1. Try Cocks

Where fitted, try cocks are to be attached directly to the shell or head of a boiler, except for water-tube boilers, where they may be attached to the water column. The lowest try cock is required to be located 51 mm (2 in.) higher than the lowest visible part of the gauge glass. Try cocks may be considered as a means for determining the water level only where the boiler is an auxiliary installation with a maximum allowable working pressure of not more than 10.3 bar (10.5 kgf/cm², 150 psi) and steam is not used for main propulsion.

5.5.2. Test Connections

For boiler-water testing, at least one valve is to be fitted and is to be directly connected to it at a convenient location, but shall not be connected to the water column or gauge.

5.5.3. Blow-off Arrangements

In each boiler, at least one blow-off valve is attached to the boiler drum, either at boiler's lowest part or is fitted with an internal pipe leading to the lowest part. Where this isn't feasible, in case of water tube boilers, the valve may be located outside the boiler casing and attached to a pipe that leads to the lowest part of the boiler. This pipe is well supported, and where it may be exposed to direct heat, is protected as well by refractory or other heat resisting material so arranged that the pipe may be inspected and is not constrained against expansion.

The valve is required to be located within the permissible range of the water level or is fitted with a scum pan or pipe at this level, where a surface blow is fitted.

5.5.4. Super heater Drain and Vent

Super heaters are to have valves or cocks fitted to allow drainage of headers. For venting the super heater and allow steam circulation through it when starting the boiler, appropriate arrangements are made.

5.6. Inspection of Openings

All boilers are to be rendered with adequate number of inspection and cleaning openings viz. manholes or hand holes. The manhole openings is not to be less than 300 mm by 400 mm (12 in. by 16 in.) and hand hole opening in a boiler shell is not to be less than 60 mm by 90 mm (2.25 in. by 3.5 in.). Where it is not possible to give a manhole or other appropriate opening for direct access, due to interior arrangement or size of a boiler, two or more hand holes or other suitable openings through which the interior can be inspected are required to be given. Alternative provisions are considered in other boiler standards or codes.

5.7. Dampers

When dampers are installed in the funnels or uptakes of ships using oil, they shall not obstruct more than 2/3rd of the flue area when closed, and they are required to be capable of being locked in the open position when the boilers are in operation. In any such installation, position of the damper and the degree of its opening is to be marked properly. Where power-operated dampers are fitted for the regulation of super heater steam temperatures, in every single case, these are to be submitted for approval.

5.8. Guidance for Spare Parts

While spare parts are not required for class, the ones listed below are for serving the purpose of unrestricted service and are given as guidance to help in ordering spare parts which may be appropriate for the intended service.

The owner bears the responsibility of maintenance of spare parts aboard each ship.

Owners as required may consult Manufacturer for ranging & scaling of spares,

- 1 set of springs and one set of studs and nuts for one safety valve of each size
- 1 boiler pressure gauge or gauge-testing apparatus
- 12 gauge glasses with packing's per boiler if of the round gauge glass type
- 2 gauge glasses with packing's per boiler and 1 frame for each of 2 boilers if of the flat-gauge-glass type
- 24 tube stoppers, but need not be more than the number necessary to plug 5% of each size of generator, economizer, water wall and super heater tube for one boiler
- Tube material, special welding rods, welding machine and other materials required to make weld repairs on welded wall boiler tubes. This equipment would replace tube stoppers needed for water walls
- Required special tools

5.9. Additional Requirements for Shell Type Exhaust Gas Economizers

5.9.1. Application

This requisite is applicable to shell type exhaust gas economizers that are intended to be run in flooded condition and that can be cut off from the steam piping system.

5.9.2. Design and Construction

Design and construction of shell type exhaust gas economizers is done keeping in mind the heat treatment, welding and inspection arrangements at the tube plate connection to the shell.

5.9.3. Pressure Relief

- a) *Number of Valves.* As per Sect [5.1.1], the shell type exhaust gas economizer is to be provided with at least one safety valve, and when it has a total heating surface of 46.5 m² (500 ft²) or more, at least two safety valves.
- b) *Discharge Pipe.* To prevent the accumulation of condensate on the outlet side of safety valves, safety valve housings and/or discharge pipes are to be fitted with drainage arrangements from the lowest part, directed with continuous fall to a position clear of the shell type exhaust gas economizers so that there is no threat to either personnel or machinery. No cocks or valves are required to be fitted in the drainage arrangements.

5.9.4. Pressure Indication

Every shell type exhaust gas economizer is to have means of indicating the internal pressure and it is to be so located that the pressure can be easily read from any position from which it may be controlled.

5.9.5. Lagging

Every shell type exhaust gas economizer is to have detachable lagging at the circumference of the tube end plates to enable ultrasonic examination of the tube plate to shell connection.

5.9.6. Feed Water

Every shell type exhaust gas economizer is to have arrangements for de-aeration, pre-heating and addition of water treatment or their combination to control the quality of feed water and maintain them within manufacturer's recommendations.

5.9.7. Operating Instructions

The operating instructions for each shell type exhaust gas economizer are to be given by the manufacturer and shall include reference to:

- i) Feed water treatment and sampling arrangements.
- ii) Operating pressure.
- iii) Inspection and cleaning procedures.
- iv) Operating temperatures – exhaust gas and feed water temperatures.
- v) Records of maintenance and inspection.
- vi) The need to maintain adequate water flow through the economizer under all operating conditions.
- vii) Periodical operational checks of the safety devices to be executed by the operating personnel and documented accordingly.
- viii) Procedures for using the exhaust gas economizer in the dry condition.
- ix) Procedures for maintenance and overhaul of safety valves.

SECTION 6 BOILER CONTROL

Contents

6.1. Local Control and Monitoring 535

6.2. Manual Emergency Shutdown 535

6.3. Control of Fired Boilers 535

6.4. Control for Waste Heat Boilers 537

6.5. Control for Fired Water Heaters 537

6.1. Local Control and Monitoring

For locally operating, controlling and monitoring the oil fired boilers and their associated auxiliaries, appropriate means are to be provided. The conventional instruments, gauges, lights or other devices are used to indicate and show the functional condition of the fuel system, feed water and steam systems. For details of the piping systems, refer to Ch-8, Sec-5.

6.2. Manual Emergency Shutdown

In the event of outbreak of fire in a space where boiler forced-draft or induced-draft fans and fuel oil service pumps are fitted, some remote means of control shall be there outside that space so that they may be stopped in cases of emergency.

6.3. Control of Fired Boilers**6.3.1 Automatic Shutdown**

For automatic shutdowns, all boilers, regardless of duties and degree of automation, are required to be fitted with the following:

- a) *Burner Flame Scanner.* It is required that within 6 seconds of flame extinguishment or in event of flame failure, each burner that is fitted with a flame scanner automatically shut off the fuel supply to the burner. If the flame scanner fails, the fuel to the burner is required to be shut off automatically.
- b) *High and low water level sensors.* High and low water level sensors are to be fitted in the boilers. A low water condition is to automatically shut off the fuel supply to the burners and low water sensor is set for the purpose which operates when the water level fall to minimum safe level but not lower than that visible in the gauge glass. Additionally, the water level sensor is to be located to minimize the effects of roll and pitch, or is to be provided with a time lag (approximately 5 seconds) to prevent trip-out due to transients or due to the vessel's motion. In auxiliary boilers intended for non-automatic operation and that work under local supervision, a high water level sensor need not be fitted.
- c) *Forced draft.* Automatic shut off of the fuel supply to the burners is to occur in case of forced draft failure.
- d) *Boiler control power.* In case boiler control power is lost, it shall automatically shut off the fuel supply to the burners.
- e) *Burners.* Burners are to be so arranged that they cannot be withdrawn unless the fuel supply to them is cut off.

6.3.2 Alarms

- a) *Fuel oil shutoff.* Boiler operator shall be alerted of the actuation of any of the fuel shutoffs specified in 6.3.1 at appropriate control station and at proper time with help of visual and audible alarms.
- b) *Air supply and flue.* There shall be means to detect and alarm if there is outbreak of the fire in boiler air supply and exhaust duct at an early stage. Heat (temperature) detector that is fitted in the wind box would meet the same requirement in the absence of an air casing for small boilers. For auxiliary boilers, that don't have an air casing, the means to detect and alarm of a fire in the boiler air supply duct may be done away with provided the burner system is a pressure jet type and the wind box forms part of the combustion fan housing.

Table 10.6.1 summarizes the required alarms and shutdowns for fired alarms.

Table 10.6.1: List of Alarms and Shutdowns – Fired Boilers

Monitored Parameter		Alarm	Automatic Shutdown with Alarm	Notes
A1	Boiler drum water level – low	X		Sec-6, [6.3.1(b)]
A2	Boiler drum water level – low-low		X	Sec-6, [6.3.1(b)]
A3	Boiler drum water level – high	X		Sec-6, [6.3.1(b)]
B1	Forced draft fan – failure		X	Sec-6, [6.3.1(c)]
B2	Air Supply Casing – fire	X		Sec-6, [6.3.2(b)]
C1	Burner flame – failure		X	Sec-6, [6.3.1(a)]
C2	Flame scanner – failure		X	Sec-6, [6.3.1(a)]
D1	Atomizing medium – off-limit condition	X		Sec-6, [6.3.3(e)]
E1	Uptake gas temperature – high	X		Sec-6, [6.3.2(b)]
F1	Control power supply – loss		X	Sec-6, [6.3.1(d)]

6.3.3 Automatic Boiler Control

Regardless of duties, automatically controlled boilers are to fulfill the requisites given in Sect [6.3.1] & [6.3.2] above and those given under:

- Automatic boiler purge.* A timed boiler purge with all air registers open is needed where boilers are fitted with an automatic ignition system. It is required before ignition of the initial burner and may be initiated manually or automatically. The purge time depends on a minimum of four air changes of the combustion chamber and furnace passes. It is to be confirmed that the air registers and dampers are open and the forced draft fan is operating before the purge time starts.
- Trial-for-ignition period.* Temporarily means to by-pass the flame-scanner control system during a trial-for-ignition period is to be restricted to 15 seconds from the time the fuel reaches the burners. Except for this period, no other means are to be provided to by-pass one or more of the burner flame scanner systems unless the boiler is being locally controlled.
- Automatic burner light-off.* Where an automatic ignition system is fitted and residual oil is used in a boiler, means are to be provided for lighting off the burners with igniters lighting properly-heated residual fuel oil. Alternatively, the burners may be lighted off using light oil as a pilot to ignite residual fuel oil. If all burners experience a flame failure, the initial burner is to be brought back into automatic service only in the low-firing position. So that there is no false indication due to the failure of the flame scanner in the “flame-on” mode, the initial light-off burner is to be fitted with dual scanners or a scanner of the self-checking type.
- Post purge.* After normal shutdown of the boiler, immediately an automatic purge of the boiler equal to the volume and duration of the pre-purge is to take place. After master fuel valve is closed as part of a preventive action, the post purge is not to automatically occur rather it is to be executed under manual control.
- Atomizing medium.* Off-limit condition of atomizing steam pressure or burner primary-air pressure is to be alarmed.

6.4. Control for Waste Heat Boilers

Control of fired water heaters is to be similar to that for fired boilers or as applicable. The underlying requirements are also applicable.

6.4.1. Boilers not Designed to Operate with Low Water Level

- a) *Smoke tube type*. It is to be alarmed that there is a low water level condition and simultaneously arrangements are to be provided to divert the exhaust gas in such a condition, either manually or automatically. Automatic diversion of exhaust gas is also required to be alarmed.

Note: The aforementioned requirements for by-pass/diversion arrangements are not applicable to waste heat boilers designed for operating in dry conditions.

- b) *Water tube type*. It is to be alarmed that there is low water flow condition and simultaneously arrangements for automatically starting a standby feed water pump shall be activated. Table 10.6.2 summarizes the required alarms for waste heat boilers.

6.4.2. Soot Cleaning

Soot cleaning arrangements are to be made for the waste heat boilers with extended surface tubes and shall be readily available during the time boiler is in operation.

Table 10.6.2: List of Alarms – Waste Heat Boilers

(not designed to operate with low water level)

Monitored Parameter		Alarm	Notes
SMOKE TUBE TYPE			
A1	Boiler drum water level – low	X	Sec-6, [6.4.1(a)]
B1	Exhaust gas automatic diversion	X	Sec-6, [6.4.1(a)]
C1	Exhaust gas temperature at outlet – high	X	Sec-6, [6.3.2(b)]
WATER TUBE TYPE			
D1	Water flow in the tubes – low	X	Sec-6, [6.4.1(b)]
E1	Exhaust gas temperature at outlet – high	X	Sec-6, [6.3.2(b)]

6.5. Control for Fired Water Heaters

Control of fired water heaters is to be similar to that for fired boilers or as applicable. Table 10.6.3 summarizes the required alarms and shutdowns for fired water heaters.

Table 10.6.3: List of Alarms and Shutdowns – Fired Water Heaters

Monitored Parameter		Alarm	Automatic Shutdown with Alarm	Notes
A1	Heater water level – low	X		Sec-6, [6.3.1(b)]
A2	Heater water level – low-low		X	Sec-6, [6.5] Sec-6, [6.3.1(b)]
A3	Heater water level – high	X		Sec-6, [6.3.1(b)]
B1	Forced draft fan – failure		X	Sec-6, [6.5] Sec-6, [6.3.1(c)]
B2	Air supply casing – fire	X		Sec-6, [6.3.2(b)]
C1	Burner flame – failure		X	Sec-6, [6.5] Sec-6, [6.3.1(a)]
C2	Flame scanner – failure		X	Sec-6, [6.5] Sec-6, [6.3.1(a)]
D1	Atomizing medium – off limit condition	X		Sec-6, [6.5] Sec-6, [6.3.3(e)]
E1	Uptake gas temperature – high	X		Sec-6, [6.3.2(b)]
F1	Control power supply – loss		X	Sec-6, [6.5] Sec-6, [6.3.1(d)]

SECTION 7 THERMAL OIL HEATERS

Contents

7.1. Accessories 540

7.2. Thermal Oil Heater Control 540

7.3. Exhaust-gas Thermal Oil Heaters 541

7.1. Accessories

7.1.1. Relief Valve

Each exhaust or fired gas heater for thermal oil is to be fitted with a liquid relief valve that is arranged to expel its contents into a collection tank.

7.1.2. Sampling

It is required that such means are fitted that help to take samples of thermal oil from time to time for testing purpose. Onboard facilities to carry out the required tests are to be provided.

7.1.3. Expansion Tank

Vents from the thermal oil storage tank and thermal oil expansion tank are to be led to the external environment. The pipe connection between the expansion tank and the heater is to be fitted with a valve that is capable of local manual operation and remote shutdown from external place and not from where the tank is located.

7.2. Thermal Oil Heater Control

7.2.1. Local Control and Monitoring

For locally operating, controlling and monitoring the oil fired thermal oil heaters and their associated auxiliaries, appropriate means are to be provided. Their operational status is to be indicated by conventional instruments, gauges, lights or other devices to show the functional condition of fuel system, forced-draft system, thermal oil circulation system and flue gas system.

7.2.2. Automatic Control

To maintain thermal oil at the desired temperature during operations, thermal oil heating system is to be operated with an automatic burner and appropriate flow regulation controls.

7.2.3. Monitoring and Automatic Shutdown

The Sec-6, [6.3.1 (a), (c), (d) and (e)] requisites are also applicable for thermal oil heaters. Additionally, automatic fuel shutoff is to be present to work under conditions indicated in Table 10.7.1.

7.2.4. Remote Shutdown

Fuel oil service pumps, thermal oil circulating pumps and forced-draft fans are required to be fitted with local means of stopping and remote means of stopping from outside the space in which these equipment are located.

7.2.5. Valve Operation

The thermal oil main inlet and outlet are fitted with stop valves arranged in such a manner that they can be actuated or shut locally either manually or remotely from external space and not from where heater is located. Alternatively, arrangement for quick gravity discharge of the thermal oil to a collection tank is to be provided.

7.2.6. Fire Extinguishing System

The furnaces of thermal oil heaters are to be fitted with a fixed fire extinguishing system that can be actuated locally and remotely from external space and not where the heater is located.

Table 10.7.1: List of Alarms and Shutdowns – Fired Thermal Oil Heaters

Monitored Parameter		Automatic Shutdown with Alarm	Notes
A1	Burner flame – failure	X	[7.2.3] Sec-6, [6.3.1(a)]
A2	Flame scanner – failure	X	[7.2.3] Sec-6, [6.3.1(a)]
B1	Forced draft system – failure	X	Sec-6, [6.3.1(c)]
C1	Control power supply – loss	X	Sec-6, [6.3.1(d)]
D1	Thermal oil expansion tank level – low	X	[7.2.3]
D2	Thermal oil temperature at oil outlet – high	X	[7.2.3]
D3	Thermal oil pressure or flow in circulation system – low	X	[7.2.3]
E1	Flue gas temperature – high	X	[7.2.3]

7.3. Exhaust-gas Thermal Oil Heaters

7.3.1. Exhaust-gas thermal oil heaters are to conform to the additional requirements given below:

- i) The heater design and installation is to be such that the tubes may be easily accessed and examined for indications of corrosion and leakage.
- ii) A high temperature alarm is to be fitted in the exhaust gas piping for detecting fire.
- iii) A cooling system and fixed fire extinguishing system is to be installed within the exhaust gas piping which may be a water drenching system, provided that there are adequate arrangements below the heater to collect and drain water from it.

Table 10.7.2 summarizes the required alarms and shutdown for exhaust gas thermal heaters.

Table 10.7.2: List of Alarms and Shutdowns – Exhaust-gas Thermal Oil Heaters

Monitored Parameter		Alarm	Automatic Shutdown with Alarm	Notes
A1	Thermal oil expansion tank level – low		X	[7.3 (7.2.3)]
A2	Thermal oil temperature at oil outlet – high		X	[7.3 (7.2.3)]
A3	Thermal oil pressure or flow in circulation system – low		X	[7.3 (7.2.3)]
B1	Exhaust gas temperature – high	X		[7.3.1 (ii)]

SECTION 8 INCINERATORS

Contents

8.1. Local Control and Monitoring 543

8.2. Emergency Shutdown 543

8.3. Automatic Shutdown..... 543

8.1. Local Control and Monitoring

For locally operating, controlling and monitoring the operation of incinerators and their associated auxiliaries, appropriate means are to be provided. Their operational status is to be indicated by conventional instruments, gauges, lights or other devices to show the functional condition of fuel system, forced-draft system, thermal oil circulation system and flue gas system. The provisions given in Ch-8, Sec-5, [5.4] pertaining to the boiler fuel oil service piping system are also applicable to the incinerator fuel oil system.

8.2. Emergency Shutdown

Fuel oil service pumps and forced-draft fans are to be fitted with local and remote means of operation and stopping from an external location.

8.3. Automatic Shutdowns

The Sec-6/ [6.3.1 (a), (c), (d) and (e)] gives requisites for boilers and those are also applicable for incinerator. Additionally, automatic fuel shutoff is required to be fitted for the conditions given below:

- Furnace temperature high
- Flue gas temperature high

SECTION 9 PRESSURE VESSEL AND HEAT EXCHANGER ACCESSORIES

Contents

9.1. Pressure Relief Valve	545
9.2. Inspection Openings	545
9.3. Drain	545

9.1. Pressure Relief Valve

A pressure relief valve of adequate capacity is to be fitted in every pressure vessel and every chamber of each heat exchanger which can be subjected to a pressure greater than its design pressure. It is not to be set at more than the maximum allowable working pressure and is so sized that it prevents the pressure in the vessel from rising more than 10% or 0.21 bar (0.21 kgf/cm², 3 psi), whichever is greater, above the maximum allowable working pressure. It is also considered that the pressure relief valve is installed in the piping system connected to the pressure vessel, provided that it is of the required capacity and cannot be isolated from the pressure vessel by the intervening valve. The requirements of the safety relief valve in the code or standard of compliance is also taken into consideration.

9.2. Inspection Openings**9.2.1. Diameter Over 915 mm (36 in.)**

All pressure vessels and heat exchangers over 915 mm (36 in.) inside diameter are to be provided with a manhole or at least two hand holes. An elliptical or oblong manhole shall not be less than 279 mm by 381 mm (11 in. by 15 in.) or 254 mm by 406 mm (10 in. by 16 in.). A circular manhole is not be less than 381 mm (15 in.) inside diameter and a hand hole is not to be less than 102 mm by 152 mm (4 in. by 6 in.).

9.2.2. Diameter Over 457 mm (18 in.)

At least two inspection openings which are closed by pipe plugs of not less than 50 mm (2 in.) nominal, will be acceptable for vessels with diameters of 915 mm (36 in.) or less and over 457 mm (18 in.).

9.2.3. Diameter Over 305 mm (12 in.)

At least two pipe plugs of not less than 40 mm (1.5 in.) nominal may be used for vessel diameters 457 mm (18 in.) or less and over 305 mm (12 in.).

9.2.4. Diameter 305 mm (12 in.) or Less

At least two pipe plugs of not less than 20 mm (3/4 in.) nominal may be used, for vessel with diameters 305 mm (12 in.) or less.

9.2.5. Alternative Arrangements

Alternative arrangements which can be made to provide an equivalent degree of internal inspection are to be considered. Flanged and/or threaded connections from which piping instruments or its attachments can be removed may be an acceptable alternative, provided that the connections are at least equal to the size of the required openings and the connections are sized and located to afford at least an equal view of the interior as the required openings.

9.3. Drain

In the pressure vessels subject to corrosion, a drain opening shall be given at the lowest possible point; or a pipe may be used to extend inward from any location to the lowest point.

SECTION 10 INSTALLATION AND SHIPBOARD TRIALS

Contents

10.1. Seating Arrangements..... 547

10.2. Boiler Installation 547

10.3. Installation of Thermal Oil Heaters and Incinerators 547

10.4. Shipboard Trials 548

10.1. Seating Arrangements

- 10.1.1. Pressure vessels, boilers and other pressurized or fire equipment are to be properly secured in position on supports constructed as per approved plans. Structural supports for fire equipment's are not to be made from heat sensitive material.

10.2. Boiler Installation**10.2.1. Bottom Clearance**

The distance between the boiler and the floors or inner bottom shall not be less than 200 mm (8 in.) at the lowest part of a cylindrical boiler. This distance shall not be less than 750 mm (30 in.) between the bottom of the furnace (or boiler pan) and tank top (or floor) in the case of water-tube boilers.

10.2.2. Side Clearance

The distance between boilers and vertical bulkheads is required to be sufficient to provide access for maintenance of the structure; and, the clearance is to be sufficient to prevent the temperature of the bulkhead from approaching the flash point of the oil, in the case of bulkheads in way of fuel oil and other oil tanks. Generally, this clearance is required to be at least 750 mm (30 in.).

10.2.3. Top Clearance

Enough head room is to be provided at the top of boiler to allow for adequate heat dissipation. Generally, this clearance shall not be less than 1270 mm (50 in.). No fuel oil or other oil tank is to be installed directly above any boiler.

10.2.4. Tween Deck Installation

Where boilers are located on tween decks in boiler rooms and machinery spaces are not separated from a machinery space by watertight bulkheads, these decks are to be provided with coamings at least 75 mm (3 in.) in height. This area may be drained to the bilges.

10.2.5. Hot Surfaces

During operation, hot surfaces that are likely to come into contact with the crew are to be suitably guarded or insulated. Where their temperature is likely to exceed 220°C (428°F), and where any leakage, under pressure or otherwise, of fuel oil, lubricating oil or other flammable liquid is likely to come into contact with such surfaces, they are required to be suitably insulated with materials impervious to such liquid. Insulation material not impervious to oil is to be encased in sheet metal or an equivalent impervious sheath.

10.2.6. Ventilation

The spaces in which the oil fuel burning appliances are fitted are to be properly ventilated.

10.2.7. Fire Protection

As specified in latest IMO Requirements boiler space is required to be considered a machinery space of category A and is to be provided with fixed fire extinguishing system and other fire-fighting equipment.

10.3. Installation of Thermal Oil Heaters and Incinerators

- 10.3.1. In general, the installation of incinerators, other fire equipment and thermal oil heaters is to be as per Sect [10.2] of this section. It is considered that thermal oil heaters in a space separated from the propulsion machinery space are installed. Where fire equipment is installed in a space which is not continuously manned, it is also to be protected by fire detection and alarm system.

10.4. Shipboard Trials

10.4.1. Boilers

All boilers are to be functionally tested after installation in Surveyor's presence. The test is to comprise of proof of actuation of all safety devices. Safety valves are required to be tested by boiler pressure accumulation test or its equivalent; refer to Sect-5, [5.1.8].

10.4.2. Pressure Vessels and Heat Exchangers

Pressure vessels and heat exchangers are to be functionally tested with the systems of which they are a part.

10.4.3. Thermal Oil Heaters and Incinerators

Incinerators, other fired equipment and thermal oil heaters are required to be functionally tested after installation in the Surveyor's presence.

CHAPTER 11 PROPULSION REDUNDANCY

CONTENTS

SECTION 1 GENERAL REQUIREMENTS	550
SECTION 2 CLASSIFICATION NOTATIONS AND SURVEYS	553
SECTION 3 SINGLE FAILURE CONCEPT	556
SECTION 4 PROPULSION AND STEERING CAPABILITY	558
SECTION 5 SYSTEM DESIGN	560
SECTION 6 FIRE PRECAUTIONS AND OPERATIONAL MANUAL	564
SECTION 7 TEST AND TRIAL	566

SECTION 1 GENERAL REQUIREMENTS

Contents

1.1. Scope 551

1.2. Objective..... 551

1.3. General Definitions 551

1.4. Documents to be Submitted 552

1.1. Scope

- 1.1.1. In this section, the given requirements are applicable to ships fitted with propulsion and steering systems so designed that they provide enhanced reliability and availability via functional redundancy. However, the applications of these requirements are optional.
- 1.1.2. When a ship is designed, built and surveyed in line with this section, and when found satisfactory, a classification notation, as given in Sec-2 of this chapter, or as appropriate, will be granted.
- 1.1.3. It is a pre-requisite that the vessels are also classed to  **UM** notation.

1.2. Objective

- 1.2.1. The objective is to furnish requirements which diminishes the risk to personnel, the ship, other ship or structures, the environment and the economic consequences due to a single failure causing loss of propulsion or steering capability. This is attained through varying degrees of redundancy based upon the ship's Classification Notations, as detailed in Sec-2 of this chapter.
- 1.2.2. The requirements aim to ascertain that after a single failure, the ship is capable of either:
 - i) Maintaining maneuverability and its line of course at reduced speeds without interfering with the course of other ships, or
 - ii) Maintaining position under unfavorable weather conditions, as given in Sec-4, [4.2], or to evade uncontrolled drift and navigating back to safe harbor when weather conditions are normal.
- 1.2.3. Additionally, this section addresses aspects which would diminish the harmful effects to the propulsion systems due to a localized fire in the machinery spaces.

1.3. General Definitions

- 1.3.1. Auxiliary Services System

All support systems (e.g., lubricating oil system, fuel oil system, compressed air, cooling water system and hydraulic systems, etc.) which run propulsion machinery and propulsors.
- 1.3.2. Propulsion Machine

A propulsion machine is a device that generates mechanical energy to drive a propulsor. For e.g. turbine, diesel engine, electrical motor etc.
- 1.3.3. Propulsion Machinery Space

Any space which houses machinery or equipment and are part of the propulsion systems.
- 1.3.4. Propulsion System

A propulsion system is so designed that it provides thrust to a ship, consisting of one or more propulsion machines, propulsors, all requisite auxiliaries and associated control, alarm and safety systems.
- 1.3.5. Propulsor

A propulsor is a device (e.g., water jet, propeller/ Thruster etc) that transmits force to a column of water to propel a ship, together with equipment that are vital to transmit the power from the propulsion machinery to the device (e.g., shafting, gearing, etc.).
- 1.3.6. Steering System

Steering system is designed to control the direction of movement of a ship, including the rudder, steering gear, etc.

1.3.7. For the purpose of this Chapter, items of active equipment are those which have a defined function for operation of a propulsion or steering system, such as but not limited to:

- Prime movers, i.e. diesel engines, electric motors, steam turbines and gas turbines;
- Generators and their excitation equipment;
- Transformers and converters;
- Gearing and shafting systems;
- Propulsion devices, i.e. propellers, water-jets and thrusters;
- Pumps;
- Valves (where power actuated);
- Fuel treatment plant;
- Coolers/heaters;
- Filters;

Piping and electrical cables connecting items of active equipment are not considered to be active.

1.4. Documents to be Submitted

Along with the plans and data required by the Rules, following are to be submitted:

- a) Computations results showing that after a single failure in the propulsion and steering systems, the ship meets the capability requirements of Sec-4, [4.1], if applicable, with details of the computational methods used. Alternatively, as evidence, the results of model testing are acceptable.
- b) A Failure Mode and Effect Analysis (FMEA) or equivalent is required to be submitted. The integrity of the propulsion systems, steering systems and auxiliary service systems is to be verified using Failure Mode and Effect Analysis (FMEA) or equivalent method and is to show that a single failure will not compromise the criteria specified in Sec-4 of this chapter.
- c) A Testing Plan to cover the means with which the verification of the redundancy arrangements will be successfully done.
- d) Details of general arrangement including locations of all machinery and equipment necessary for the correct functioning of the propulsion and steering systems, including the routing of all associated power, control and communication cables. (Required for **IR₁-S** and **IR₂-S** only).
- e) Operation Manual, as specified in Sec-6, [6.2] of this chapter.

SECTION 2 CLASSIFICATION NOTATIONS AND SURVEYS

Contents

2.1. Classification Notations	554
2.2. Survey after Construction.....	554

2.1. Classification Notations

Upon Owner's request, propulsion and steering installations which comply with the requirements of this chapter and which have been constructed and installed under Surveyor's supervision will be assigned with the appropriate class notations, as given below.

- i) **IR₁** A ship fitted with multiple propulsion machines but one propulsor and steering system will be assigned the class notation **IR₁**.
- ii) **IR₂** A ship fitted with multiple propulsion machines and also multiple propulsors and steering systems (hence, multiple propulsion systems) will be assigned the class notation **IR₂**.
- iii) **IR₁-S** A ship fitted with only a single propulsor but having the propulsion machines arranged in two distinct spaces such that a fire or flood in one space would not affect the propulsion machine(s) in the other space(s) will be assigned the class notation **IR₁-S**.
- iv) **IR₂-S** A ship fitted with multiple propulsors (hence, multiple propulsion systems) which has the propulsion machines and propulsors, and associated steering systems arranged in two distinct spaces (propulsion machinery space and steering gear flat) such that a fire or flood in one space would not affect the propulsion machine(s) and propulsor(s), and associated steering systems in the other space(s) will be assigned the class notation **IR₂-S**. Fig.11.2.1 illustrates arrangements for each of the aforementioned notations.
- v) **+** (Plus Symbol) The **+** mark will be suffixed to any of the above class notations (e.g., **IR₁+**, **IR₂-S+**) to denote that ship's propulsion capability is such that, upon a single failure, propulsive power can be maintained or instantly restored to the extent required to bear unfavorable weather conditions without drifting, as per Sec-4, [4.2]. The absence of the **+** mark after the class notation indicates that the ship is not intended to bear the unfavorable weather conditions as given in Sec-4, [4.2], but can maintain course and maneuverability at a reduced speed under normal and expected weather conditions, as specified in Sec-4, [4.1].

2.2. Survey after Construction

The surveys after construction are to be in line with the applicable requirements as given in the Part-1, Chapter-3 of INTLREG Rule.

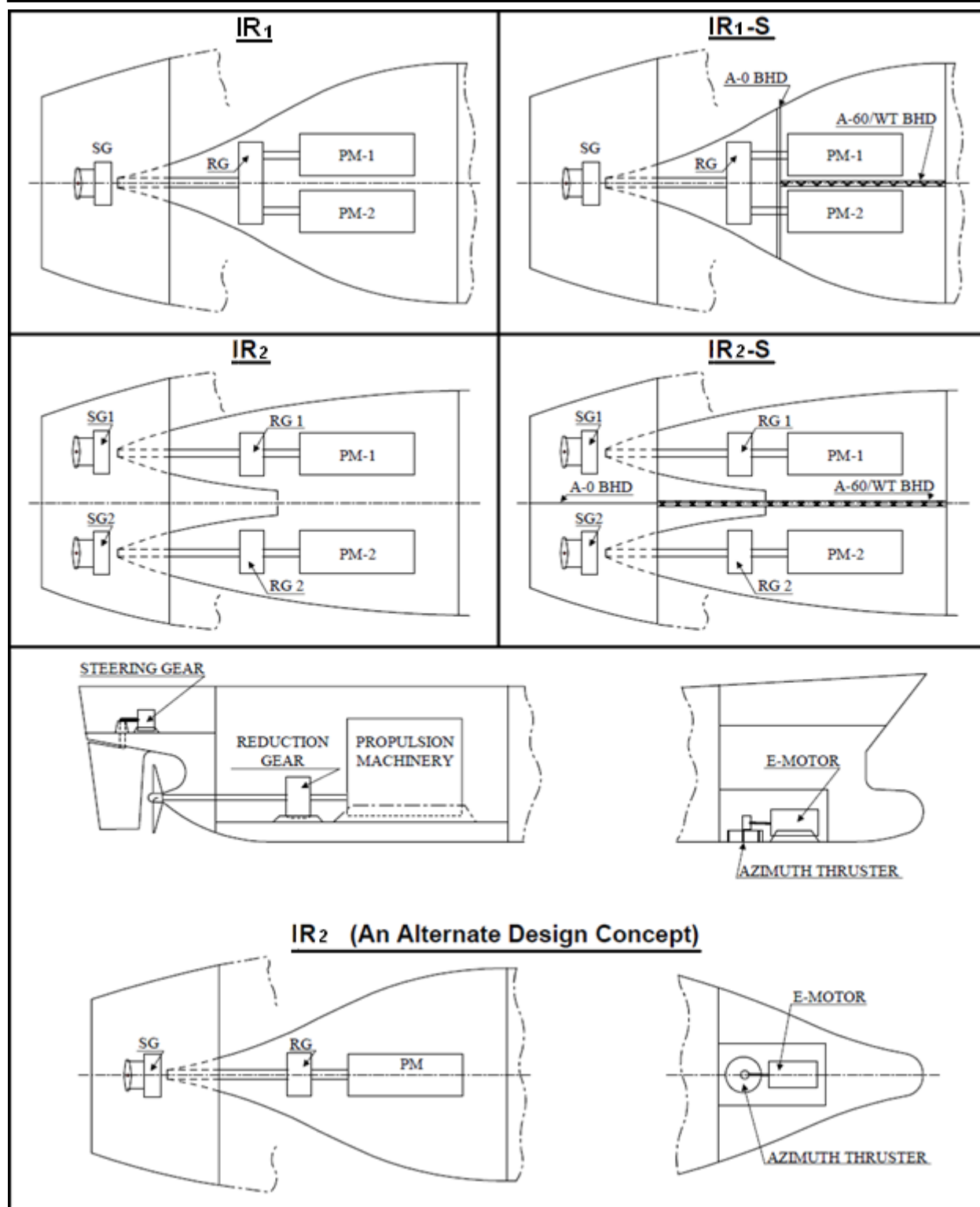


Figure 11.2.1: Arrangements of Propulsion Redundancy

SECTION 3 SINGLE FAILURE CONCEPT

Contents

3.1. General	557
3.2. Single Failure Criteria	557

3.1. General

- 3.1.1. Upon a single failure concept, the degree of redundancy required to meet the objectives is based. According to this concept, failures may occur but only one such failure is likely to occur at any time.
- 3.1.2. The final consequence of any single failure shall not compromise the propulsion and steering capability (as required in Sec-4 of this chapter), unless otherwise specified.

3.2. Single Failure Criteria**3.2.1. IR_1 Notation**

For IR_1 , the single failure criterion is applied to the propulsion machines, its auxiliary service systems and its control systems but does not consider failure of the propulsor or rudder, or total loss of the propulsion machinery space or steering gear flat due to fire or flood.

3.2.2. IR_2 Notation

For IR_2 , the single failure criterion is applied to the propulsion machines, auxiliary service systems, control systems and steering systems and also propulsors. Yet, total loss of the propulsion machinery space or steering gear flat due to fire or flood is not considered by this notation.

3.2.3. IR_1 -S Notation

For IR_1 -S, the single failure criterion is applied just as for IR_1 , and a fire or flood in one of the propulsion machinery spaces is also considered.

3.2.4. IR_2 -S Notation

For IR_2 -S, the single failure criterion is applied just as for IR_2 , and a fire or flood in one of the propulsion machinery spaces or steering gear flats is also considered.

SECTION 4 PROPULSION AND STEERING CAPABILITY

Contents

4.1. Vessels Without + in Class Notation	559
4.2. Vessels with + in Class Notation	559

4.1. Vessels Without + in Class Notation

It is required that upon a single failure, the propulsion system is constantly maintained or restored within two (2) minutes (alternate standby propulsion is as per [4.2] below) such that the vessel, in her fully loaded condition, is able to advance at least at one-half its design speed or seven knots, whichever is less, for not less than 36 hours. At this speed, an adequate steering capability is also to be maintained.

4.2. Vessels with + in Class Notation

In addition to [4.1] above, upon a single failure, the propulsion and steering system is required to be constantly maintained or instantly restored within two (2) minutes, as is done when an alternate standby propulsion type is provided, (e.g., diesel engine, electric motor, water jet propulsion, etc.) such that the vessel is capable of maneuvering into an orientation of least resistance to the weather, and once in that orientation, maintaining position such that the vessel will not drift for at least 36 hours. This may be attained using all available propulsion and steering systems including thrusters, if provided. This is to be feasible in all weather conditions up to a wind speed of 17 m/s (33 knots) and significant wave height of 4.5 m (15 ft) with 7.3 seconds mean period, both of which are acting concurrently in the same direction. The severest loading condition for ship's maneuverability is also to be considered for compliance with this weather criterion and further verified by computational simulations, and its results are to be submitted for approval. The estimated optimum capability is documented in the operating manual, as required in Sec-6, [6.2] of this chapter.

SECTION 5 SYSTEM DESIGN

Contents

5.1. Propulsion Machinery and Propulsors.....	561
5.2. System Segregation	561
5.3. Steering Systems	561
5.4. Auxiliary Service Systems	562
5.5. Electrical Distribution Systems	562
5.6. Control and Monitoring Systems	563
5.7. Communication Systems.....	563

5.1. Propulsion Machinery and Propulsors

Two independent propulsion machines are to be provided as a minimum and a single failure in any one such machine or auxiliary service system is not to result in propulsion performance inferior to that required by Sec-4/ [4.1] or [4.2], or as applicable.

5.1.1. IR₁Notation

For **IR₁**notation, the propulsion machines and auxiliary service systems may be located in the same propulsion machinery space and these machines may drive a single propulsor.

5.1.2. IR₂Notation

For **IR₂**notation, minimum two propulsors are to be provided such that a single failure of one will not result in propulsion performance inferior to that required by Sec-4, [4.1] or [4.2], or as applicable. These, however, may be located in the same propulsion machinery space.

5.1.3. IR₁-S Notation

For **IR₁-S** notation, the propulsion machines and auxiliary service systems are to be separated in such a manner that total loss of any one such space (due to fire or flood) will not result in propulsion performance inferior to that required by Sec-4, [4.1] or [4.2], or as applicable. However, the propulsion machines may drive a single propulsor and the main propulsion gear or power transmitting gear is to be located outside the propulsion machinery spaces separated by a bulkhead and meeting the criteria as specified in [5.2] below.

5.1.4. IR₂-S Notation

For **IR₂-S** notation, minimum two propulsors are to be provided, and the propulsion systems are to be installed in distinct spaces such that a single failure in one propulsor or a total loss of any one such space (due to fire or flood) will not result in propulsion performance inferior to that required by Sec-4, [4.1] or [4.2], or as applicable.

5.2. System Segregation

5.2.1. Where failure is deemed to include loss of propulsion machinery space completely due to fire or flooding (**IR₁-S** and **IR₂-S** notations), redundant systems and components are required to be separated by watertight bulkheads with an A-60 fire classification.

5.2.2. Service access doors which conform to Pt 6,Ch8,Sect 4[4.2.1] may be provided between segregated propulsion machinery spaces. A clear indication of open/closed status of the doors is to be provided at the centralized control station and in the bridge. Unless approved specially by the flag Administration, these service access doors are not to be considered as the means of escape from the machinery space Category A as required by the requirements of Regulation II-2/13 of SOLAS 1974, as amended.

5.3. Steering Systems

5.3.1. For each propulsor, an independent steering system is to be provided. Irrespective of the size and type of ship, each steering system is required to meet the requirements of Regulation II-1/29.16 of SOLAS 1974, as amended.

5.3.2. The rudder design is to be such that the ship can turn in either direction despite of only one operating propulsion machine or steering system.

5.3.3. For **IR₂-S** notation, the steering systems are to be kept in distinct compartments such that a fire or flood in one compartment will not affect the steering system(s) in the other compartment(s), and performance as specified in Sec-4, [4.1] or [4.2], as applicable, is maintained.

5.3.4. For **IR₂** and **IR₂-S** notations, if steering system fails, means to secure rudders in the amidships position are to be provided.

5.4. Auxiliary Service Systems

- 5.4.1. At least two independent auxiliary service systems, including fuel oil service tanks, are required to be provided and arranged in such a way so that a single failure will not result in propulsion performance inferior to that required by Sec-4/ [4.1] or [4.2], or as applicable. However, a single failure in the vital auxiliary machinery (e.g., pumps, heaters, etc.), excluding failure of fixed piping, shall not result in reduction of the full propulsion capability. To meet this requirement, it will be mandatory to either cross-connect the auxiliary service systems and size the components (pumps, heaters, etc.) so that it is able to supply two or more propulsion machines simultaneously, or provide duplicate components (heaters, pumps, etc.) in each auxiliary system if one fails.
- 5.4.2. Except for the fuel oil service tank venting system, interconnections between auxiliary service systems will be considered, provided these are fitted with means (as in valves) to disconnect or isolate the systems from each other.
- 5.4.3. For IR₁-S and IR₂-S notations, the above-mentioned independent auxiliary service systems are required to be segregated in the separate propulsion machinery spaces. Except fuel oil service tank venting systems, interconnections of auxiliary service systems will be acceptable, provided required disconnection or isolation means are fitted at both sides of the bulkhead separating the propulsion machinery spaces. Position status of these disconnection or isolation means is to be provided at the centralized control station and navigation bridge. Penetrations in the bulkhead segregating the propulsion machinery spaces and steering gear flats (as in the case of IR₂-S notations) are not to compromise with its fire and watertight integrity.

5.5. Electrical Distribution Systems

- 5.5.1. Electrical power generation and distribution systems are required to be arranged in such a way so that following a single failure in the systems the electrical power supply is maintained or instantly restored to the extent that the requirements outlined in Sec-4 of this chapter are met.
- 5.5.2. The bus bars are required to be divided into at least two sections, where the ship's vital equipment is fed from one main switchboard. Where the sections are normally connected, detection of a short circuit on the bus bars shall result in automatic separation. The circuits supplying equipment vital to the operation of the propulsion and steering systems are to be divided between the sections such that a loss of one will not result in performance inferior to that defined in Sec-4 of this chapter. A fully redundant power management system that can aid in independent functioning of each section of the switchboard is to be provided.
- 5.5.3. For IR₁-S and IR₂-S notations, the ship service power generators, their auxiliary systems, the switch board sections and the power management systems are to be stationed in at least two machinery spaces that are segregated by watertight bulkheads with an A-60 fire classification. The power distribution is to be such that a fire or flooding of one machinery space is not to result in propulsion capability inferior to that defined in Sec-4 of this chapter. Where an interconnection is provided between the distinct propulsion machinery spaces, a disconnection or isolation means are to be provided at both sides of the bulkhead separating the propulsion machinery spaces. Position status of these disconnection or isolation means is to be provided at the centralized control station and navigation bridge. Fire or flooding of one machinery space is not to result in propulsion capability inferior to that defined in Sec-4 of this chapter. The power cables from the service generator(s) of one propulsion machinery space shall not pass through the other space containing the rest of the service generator(s).
- 5.5.4. Additionally, for IR₁-S and IR₂-S notations, subject to approval by the flag Administration, the requisites for self-contained emergency power source may be considered satisfied without an additional emergency source of electrical power, provided that:

- i) All generating sets and other required sources of emergency source of power are designed to function at full rated power when upright and when inclined up to a maximum angle of heel in the intact and damaged condition, as determined as per Part 5A of INTLREG Rules. Not in any case, the equipment shall be designed to operate when inclined more than 22.5° about the longitudinal axis and/or when inclined 10° about the transverse axis of the ship.
- ii) The generator set(s) installed in each machinery space is of adequate capacity to meet the requisites of Part-6, Ch-2, Sec-2 and Sec-3.
- iii) The arrangements required in each machinery space are equivalent to those required by Part-6, Ch-2, Sec-3/ [3.1.8], [3.1.11] & [3.2], so that electrical power source is available at all times for the services required by Part-6, Ch-2, Sec-3.

5.6. Control and Monitoring Systems

- 5.6.1. The control systems are to be such that they are operable in both independent and combination and from both the bridge and the centralized control station. For sake of easy operability, the mode of operation of the propulsion machinery is to be clearly indicated at each position.
- 5.6.2. It shall be feasible to locally control the propulsion machinery and the propulsor.
- 5.6.3. For IR₁-S and IR₂-S notations, the propulsor's control and monitoring system (e.g., controllable pitch propeller control), and all associated cabling, is to be duplicated in each space, so that fire or flooding of one space does not adversely affect operation of the propulsor from the other space.

5.7. Communication Systems

- 5.7.1. The requisites of Part-6, Ch-7, Sec-3/ [3.2] are to be conformed to all installed propulsion control positions.
- 5.7.2. For IR₁-S and IR₂-S notations, the communications cables to each control position shall not be routed through the same machinery space.

SECTION 6 FIRE PRECAUTIONS AND OPERATIONAL MANUAL

Contents

6.1. Fire Precautions	565
6.2. Operational Manual	565

6.1. Fire Precautions

- 6.1.1. The requirements of [6.1] is only applicable to Category A machinery spaces.
- 6.1.2. Pumps for oil services are to be fitted with shaft sealing devices as these do not require frequent maintenance to prevent oil leakage, like mechanical seals.
- 6.1.3. For IR_1 and IR_2 notations, the requirements given below are to be fulfilled to minimize the risk of common damage due to a localized fire in the machinery space.
 - i) Each auxiliary services system is to be grouped and kept segregated, as far as feasible.
 - ii) Electrical cables supplying power to redundant equipment are to exit the switchboard and be routed to the equipment, as far apart, as possible.

6.2. Operational Manual**6.2.1. General**

- 6.2.1.1. For the sake of guiding the operating personnel, an operating manual, which is consistent with the information and criteria upon which the ship's classification is based, is to be placed aboard the ship. This manual is to be such that it gives clear guidance to the ship's crew about its redundancy features and measures that need to be taken for effectively and quickly putting it back into service in the event that its normal propulsion capability is lost.
- 6.2.1.2. For review by INTLREG, the operating manual is to be submitted. It is thereby ensured that the information given in Sect [6.2.2] below is consistent with the design information and limitations considered in the ship's classification. However, INTLREG is not responsible for the operation of the ship.

6.2.2. Required Information

- 6.2.2.1. The operating manual is to comprise of the following, as a minimum:
 - i) Ship's name and INTLREG ID number
 - ii) Simplified diagram and descriptions of the propulsion redundancy features
 - iii) Similar simplified diagram and descriptions of the propulsion systems in normal condition
 - iv) Reduced propulsion capability in terms of estimated worst sea-states which the ship may withstand without drifting (for vessels with + in the Class Notation)
 - v) Test results for the ship's maneuverability at reduced speed (for ships without + in the Class Notation).
 - vi) Step-by-step instructions to use the redundancy features
 - vii) Detailed instructions for local propulsion machinery control
 - viii) Description of the communication systems
- 6.2.2.2. Any amendments made to the existing propulsion systems are to be approved by INTLREG and accordingly the operating manual is to be updated and submitted for review.

SECTION 7 TEST AND TRIAL

Contents

7.1. General	567
7.2. Fault Simulation Test.....	567
7.3. Communication System Test	567

7.1. General

During the sea trial, the propulsion and steering capability are to be tested as per an approved test program to validate conformance to this section.

7.2. Fault Simulation Test

Simulation tests for the redundancy arrangements are to be done to verify that, upon any single failure, the propulsion and steering systems remain in operational mode, or the back-up systems may speedily be brought into operation.

7.3. Communication System Test

The effectiveness of the communication systems, as required in Sec-5 [5.7], is required to be tested to validate that local control of the propulsion systems may be done as required.

CHAPTER 12 RUDDER STOCKS AND SHAFTS

CONTENTS

SECTION 1 RUDDER STOCKS	569
SECTION 2 RUDDER SHAFTS	578

SECTION 1 RUDDER STOCKS

Contents

1.1 General..... 570

1.2 Rudder stock with couplings 570

1.1. General

- 1.1.1. Stresses determined by direct calculations as indicated in Part-4, Ch-2, Sec-7, [7.1.1] are normally to give maximum equivalent stress, $\sigma_e = 118 f_1$ N/mm² and Maximum Shear stress $\tau = 68 f_1$ N/mm². The equivalent stress for axles in combined bending and torsion may be taken as:

$$\sigma_e = \sqrt{\sigma^2 + 3 \tau^2} \text{ , N/mm}^2$$

Where;

σ = bending stress in N/mm²

τ = torsional stress in N/mm²

- 1.1.2. The requirements to diameters are applicable regardless of liner. Both ahead and astern conditions are required to be considered.
- 1.1.3. A rudder stock cone coupling connection without hydraulic arrangement for mounting and dismounting are not required to be applied for spade rudders.
- 1.1.4. At each end of the cone coupling, an effective sealing is required to be provided.
- 1.1.5. The Expected Torque considered necessary to operate the rudder, in accordance with Ch-6, Sec-7/ [7.4.1(i)], is to be indicated on the submitted rudder or steering gear plan. It is to be noted that this expected torque is not the design torque for rudder scantlings.
- 1.1.6. Strong and effective structural rudder stops are to be fitted. Where adequate positive mechanical stops are provided within the steering gear in accordance with Ch-6, Sec-3/ [3.6], structural stops will not be required.

1.2. Rudder stock with couplings

- 1.2.1. The diameter requirement is given by:

$$d_s = 42 k_b \sqrt[3]{M_{TR} \cdot k} \text{ , mm}$$

k_b = 1 above the rudder carrier, except where the rudder stock is subjected to bending moment induced by the rudder actuator (bearing arrangement versus rudder stock bending deflections, or actuator forces acting on tiller)

$$= \left(1 + \frac{4}{3} \left(\frac{M_B}{M_{TR}} \right)^2 \right)^{\frac{1}{6}} \text{ , at arbitrary cross-section}$$

M_B = calculated bending moment in kN-m at the section in question.

$$M_B = F_R \cdot h_s \text{ (kN-m) at neck bearing for spade rudder.}$$

For other rudder types M_B may generally be based on direct calculation of bending moment distribution. At neck bearing for semi-spade rudder M_B shall not be taken less than $0.5 M_B$ as given in formula below. If direct calculations of bending moment distribution are not carried out, M_B at the neck bearing or the rudder coupling may be taken as follows:

- For balanced rudder with heel support:

$$M_B = \frac{F_R H}{7} \text{ , kN-m}$$

- For semi-spade rudder:

$$M_B = \frac{F_R H}{17} \text{ , kN-m}$$

h_s = vertical distance in m from the centroid of the rudder area to the middle of the neck bearing or the coupling.

For rudders where the neck bearing is mounted on a trunk extending into the rudder, h_s is not to be taken less than $H/6$.

At the bearing above neck bearing $M_B = 0$ except as follows:

- For rotary vane type actuators with two rotor bearings, which allow only small free deflections, calculation of bending moment influence may be required if bending deflection in way of upper bearing, for the design rudder force, F_R , exceeds two times the diametrical bearing clearances. In lieu of a direct calculation, the deflection of the rudder stock between the rotor bearings δ_{ub} may be taken equal to:

$$\delta_{ub} = \frac{10^5 l h_{ub} M_B}{6 E I_a}, \text{ mm}$$

I_a = moment of inertia of rudder stock in cm⁴

$l = l_a h_f$ for arrangements with upper pintle bearing

$l = l_a$ for arrangements with neck bearing

l_a = distance in m from mid-height of neck bearing or upper pintle bearing, as applicable, to mid-height of upper stock bearing

h_f = distance in m from upper end of rudder to mid-height neck bearing

h_{ub} = centre distance of the rotor bearings in mm

- For actuator force induced bending moment the greater of the following:

$$M_{BU} = F_{des} h_A, \text{ kN-m}$$

$$M_{BU} = F_{MTR} h_A, \text{ kN-m}$$

h_A = vertical distance between force and bearing centre

F_{MTR} = net radial force on rudder stock in way of actuator, with actuator(s) working at a pressure corresponding to rule rudder torque, M_{TR} .

M_{BU} = bending moment at bearing above neck bearing

F_{des} = radial force induced by actuator at design pressure.

Minimum diameter of the rudder stock between the neck and the bearing above shall not be less than if tapered with $k_b = 1.0$ at the second bearing.

In steering systems with more than one rudder where the torque from one actuator can be transferred to another, for instance by means of a connecting rod, the rudders stock shall not be permanently damaged when exposed to the sum of actuating loads (refer Ch-6 of this part).

- 1.2.2. A key shall be provided for coupling between stock and rudder when dry fitting is applied. Tapered cone connections between rudder stock and rudder shall have strength equivalent to that required for rudder stock with respect to transmission of torque and bending moments as relevant and shall comply with the following (Refer Fig.12.1.1):

Table 12.1.1:

	Dry fitting with key	Oil injection ¹⁾
Length/diameter ratio (l_t/d_s)	≥ 1.5	≥ 1.2
Hub/Shaft diameter ratio (D/d_s)	≥ 1.5	≥ 1.25
Taper of cone	1:8 – 1:12	1: ≥ 12 ²⁾
Contact Surface roughness in micron (R_A)	maximum 3.5	maximum 1.6
1) The design must enable escape of the oil from between the mating surfaces.		
2) Tapering 1 ≥ 15 is recommended for higher tolerances for push-up length		

- Contact area minimum 70% evenly distributed (Refer Pt 4,Ch 2, Sect [7.4.6] and sect [10.2] for control and testing)
- The connection shall be secured by a nut which is properly locked to the shaft

1.2.3. Connection between rudder stock and steering gear to be according to Chapter-6 of this part.

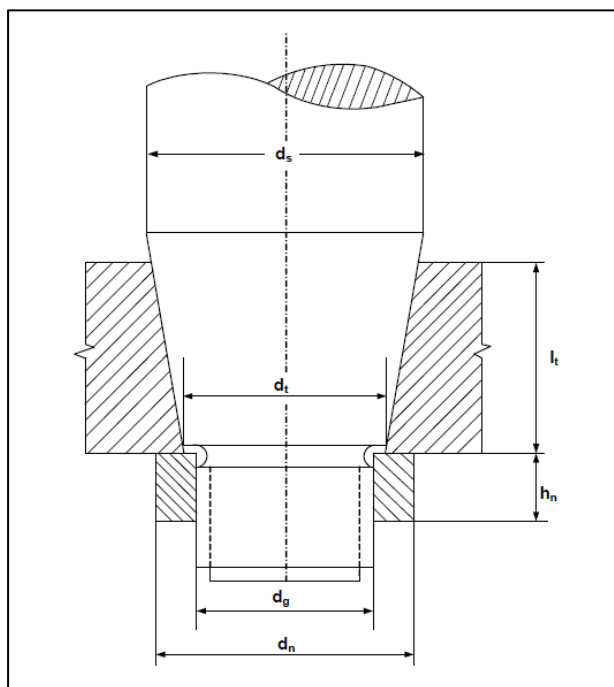


Figure 12.1.1: Cone coupling

1.2.4. Where the tapered end of the rudder stock is shrink fitted to the rudder, with hydraulic arrangement for mounting and dismounting (with oil injection and hydraulic nut), the necessary push-up length and push-up force shall be based on the following:

a) Pull-up length, minimum:

$$\delta_{min} = K(\Delta_{min} + 2(R_{Ai} + R_{Ae})10^{-3}) \text{ , mm}$$

$\delta_{min} \geq \text{mm}$ for all keyless rudder - rudder stock connections.

b) Pull-up length, maximum

$$\delta_{max} = K(\Delta_{max} + 2(R_{Ai} + R_{Ae})10^{-3}) \text{ (mm)}$$

δ = pull-up length (mm)

$$K = \text{taer of the cone} = l_t / (d_s - d_t) \text{ (mm)}$$

Δ_{min} = calculated minimum shrinkage allowance

Δ_{max} = calculated maximum shrinkage allowance

R_{Ai} = surface roughness R_A of shaft (micron)

R_{Ae} = surface roughness R_A of hub (micron)

- c) Shrinkage allowance = Δ (mm)

$$\Delta = \frac{2d_p}{E} \left(\frac{1}{1 - c_e^2} \right)$$

Where;

E = Modulus of elasticity = 2.06×10^5 N/mm².

c_e = diameter ratio d/D at considered section

d = mean shaft diameter (mm)

p = surface pressure

D = outer diameter of the hub at considered section (mm).

Minimum shrinkage allowance ($\Delta_{\min}$) shall be calculated based on average diameters and the minimum required surface pressure ($p_{\min}$).

Maximum shrinkage allowance ($\Delta_{\max}$) shall be calculated based on average diameters and maximum Permissible surface pressure ($p_{\max}$).

In case hub wall thicknesses have large variation the mean outer diameter of the hub will have to be specially considered.

- d) The minimum surface pressure used for calculation of pull-up length ($\delta_{\min}$) shall be taken as the greater of:

$$p_{\min} \geq p_r \quad , \text{ or } \quad p_{\min} \geq 1.25p_b$$

The maximum surface pressure used for calculation of pull-up length ($\delta_{\max}$) shall not exceed:

$$P_{\max} \leq \left[\left(k \sigma_t \frac{1 - c_e^2}{\sqrt{3 + c_e^4}} \right) - P_b \right] \text{ (N/mm}^2\text{)}$$

k = 0.95 for steel forging and cast steel

= 0.90 for nodular cast iron

= 0.50 for keyed connections.

Variation due to different hub wall thickness shall be considered.

Pressure at the bigger end due to bending moment, M_b may be taken as:

$$P_b = \frac{3.5M_b}{d_m l^2} 10^6 \text{ (N/mm}^2\text{)}$$

Which may be reduced to zero at a distance $l_x = 0.5 d$ or $0.5 l$ (smaller applies) as follows:

$$P_{bx} = P_b \left(1 - \sqrt{\frac{l_x}{0.5d_x}} \right) \text{ (N/mm}^2\text{)}$$

p_{bx} = pressure due to bending moment at position x

l_x = distance from top of cone, Refer Fig.12.1.1 (mm)

d_x = ditto shaft diameter at distance l_x (mm)

M_b = bending moment (kNm).

- e) Average surface pressure (p_r) due to shrinkage for transmission of torque by means of friction shall be

$$P_r \geq \frac{2 T_{fr} 10^6}{\pi d_m^2 l \mu} \quad (\text{N/mm}^2)$$

T_{fr} = required torque to be transmitted by means of friction in following coupling = $3 M_{TR}$

d_m = mean diameter = $0.5 (d_s + d_t)$ (mm)

l = effective cone length, which may normally be taken as boss length l_t (mm), Refer Fig.12.1.1

μ = maximum 0.14 for oil injection fitting
= maximum 0.17 for dry fitting

M_{TR} = rule rudder torque (kNm), Refer-Pt 4, Ch 2, Sect [4.1.2] and [4.2.2]

- f) Force, F for pull-up corresponding to a surface pressure, p may be estimated as follows:

$$F \geq \pi d_m l p \left(\frac{1}{2K} + \mu_{pu} \right) 10^{-3} \quad (\text{kN})$$

μ_{pu} = Average friction coefficient for pull-up.

For oil injection usually in the range 0.01 to 0.03.

For dry fitting usually in the range of 0.1 to 0.2, typically 0.15.

- 1.2.5. In order to avoid mutual movements between rudder stock and hub, tapered key-fitted (keyed) connections shall be designed to transmit rudder torque in all normal operating conditions by means of friction. The key shall be regarded as a securing device.

For calculation of required pull-up length (δ), Refer [1.2.4] (a), (b) and (e) where p_r is given with $T_{fr} = 1.5 M_{TR}$.

Where it is not possible or feasible to obtain the required pull-up length (δ), special attention shall be given to fitting of the key in order to ensure tight fit (no free sideways play between key and key-way). In this case T_{fr} may be taken as $T_{fr} = 0.5 M_{TR}$.

Tapered key-fitted connections shall in addition comply with the following:

- a) Key-ways shall not be placed in areas with high bending stresses in the rudder stock and shall be provided with sufficient fillet radii (r):

$$r \geq 0.01 d_s$$

- b) The abutting surface area between the key and key-way in the rudder stock and hub respectively, shall not be less than:

$$A_{ab} \geq \frac{65 T_{key}}{d_m f_k} (\text{cm}^2)$$

Where;

Torque, T_{key} is (kNm):

$$T_{key} \geq 2 M_{TR} - T_{fr} \quad , \text{ based on verification of pull-up force, and}$$

$$T_{key} \geq 2 M_{TR} - 0.7 T_{fr} \quad , \text{ based on verification of pull-up distance,}$$

$$\text{but not less than: } T_{key} = M_{TR} (\text{kNm}).$$

Yield strength used for calculation of f_k shall not exceed the lowest of: $\sigma_{f, key}$
and $1.5 \sigma_{f, hub}$ (for calculation of hub) or
 $1.5 \sigma_{f, stock}$ (for calculation of stock).

A_{ab} = effective abutting area of the key-way in stock and hub respectively (cm^2)

f_k = material factor

$\sigma_{f, \text{hub}}$ = yield strength of hub material (N/mm²)

$\sigma_{f, \text{key}}$ = yield strength of key material (N/mm²)

$\sigma_{f, \text{stock}}$ = yield strength of stock material (N/mm²).

c) The height/width ratio of the key shall be

$$\frac{h}{b} \leq 0.6$$

h = height (thickness) of the key

b = width of the key.

Where necessary tapered connections shall be provided with suitable means (e.g. oil grooves and bores to connect hydraulic injection oil pump) to facilitate dismantling of the hub.

The dimensions at the slugging nut shall not be less than .Refer Figure 12.1.1

- External thread diameter:

$$d_g = 0.65 d_s$$

- Height of nut:

$$h_n = 0.6 d_g$$

- Outer diameter of nut:

$$d_n = 1.2 d_t, \text{ or } d_n = 1.5 d_g, \text{ whichever is the greater.}$$

1.2.6. Where the rudder stock is connected to the rudder by horizontal flange coupling the following Requirements shall be complied with:

- At least 6 tight fitted coupling bolts shall be used.
- The shear diameter of coupling bolts shall not be less than:

$$d_b = 0.62 \sqrt{\frac{d_s^3 f_{ms}}{n e f_{mb}}} \text{ mm}$$

d_s = rule diameter as given in [1.2.1] for the rudder stock at coupling flange.

For rudder stocks with a slanted lower part, d_s shall be determined with

$$M_{TR} = M_{TRf}$$

where M_{TRf} given as $M_{TRf} = M_{TR} + \frac{y_l M_B}{l}$, where denotes the bending moment of the stock at the coupling flange according to [1.2.1], l denotes the vertical distance from the upper bearing to the flange attachment to the rudder, and y_l denotes the longitudinal distance, if any, from the rudder axis to the centre of the coupling bolt system

n = number of coupling bolts

e = mean distance in mm from the Centre of bolts to the Centre of the bolt system

f_{ms} = material factor (1/k) for rudder stock

f_{mb} = material factor (1/k) for bolts.

c) Nuts shall be securely fastened by split pins or other efficient means.

- d) If the coupling is subjected to bending stresses, the mean distance a from the Centre of the bolts to the longitudinal Centre line of the coupling shall not be less than $0.6 d_s$. Further, bolt pre-stress in shear part of bolt shall normally be in the range of $60 f_{mb}$ to $120 f_{mb}$. In the minimum section of the bolt, pre-stress shall not exceed $165 f_{mb}$.
- e) The width of material outside the bolt holes shall not be less than $0.67 d_b$.
- f) The thickness of coupling flanges shall not be less than:

$$t = k_t \sqrt{\frac{\beta M_B}{a f_{mf}}}, \text{ mm}$$

at the root section, however, not less than $0.25 d_s$. Away from the root section the flange thickness may be evenly tapered down to $0.25 d_s$ in way of the clamping bolts.

f_{mf} = material factor ($1/k$) for flange,

M_B = bending moment in kN-m at coupling

a = mean distance from Centre of bolts to the longitudinal Centre line of the coupling, in mm

d = diameter as built of rudder stock for stock flange, breadth of rudder for rudder flange, both in mm

β = factor to be taken from following Table-12.1.2.

Table 12.1.2: Value of β

d/a	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6
β	1.8	1.5	1.25	1.0	0.8	0.6	0.45	0.35	0.25

K_r is determined according to the following Table-12.2.3.

Table 12.1.3: Value of K_r

K_f	0.5	0.4	0.3
K_r	70	75	84

$$k_f = \frac{r_f}{(a - 0.5d)}$$

r_f = radius of fillet, not to be taken less than $0.3(a - 0.5d)$

Note: The mean distance from Centre of bolts to the longitudinal centerline of the coupling, a , may in general be taken as:

$$a = \frac{\sum y_i}{n}$$

The mean distance, e , from the Centre of bolts to the Centre of the bolt system may in general be taken as:

$$c = \frac{\sum \sqrt{(x_i - x_o)^2 + y_i^2}}{n}$$

$$x_o = \frac{\sum x_i}{n}$$

n = number of bolts.

y_i = distance from the longitudinal centerline of the rudder to the Centre of bolt i .

x_i = longitudinal distance from, e.g. the rudder axis to the Centre of bolt i .

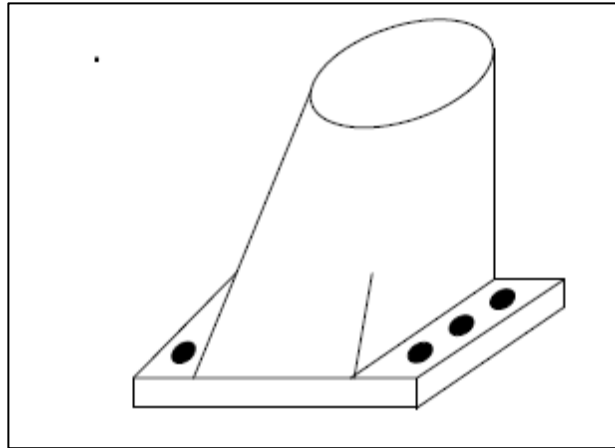


Figure 12.2.2: Rudder stock / flange

- 1.2.7. The welded joint between the rudder stock and the flange shall be made in accordance with Fig.12.2.3 or equivalent

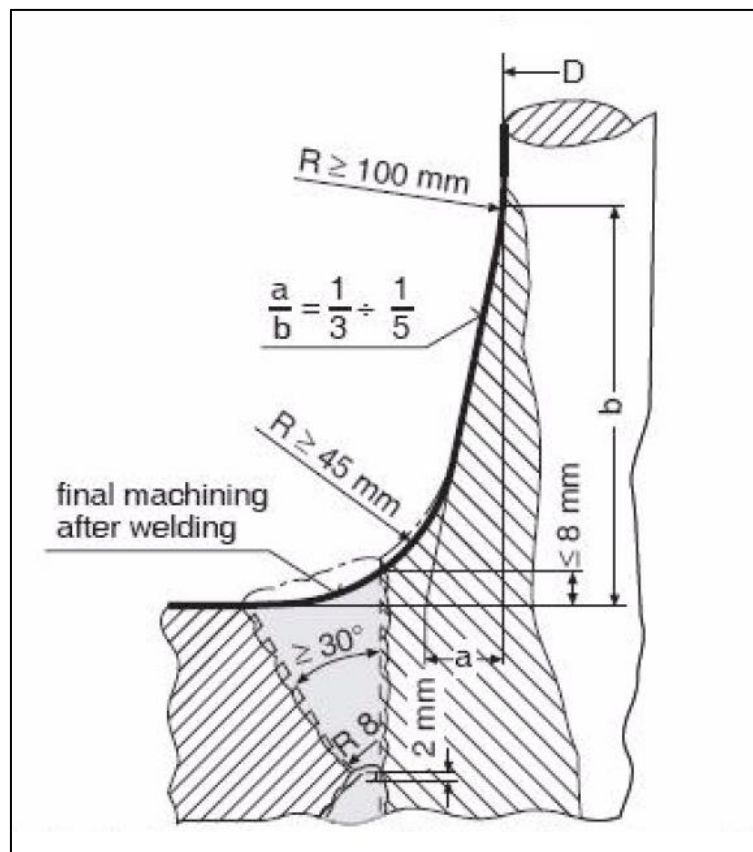


Figure 12.2.3: Welded joint between rudder stock and coupling flange

SECTION 2 RUDDER SHAFTS

Contents

2.1. Rudder shaft 579

2.2. Bearings and pintles 579

2.1. Rudder shaft

2.1.1. At the lower bearing, the rudder shaft diameter shall not be less than:

$$d_l = 39 \left(\frac{F_R c (l-c)}{l f_1} \right)^{\frac{2}{3}}, \text{ mm}$$

$$c = \frac{a + b}{2}$$

l , a and b are given in Fig-12.2.1 in m.

The diameter d_f below the coupling flange shall be 10% greater than d_l . If, however, the rudder shaft is protected by a corrosion-resistant composition above the upper bearing, d_f may be equal to d_l .

2.1.2. The taper, nut, etc. at lower end of rudder shafts, shall be taken as for rudder stock given in Sec-1/ [1.2.2].

2.1.3. The scantlings of the vertical coupling at the upper end of the rudder shaft shall be as required for horizontal rudder couplings in Sec-1, [1.2.6], inserting the shaft d_l instead of the stock diameter d_s in the formula for bolt diameter.

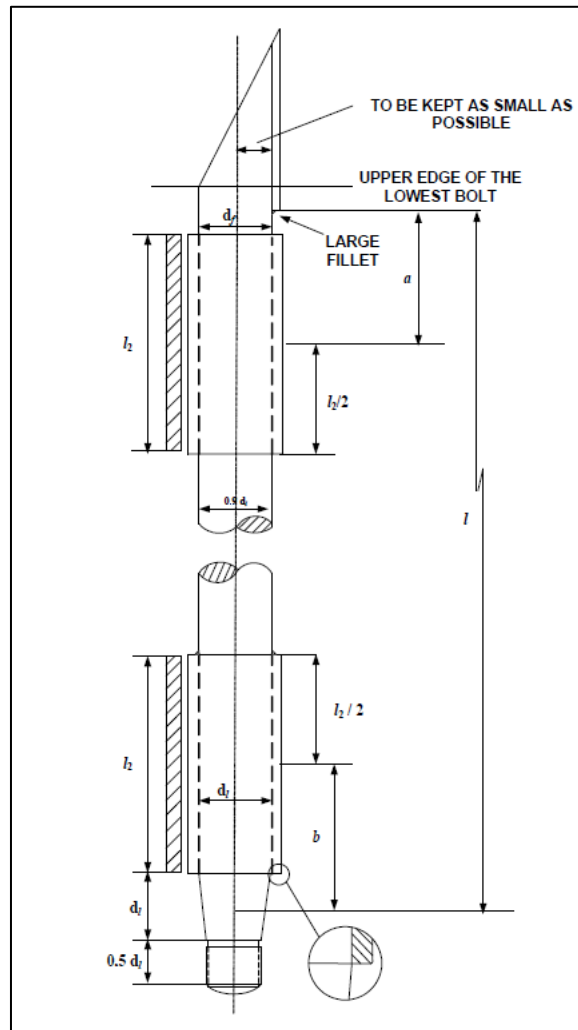


Figure 12.2.1: Rudder shaft

2.2. Bearings and pintles

2.2.1. The height of bearing surfaces shall not be greater than:

$$h_b = 1.2 d_{sl} , (\text{mm})$$

d_{sl} = diameter in mm of rudder shaft or pintle measured on the outside of liners. Bearing arrangements with a height of the bearing greater than above, may be accepted based on direct calculations provided by the designer showing acceptable clearances at the upper and lower edges of the bearing.

2.2.2. The bearing surface area shall not be less than:

$$A_B = h_b d_{sl} = \frac{P}{p_m} 10^6 , (\text{mm}^2)$$

h_b and d_{sl} = as given in [2.2.1] above.

P = calculated reaction force in kN at the bearing in question

p_m = maximum surface pressure as given in Part-4, Ch-2, Table-2.2.2.

If direct calculations of reaction forces are not carried out, P at various bearings may be taken as given in the following (note that values given for stern pintle or neck bearing in semi-spade rudders are minimum values):

- a) For balanced rudder with heel support:
 - $P = 0.6 F_R$, kN, at heel pintle bearing
 - $P = 0.7 F_R$, kN, at stern pintle or neck bearing
 - $P = 0.1 F_R$, kN, at upper bearing.
- b) For semi-spade rudder (The horn pintle bearing is assumed to be situated not more than 0.1 H above or below the Centre of the rudder area):
 - $P = 1.1 F_R$, kN, at horn pintle bearing
 - $P_{min} = 0.4 F_R$, kN, at stern pintle or $0.3 F_R$, kN, at neck bearing
 - $P = 0.1 F_R$, kN, at upper bearing
- c) For spade rudder:
 - $P = \frac{h_1+h_2}{h_2} F_R$, (kN) at neck bearing
 - $P = \frac{h_1}{h_2} F_R$, (kN) at upper bearing
 - h_1 = vertical distance from the centroid of rudder area to the middle of the neck bearing
 - h_2 = vertical distance from the middle of the neck bearing to the middle of the upper bearing. H = as defined in Part-4, Ch-2, Sec-7/ [7.4.2 (c)].
- d) Upper bearing:
 - P shall not be taken less than specified in a), b) or c)
 - For ram type actuator, P shall be calculated considering reaction force induced by one ram.

2.2.3. The diameter of pintles shall not be less than:

$$d_p = 10\sqrt{P \cdot k} , \text{mm}$$

P = as given in [2.2.2] above.

2.2.4. The thickness of any bushings in rudder bearings shall not be less than:

$$t_v = 0.32 \sqrt{P}$$

- Minimum 8 mm for steel and bronze
- maker's specification for synthetic materials

- Minimum 22 mm for Lignum Vitae
- Other materials shall be especially considered.
- P = as given in [2.2.2] above.

The bushing shall be effectively secured to the bearing. The thickness of bearing material outside of the bushing shall not be less than:

- a) For balanced rudder or semi-spade rudders:

$$t = 1.7\sqrt{P \cdot k} \text{ , mm}$$

- b) For spade rudders:

$$t = 2.0\sqrt{P \cdot k} \text{ , mm}$$

Reduced thickness may be accepted based on direct analysis.
P = as given in [2.2.2] above.

- 2.2.5. With metal bearings the clearance on the diameter is normally not to be less than:

$$0.001 d_b + 1.0 \text{ , mm}$$

d_b = inner diameter in mm of the bushing.

If non-metallic bearing material is applied, the bearing clearance shall be specially determined considering the materials' swelling and thermal expansion properties. This clearance shall not be taken less than 1.5 mm on the bearing diameter.

The clearance should be related to the calculated angular deflection over the bearing length e.g. neck bearing of spade rudder. However, due attention should be given to the manufacturer's recommended clearance. For pressure lubricated bearings the clearance will be especially considered.

- 2.2.6. Pintles shall have a conical attachment to the gudgeons. The pintle fitting shall be as required for rudder stock in Sec-1, [1.2.4], inserting the pintle diameter d_p instead of the stock diameter d_s in the various formulae with the following exemptions:

- In the case of dry pintle fitting, p_{min} used for calculation of pull-up length (δ_{min}) shall be taken as the greater of p_r and p_b .
- Irrespective of pintle fitting calculation result, pull-up length (δ_{min}) shall be not less than 0.5 mm for dry fitting and 2.0 mm for oil injection fitting.

The conical pintle connection shall comply with the following Table-12.2.1.

Table 12.2.1:

	Dry fitting (Refer note 1)	Oil injection (Refer note 2)
Length/diameter ratio(l_t/d_p)	≥ 1.0	≥ 1.0
Hub/pintle diameter ratio (D/d_p)	≥ 1.5	≥ 1.5
Taper of cone	1:8 to 1:12	1: ≥ 12
Contact Surface roughness in micron (R_A)	maximum 3.5	Maximum 1.6
Note: 1. Slugging nut to be provided in accordance with Sec-1, [1.2.5]. 2. The design must enable escape of the oil from between the mating surfaces.		

An effective sealing against sea water shall be provided at both ends of the cone.

Contact area shall be minimum 70% evenly distributed (refer Part-4, Ch-2, Sec-7, [7.4.6] for control and testing).

The connection shall be secured by a nut which is properly locked to the pintle.

The Values for Bending moment, M_b and friction torque, T_{fr} in the fitting calculations, shall be taken as given in the following:

$$M_b = P h_p 10^{-3}, (\text{kN-m})$$

$$T_{fr} = 1.5 P d_p 10^{-4}, (\text{kN-m})$$

Where P is pintle force as given in [2.2.2] of this section and h_p is bending moment arm (mm) taken as the distance from bigger end of cone to 1/3 of bearing height (shown in Fig. 12.2.2)

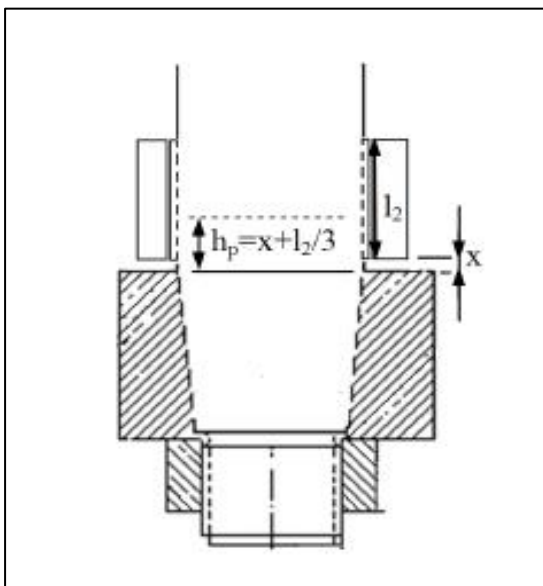


Figure 12.2.2: Bending moment arm for pintle force

CHAPTER 13 FIRE SAFETY

CONTENTS

SECTION 1 GENERAL.....	584
SECTION 2 FIRE PREVENTION.....	598
SECTION 3 SUPPRESSION OF FIRE.....	618
SECTION 4 ESCAPE AND OPERATIONAL REQUIREMENTS.....	675
SECTION 5 ALTERNATIVE DESIGN ARRANGEMENTS AND SPECIAL REQUIREMENTS.....	688

SECTION 1 GENERAL

Contents

1.1. Application 585

1.2. Objectives And Requirements 588

1.3. Definitions 589

1.1. Application**1.1.1 General**

1.1.1.1 This part and its requirements generally applicable to ships to be classed for unrestricted service under the categories mentioned below :

- Cargo ships of 500 gross tons and above
- Passenger ships

Any exemptions granted by the National Statutory Authorities will be given consideration in case of Special Trade Passenger Vessels (Such cases normally requires full conformation to the IMO Rules, annexed to the Special Trade Passenger Ships, 1971 and the Protocol on Space Requirements for Special Trade Passenger Ships, 1973).

Similarly, consideration will be given to any exemptions granted by the National Statutory Authorities in case the sheltered nature and conditions of usual operation are such that the application of any specific requirements of this part is rendered unnecessary or unreasonable.

Even though the requirements for Cargo Ships below 500 GT will be specially considered, these requirements are also not supposed to be less than that required by the National Statutory Authorities.

1.1.1.2 At the same time, the requirements of this part are considered to meet the Regulations of the International Convention for the Safety of Life at Sea (SOLAS), 1974, and applicable amendments. However, special attention is also given to any applicable requirements of the National Statutory Authority.

1.1.1.3 The acceptance of underlying requirements will be given consideration as an alternative to the requirements of this part:

- 1.1.1.3.1 Firefighting appliances and equipment and insulating materials approved by the National Statutory Authority.
- 1.1.1.3.2 Requirements of the National Statutory Authority.

1.1.1.4 A list of IMO MSC Circulars and Assembly Resolutions referred to in this part is given at the end of this chapter (Table 13.1.1)

1.1.2 Documentation

1.1.2.1 The plans and particulars detailed in Sect [1.2.2] to [1.2.3], where applicable, are to be presented at the time of approval, alongside all additional relevant information such as number of passengers, gross tonnage, date of build (for existing ships) and arrangement of helideck etc.

1.1.2.2 At the time of approval, for Fire Protection, the plans and information mentioned below are to be:

- 1.1.2.2.1 A declaration of the method adopted for structural fire protection clearly indicating fulfillment of the regulations;
- 1.1.2.2.2 A General Arrangement Plan indicating the major fire zones, escape stairways and

- 1.1.2.2.3 the structural fire protection bulkheads and decks within the major fire zones, including the boiler and engine rooms, paint stores, the galleys, navigating bridge, firefighting control room, radio room, battery locker and emergency generator rooms.
 - 1.1.2.2.4 A plan clearly exhibiting the details of construction of the fire protection bulkheads and decks along with the particulars of any surface laminates employed;
 - 1.1.2.2.5 A plan showing the construction of the fire doors;
 - 1.1.2.2.6 A ventilation plan displaying the ducts and dampers therein and the positions of the controls for halting the system;
 - 1.1.2.2.7 A plan showing the detection system and/or sprinkler system, as applicable;
 - 1.1.2.2.8 A plan indicating the remote control for the fire doors, if applicable;
 - 1.1.2.2.9 A plan exhibiting the location and arrangement of the emergency stop for the oil fuel unit pumps and for closing the valves on the pipes from oil fuel tanks;
 - 1.1.2.2.10 A plan of the fire alarm system;
 - 1.1.2.2.11 Copies of the certificates of approval by National Authorities in respect of all 'A' and 'B' Class fire divisions, materials having low flame-spread characteristics, non-combustible materials etc., which are to be used but have not been approved by INTLREG.
- 1.1.3 For Fire Extinguishing system, underlying plans are to be submitted:
- 1.1.3.1 A General Arrangement Plan where the disposition of all the firefighting equipment including the fixed fire extinguishing systems in the cargo holds, on deck and in the machinery spaces; the fire main, the disposition of the non-portable and portable extinguishers and the types used; and the site and details of the firemen's outfits is given;
 - 1.1.3.2 A plan indicating the layout and construction of the fire main, including the emergency and main fire pumps, pipe sizes and materials; isolating valves, the international shore connections and the cross connections to any other system;
 - 1.1.3.3 A plan showing the details of each fixed firefighting system, including calculations for the quantities of the media used and the intended rates of their application.
- 1.1.4 Requirements applicable to existing ships
- 1.1.4.1 Unless expressly provided otherwise, for ships constructed before 1 July 2002 the requirements which are applicable under Chapter II-2 of the International Convention for the Safety of Life at Sea, 1974, as amended by resolutions MSC.1(XLV), MSC.6(48), MSC.13(57), MSC.22(59), MSC.24(60), MSC.27(61), MSC.31(63) and MSC.57(67) are to be met..

1.1.5 Applicable requirements depending on ship type

Unless expressly provided otherwise:

- 1.1.5.1 Requisites referring to "tankers" apply to tankers Section 3 [3.3.4] for definition, however these are also subject to the requirements specified in Section 5 below;
- 1.1.5.2 Requisite not referring to a specific ship type apply to ships of all types.

1.1.6 Application of requirements for tankers

1.1.6.1 Requirements for tankers in this part are to apply to tankers carrying:

- 1.1.6.1.1 Petroleum products having a flashpoint not surpassing 60°C (closed cup test), as determined by an approved flashpoint apparatus and a Reid vapour pressure which is below the atmospheric pressure or
- 1.1.6.1.2 Crude oil or ;
- 1.1.6.1.3 Other liquid products with same fire hazard.
(Also Refer Section 3[3.3.4] for definition of 'tanker').
- 1.1.6.1.4 Where liquid cargoes other than those referred to in Section [1.1.6] or liquefied gases which bring in additional fire hazards are proposed to be carried.

1.1.6.2 A liquid cargo with a flashpoint of not surpassing 60°C, for which a regular foam firefighting system conforming to the Fire Safety Systems Code is not effective, is considered to be a cargo introducing additional fire hazards in this context. The underlying additional measures are required:

- 1.1.6.2.1 The foam is to be of alcohol resistant type;
- 1.1.6.2.2 The National Statutory Authority is to approve of the type of foam concentrates for use in chemical tankers (refer to the guidelines for performance and testing criteria and surveys of expansion foam concentrates for fire extinguishing systems for chemical tankers (MSC/circ.799)); and
- 1.1.6.2.3 The capacity and application rates of the foam extinguishing system is to conform to Pt.7B, except that lower application rates may be accepted based on performance tests. For tankers fitted with inert gas systems, a quantity of foam concentrate enough for 20 min of foam generation may be accepted. (Refer to the information on flashpoint and recommended fire-fighting media for chemicals to which neither the IBC nor BCH codes apply (MSC/circ. 553)).

1.1.6.3 For the purpose of this Section, a liquid cargo with vapor pressure greater than 1.013 bar absolute at 37.8°C is considered to be a cargo introducing additional fire hazards and ships carrying such substances are to fulfill the requirements of Pt.7B.

1.1.6.4 When such ships run in restricted areas and at restricted times, the requirements for refrigeration systems may be waived in as per the requirements of Pt 7B.

1.1.6.5 Liquid cargoes with a flashpoint surpassing 60°C, other than oil products or liquid cargoes subject to the requirements of Pt.7B, are considered to comprise of low fire risk, not requiring the protection of a fixed foam extinguishing system.

- 1.1.6.6 Tankers carrying petroleum products with a flashpoint exceeding 60°C are to comply with the requirements provided in Section [3.4.3.4] and the requirements for cargo ships other than tankers, except that, in lieu of the fixed fire extinguishing system required in Section [3.4], they are to be fitted with a fixed deck foam system which is to comply with the provisions of the Fire Safety Systems Code.
- 1.1.6.7 Combination carriers are not to carry cargoes other than oil unless all cargo tanks are empty of oil and gas freed or unless the arrangements in each case are approved as per the Guidelines for inert gas systems (MSC/Circ.353), as amended by (MSC/Circ.387).
- 1.1.6.8 Chemical tankers and gas carriers are to fulfill the requirements for tankers, except where alternative and supplementary arrangements are provided as per Pt.7B.
- 1.1.6.9 , Pt 7B Sections as appropriate.
- 1.1.6.10 The requisites of Pt 7B and a system for continuous monitoring of the concentration of hydrocarbon gases are to be fitted on all tankers constructed prior to 1 July 2002 by the date of the first scheduled dry-docking after 1 July 2002, but not after 1 July 2005. Sampling points or detector heads are to be placed in suitable positions so that the potentially dangerous leakages are readily detected. When the hydrocarbon gas concentration attains a pre-set level which is not to be higher than 10% of the lower flammable limit, an audible and visual alarm signal is to be automatically effected in the pump-room and cargo control room to alert personnel to the potential hazard. However, existing monitoring systems already fitted having a pre-set level not more than 30% of the lower flammable limit may be accepted.

1.2. OBJECTIVES AND REQUIREMENTS

1.2.1 Fire safety objectives

- 1.2.1.1 The fire safety objectives of this part are to:
 - 1.2.1.1.1 Prevent the occurrence of fire and explosion;
 - 1.2.1.1.2 reduce the risk to life caused by fire;
 - 1.2.1.1.3 Reduce the risk of damage caused by fire to the ship, its cargo and the environment;
 - 1.2.1.1.4 Contain, control and suppress fire and explosion in the compartment of origin; and
 - 1.2.1.1.5 Provide adequate and readily accessible means of escape for passengers and crew.

1.2.2 Functional requirements

- 1.2.2.1. In order to achieve the fire safety objectives set out in Section [2.1] above, the following functional requirements are embodied in the regulations of this chapter as appropriate:
 - 1.2.2.1.1 Division of the ship into main vertical and horizontal zones by thermal and structural boundaries;

- 1.2.2.1.2 Separation of accommodation spaces from the remainder of the ship by thermal and structural boundaries;
- 1.2.2.1.3 Restricted use of combustible materials;
- 1.2.2.1.4 Detection of any fire in the zone of origin;
- 1.2.2.1.5 Containment and extinction of any fire in the space of origin;
- 1.2.2.1.6 Identification and protection of means of escape;
- 1.2.2.1.7 Access for fire-fighting;
- 1.2.2.1.8 Ready availability of fire-extinguishing appliances; and
- 1.2.2.1.9 Minimization of possibility of ignition of flammable cargo vapor.

1.2.3 Achievement of the fire safety objectives

- 1.2.3.1 The fire safety objectives set out in Section [2.1] above are to be achieved by ensuring compliance with the prescriptive requirements specified in Section [2, 3], 4, 5 . A ship will be considered to meet the functional requirements set out in Section 2 and to achieve the fire safety objectives set out in Section 1 when either:
- 1.2.3.2 The ship's designs and arrangements, as a whole, fulfills the relevant prescriptive requirements in Sections, 2, 3, 4, and 5.
- 1.2.3.3 The ship's designs and arrangements, as a whole, have been reviewed and approved in accordance with Sect 5 [5.1].
- 1.2.3.4 Part(s) of the ship's design and arrangements have been reviewed and approved in accordance with Sect 5 and the remaining parts of the ship comply with the relevant prescriptive requirements in Sections 2, 3 & 4.

1.3. DEFINITIONS

For the purpose of this chapter, unless expressly provided otherwise, the following definitions are to apply:

- 1.3.1. **Accommodation spaces** are those spaces which are used as public spaces viz. cabins, offices, corridors, hospitals, cinemas, games and hobbies rooms along with barber shops, lavatories and pantries containing no cooking appliances and similar spaces.
- 1.3.2. **'A' class divisions** are the divisions formed by bulkheads and decks which conforms to the criteria mentioned below:
 - 1.3.2.1. They are constructed of material equivalent to steel or steel itself;
 - 1.3.2.2. They are adequately stiffened;
 - 1.3.2.3. Their construction renders them the capability to prevent the passage of smoke and flame till the end of the one-hour standard fire test;
 - 1.3.2.4. Using approved non-combustible materials, they are insulated so that the average temperature of the unexposed side will not rise above 140°C from the original temperature, nor will the temperature, at any one point, including any joint, rise above 180°C from the original temperature within the time listed below.
 - a) Class 'A-60' 60 minutes

- b) Class 'A-30' 30 minutes
 - c) Class 'A-15' 15 minutes
 - d) Class 'A-0' 0 minutes
 - A test of prototype bulkhead or deck will be required to ascertain that it meets the requirements given above for integrity and temperature rise.
- 1.3.3. **Atriums are public** spaces located within a single main vertical zone straddling across three or more open decks.
- 1.3.4. **'B' class divisions** are those divisions formed by bulkheads, decks, ceilings or linings which fulfill the following criteria:
- 1.3.4.1. They are to be constructed so as to be capable of preventing the passage of flame to the end of the first half hour of the standard fire test;
 - 1.3.4.2. They have an insulation value such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature nor will the temperature at any point, including any joint, rise more than 225°C above the original temperature, within the time listed below:

Class 'B-15' : 15 minutes
Class 'B-0' 0 minutes
 - 1.3.4.3. They are constructed of approved non-combustible materials and all materials entering into the construction and erection of 'B' class divisions are to be non-combustible. A division comprising of a non-combustible core and combustible veneers may be accepted as a b class division, provided that the non combustible core and veneers are tested as per the relevant parts of fire test procedure code explained in Sect [1.3.22] of this section;
 - 1.3.4.4. A test of a prototype division will be required to ascertain that it meets the requirements given above for integrity and temperature rise.
- 1.3.5. **Bulkhead deck** is the uppermost deck up to which the transverse watertight bulkheads are carried.
- 1.3.6. **Cargo area** is that part of the ship that contains cargo holds, cargo tanks, slop tanks and cargo pump-rooms including pump-rooms, cofferdams, ballast and void spaces adjacent to cargo tanks and slop tanks and also deck areas throughout the length and breadth of the part of the ship over the above mentioned spaces.
- 1.3.7. **A cargo ship** is any ship which is not a passenger ship.
- 1.3.8. **Cargo spaces** are spaces used for cargo, cargo oil tanks, tanks for other liquid cargo and trunks to such spaces.
- 1.3.9. **Central Control station** is a control station in which the control and indicator functions as mentioned below are centralized:
- a) Fixed fire detection and alarm systems;
 - b) Automatic sprinklers, fire detection and alarm systems;
 - c) Fire door closures;
 - d) Fire door indicator panels;
 - e) Watertight door closures;

- f) Watertight door indicator panels;
 - g) General/fire alarms;
 - h) Communication systems including telephones;
 - i) Ventilation fans; and
 - j) Microphones to public address system.
- 1.3.10. **'C' class divisions** are divisions constructed of approved non-combustible materials. They meet neither requirements relative to the passage of smoke and flame nor limitations relative to the temperature rise. A division comprising of a non-combustible core and combustible veneers may be accepted as a 'C' class division, if that non-combustible core and veneers are tested as per the relevant portions of Fire Test Procedure Code.
- 1.3.11. **Chemical tanker** is a cargo ship constructed or adapted and used for carrying bulk of any liquid product of a flammable nature listed in Pt.7B, of the Rules.
- 1.3.12. **Closed Ro/Ro spaces** are Ro/Ro spaces which are neither weather decks nor open Ro/Ro spaces.
- 1.3.13. **Closed vehicle spaces** are neither those vehicle spaces which serve as weather decks nor open vehicle spaces.
- 1.3.14. **A combination carrier** is a cargo ship designed to transmit both oil and solid cargoes in bulk.
- 1.3.15. **Combustible material** is any material other than a non-combustible material.
- 1.3.16. **Continuous 'B' class ceilings or linings** are those 'B' class ceilings or linings which cease only at an 'A' or 'B' class division.
- 1.3.17. **Continuously manned central control station** is a central control station which is constantly manned by a responsible crew member.
- 1.3.18. **Control-stations** are those spaces where the key navigating equipment, radio or the emergency power supply sources of the ship are located or where the fire recording or fire control equipment is centralized. Spaces where the fire recording or fire control equipment is located are also considered to be a **Fire Control Station**.

Notes:

- 1) Key navigational equipment comprises, in particular, of the steering stand and the radar, compass and direction-finding equipment of the ship.
- 2) Those steering gear rooms where the emergency steering position is present do not fall under control stations.
- 3) Where, in the Rules in Chapter 13, relevant to fixed fire extinguishing systems, there are no specific requirements for the centralization within a control station of vital components of the system, such vital components may be kept in spaces which are not considered to be a control station.
- 4) Despite of battery capacity, the spaces containing, for instance, the following battery sources are to be regarded as control stations:
 - a) In general, all emergency batteries required in accordance with Pt.6,Ch.2 /Sect 3
 - b) Emergency batteries placed in separate room that serves as reserve source of energy to radiotelegraph installation.
 - c) Emergency batteries placed in separate room that supplies power during black-out and starting of the emergency generator and

d) Batteries for initiation of emergency generator

- 1.3.19. **Crude oil** is naturally occurring oil in the earth and it may be treated or kept untreated to render it fit for transportation. It comprises of the following :
- a) Crude oil from which certain distillate fractions may have been removed; and
 - b) Crude oil to which certain distillate fractions may have been added.
- 1.3.20. **Dangerous goods** are the goods referred to in SOLAS Regulation VII/2.
- 1.3.21. **Deadweight** is the disparity (in tones) between the displacement of a ship in water of a specific gravity of 1.025 at the load water-line analogous to the assigned summer freeboard and the lightweight of the ship.
- 1.3.22. **Fire safety systems code** means the International Code for Fire Safety Systems as adopted by the Maritime Safety Committee of the IMO by resolution MSC.98(73) and as may be amended by IMO (Section 21 to 35).
- 1.3.23. **Fire test procedures code** means the International Code for Application of Fire Test Procedures, as adopted by the Maritime Safety Committee of IMO by resolution MSC.61 (67), and as may be amended by IMO.
- 1.3.24. **Flashpoint** is the temperature in degrees Celsius (closed cup test) determined by means of an approved flashpoint apparatus at which a product will give off enough flammable vapour to be ignited.
- 1.3.25. **Gas carrier** is a cargo ship constructed or adapted and used for transmitting bulk of any liquefied gas or other products of a flammable nature .
- 1.3.26. **Helideck** is a purposely built helicopter landing area located on a ship including all structure, fire- fighting appliances and other equipment necessary for the safe operation of helicopters.
- 1.3.27. **Helicopter facility** is a helideck including any refueling and hangar facilities.
- 1.3.28. **Lightweight** is the displacement of a ship in tonnes without fuel, cargo, lubricating oil, ballast water, feed water and fresh water in tanks, consumable stores, and passengers and crew and their effects.
- 1.3.29. **Low flame spread** means that the surface thus described will adequately restrict the spread of flame, this being determined as per the Fire Test Procedures Code.
- 1.3.30. **Machinery spaces** are all machinery spaces of category 'A' and all other spaces containing boilers, propulsion machinery, oil fuel units, generators, steam and internal combustion engines and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces.
- 1.3.31. **Machinery spaces of category 'A'** are those spaces and trunks to such spaces which contain:
- i. Internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 [kw]; or
 - ii. Internal combustion machinery used for main propulsion; or
 - iii. Any oil-fired boiler or oil fuel unit, or any oil-fired equipment other than boilers, such as inert gas generators, incinerators, etc.

- 1.3.32. **Main vertical zones** are those sections into which the hull, superstructure, and deckhouses are divided by 'A' class divisions, the mean length of which on any deck does not generally surpass 40 [m].
- 1.3.33. **Non-combustible material** is a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750°C, this being determined in accordance with the Fire Test Procedures Code.
- 1.3.34. **Oil fuel unit** is the equipment used for the preparation of oil fuel heated or not, for delivery to an oil fired boiler (including inert gas generators, incinerator, waste disposal unit, etc.) or to an internal combustion engine (including gas turbines) and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 0.18 [N/mm²]. Oil fuel transfer pumps are not considered as oil fuel units.
- 1.3.35. **Open Ro-Ro spaces** are those Ro-Ro spaces that are either open at both ends or have an opening at one end and are provided with adequate natural ventilation effective over their entire length through permanent openings distributed in the side plating or deckhead or from above, having a total area of at least 10% of the total area of the spaces sides.
- 1.3.36. **Open vehicle spaces** are those vehicle spaces either open at both ends, or have an opening at one end and are provided with adequate natural ventilation effective over their entire length through permanent openings distributed in the side plating or deckhead or from above, having a total area of at least 10% of the total area of the space sides.
- 1.3.37. **A passenger ship** is a ship which carries more than twelve passengers, a passenger being every person other than :
- A child under one year of age; and
 - The master and members of the crew or other persons employed or engaged in any capacity on board a ship on the business of the ship.
- 1.3.38. **Prescriptive requirements** means the construction characteristics, limiting size or fire safety systems specified in Sect, 2, 3, 4, and 5.
- 1.3.39. **Public spaces** are those parts of the accommodation which are used as halls, dining rooms, lounges and similar permanently enclosed spaces.
- 1.3.40. **Rooms containing furniture and furnishings of restricted fire risk** are those rooms where the furniture and furnishing of constrained fire risk (for instance, cabins, public spaces, offices or other types of accommodation) in which :
- a) Case furniture like the desks, wardrobes, dressing tables, dressers, bureau are constructed completely of approved non-combustible materials, except that a combustible veneer not surpassing 2 [mm] may be used on the working surface of such articles;
 - b) Floor coverings have low flame spread characteristics;
 - c) Free-standing furniture like the sofas, chairs, tables et al. is constructed with frames of non-combustible materials;
 - d) Draperies, curtains and other suspended textile materials have qualities of resistance to the propagation of flame not inferior to those of wool of mass 0.8 [kg/m²], this being determined as per the fire test procedures code;
 - e) Bedding components have qualities of resistance to the ignition and propagation of flame, this being determined as per the regulations of the fire test procedures code.

- f) Bared surfaces of linings, bulkheads and ceilings that have low flame- spread characteristics; and
 - g) Upholstered furniture has property of resistance against ignition and propagation of flame, this being determined as per the regulations of the fire test procedures code.
- 1.3.41. **Ro/ro spaces** are spaces not normally sub-divided and extending to either a considerable length or the entire length of the ship in which motor vehicles with fuel in their tanks for their self-propulsion and/or goods (packaged or in bulk, in trailers, or on road or rail cars, vehicles (including road or rail tankers), demountable tanks, containers, pallets, or in or on similar stowage units or other receptacles) can be loaded and unloaded in horizontal direction.
- 1.3.42. **Ro-Ro passenger ship** means a passenger ship with Ro-Ro cargo spaces or special category spaces.
- 1.3.43. **Steel or other equivalent material.** Where the words **steel or other equivalent material** comes, 'equivalent material' means any non- combustible material which, by itself or due to insulation provided, has structural and integral properties equivalent to steel at the end of the applicable fire exposure to the standard fire test (e.g. aluminium alloy with apt insulation).
- 1.3.44. **Sauna** is a hot room where the temperatures normally vary between 80°C - 120°C and the heat is supplied by a hot surface (e.g. by an electrically-heated oven). The hot room may also include the space where the oven is sited and adjacent bathrooms.
- 1.3.45. **Service spaces** are the spaces used for galleys, pantries containing cooking appliances, store rooms, lockers, mail and specie rooms, workshops other than those forming part of machinery spaces, and similar trunks and spaces to such spaces.
- 1.3.46. **Special category spaces** are enclosed vehicle spaces above and below the bulkhead deck, where vehicles can be driven to and is accessible to passengers. Special category spaces may be there on more than one deck if the total overall clear height for vehicles does not surpass 10 [m].
- 1.3.47. **A standard fire test** is the test in which specimens of the relevant bulkheads or decks are exposed to a test furnace to temperatures corresponding approximately to the standard time temperature curve. The test method is to be as per the regulations of the Fire Test Procedures Code.
- 1.3.48. **A tanker** is a cargo ship constructed or adapted for transmitting bulk of liquid cargoes of flammable nature.
- 1.3.49. **Vehicle spaces** are basically cargo spaces proposed for lodging motor vehicles with fuel in their tanks for their self-propulsion.
- 1.3.50. **Weather deck** is a deck which is entirely exposed to the weather from minimum two sides and also from above.
- 1.3.51. **Cabin balcony** is an open deck space that is for the exclusive use of the occupants of a single cabin and is directly accessible from that cabin.

Table 13.1.1

MSC Circ./Assembly Resolution No.	Description
MSC/Circ.353	Guidelines for inert gas systems
MSC/Circ.387	Revised guidelines for inert gas systems (MSC/Circ.353), as amended by MSC/Circ.387
MSC/Circ. 450/Rev. 1	Revised factors to be taking into consideration when designing cargo tank venting and gas-freeing arrangements
MSC/Circ.451	Guidance concerning the location of fire control plans for assistance of shore side fire-fighting personnel
MSC/Circ.485	Clarification of inert gas system requirements under the Convention
MSC/Circ. 553	Information on flashpoint and recommended fire-fighting media for chemicals to which neither the IBC nor BCH Codes apply
MSC/Circ.582 Corr.1	Guidelines for performance and testing criteria and surveys of low expansion foam concentrates for fire-extinguishing systems
MSC/Circ. 608/Rev.1	Interim guidelines for open-top containerships
MSC/Circ.670	Guidelines for performance and testing criteria and surveys of high expansion foam concentrates for fire-extinguishing systems
MSC/Circ.671	List of solid bulk cargoes which are non-combustible or constitute a low fire risk or for which a fixed gas fire-extinguishing system is ineffective
MSC/Circ.777	Indication of the "assembly stations" in passenger ships
MSC/Circ.798	Guidelines for the performance and testing criteria, and surveys of medium expansion foam concentrates for fixed fire-extinguishing systems
MSC/Circ. 799	Guidelines for performance and testing criteria and surveys of expansion foam concentrates for fire extinguishing systems for chemical tankers
MSC/Circ.848 amended by MSC. 1/Circ. 1267	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

MSC Circ./Assembly Resolution No.	Description
MSC/Circ.849	Guidelines for the performance, location, use and care of emergency escape breathing devices
MSC/Circ.850	Guidelines on maintenance and inspection of fire protection systems and appliances
MSC/Circ.909	Interim Guidelines for a simplified evacuation analysis of ro-ro passenger ships
MSC/Circ.913	Guidelines for the approval of fixed water-based local application fire- fighting systems for use in category A machinery spaces
MSC/Circ.917	"Guidelines on fire safety construction in accommodation areas"
MSC/Circ.1002	Guidelines on alternative design and arrangements for fire safety
MSC/Circ.1165 Amended MSC.1/Circ. 1237 and MSC. 1/Circ. 1269	Revised guidelines for the approval of fixed water based fire extinguishing systems for machinery spaces and cargo pump rooms
MSC. 1/Circ. 1242	Guidelines for the approval of fixed fire detection and fire alarm systems for cabin balconies
MSC. 1/Circ. 1266	Document of compliance with the special requirements for ships carrying dangerous goods under the provisions of regulation II-2/19 SOLAS 74, as amended
MSC. 1/Circ. 1268	Guidelines for the approval of fixed pressure water spraying and water based fire extinguishing systems for cabin balconies

MSC Circ./Assembly Resolution No.	Description
MSC. 1/Circ. 1272	Guidelines when approving alternative fixed water-based fire-fighting systems for use in special category spaces
MSC. 1/Circ/1275	Unified interpretations of SOLAS Chapter II-2 on the number and arrangement of portable fire extinguishers on board ships
MSC. 1/Circ. 1276	Unified interpretations of SOLAS Ch.II-2

MSC. 1/Circ. 1320	Guidelines for the drainage of fire-fighting water from closed vehicle and ro-ro spaces and special category spaces of passenger and cargo ships
A. 123(V)	Recommendation on fixed fire-extinguishing systems for special cargo spaces
A.434(XI)	Code of safe practice of solid bulk cargoes (BC Code)
A.565(14)	Recommended procedures to prevent the illegal or accidental use of low flashpoint cargo oil as fuel
A.567(14)	Regulation for inert gas systems on chemical tankers
A.654(16)	Graphical symbols for fire control plans
A.752(18)	Guidelines for the evaluation, testing and application of low-location lighting on passenger ships
A.754(18)	Recommendation on fire resistance tests for 'A', 'B' and 'F' class divisions
A.756(18)	Guidelines on the information to be provided with fire control plans and booklets
A.760(18)	Symbols related to life-saving appliances and arrangements
A.800(19)	Guidelines for approval of sprinkler systems
A.830(19)	Fire alarm signaling systems in passenger ships
A.951(23)	Improved guidelines for marine portable fire extinguishers

SECTION 2 FIRE PREVENTION

Contents

2.1 Probability Of Ignition..... 599

2.2 Fire Growth Potential..... 612

2.3 Smoke Generation Potential And Toxicity..... 616

2.1 PROBABILITY OF IGNITION

2.1.1 Purpose

The main purpose of this section is prevention of ignition of combustible materials or flammable liquids. For this purpose, the functional requirements specified below are to be met:

- Adequate means are to be provided to control leakage of flammable liquids;
- Suitable measures need to be taken in order to limit the accumulation of flammable vapors;
- The ignitability of combustible materials is to be restricted;
- All possible ignition sources are to be restricted;
- Ignition sources are to be separated from combustible substances and flammable liquids;
- The atmosphere in cargo tanks is to be maintained out of the explosive range.

2.1.2 Arrangements for oil fuel, lubrication oil and other flammable oils

2.1.2.1 Limitations in the use of oils as fuel

The restrictions mentioned below have to be followed for the use of oil as fuel:

2.1.2.1.1 Except as otherwise permitted in these Sections, no oil fuel with a flashpoint of less than 60°C is to be used; (Refer to IMO Resolution A.565(14));

2.1.2.1.2 In emergency generators, oil fuel with a flashpoint of not less than 43°C may be used;

2.1.2.1.3 The use of oil fuel having a flashpoint of less than 60°C but not less than 43°C may be permitted (e.g. for feeding the emergency fire pump's engines and the auxiliary machines which are not located in the machinery spaces of category A) subject to the following conditions:

- a. Fuel oil tanks except those arranged in double bottom compartments are to be located outside the machinery spaces of category A;
- b. Provisions for the measurement of oil temperature are provided on the suction pipe of the oil fuel pump;
- c. Stop valves and/or cocks are provided on the inlet side and outlet side of the oil fuel strainers; and
- d. Pipe joints of welded construction or of circular cone type or spherical type union joint are applied as much as possible;

2.1.2.1.4 In cargo ships, the use of fuel having a lower flashpoint than otherwise specified in Sect [2.1.2.1.3] above for example crude oil, may be permitted provided that such fuel is not stored in any machinery space and subject to the approval of the complete installation by INTLREG.

2.1.2.2 Arrangements for oil fuel

In a ship in which oil fuel is used, the arrangements for the storage, distribution and utilization of the oil fuel are to be such as to ensure the safety of the ship and persons on board and are to at least comply with the following provisions:

2.1.2.2.1 Location of oil fuel systems

As far as practicable, parts of the oil fuel system containing heated oil under pressure exceeding 0.18 [N/mm²] are not to be placed in any concealed position where defects and leakage cannot readily be observed. The machinery spaces in way of such parts of the oil fuel system are to be adequately illuminated.

2.1.2.2.2 Ventilation of machinery spaces

The ventilation of machinery spaces is to be adequate under normal conditions to prevent accumulation of oil vapor. Cofferdams are to be provided between the following spaces to separate them from each other:

- Tanks for fuel oil or lubricating oil
- Tanks for edible oil
- Tanks for fresh water and feed water.

2.1.2.2.3 Oil fuel tanks

- a. Fuel oil, lubrication oil and other flammable oils are not to be carried in forepeak tanks.
- b. As far as practicable, oil fuel tanks are to be part of the ship's structure and are to be located outside machinery spaces of category A. Where oil fuel tanks, other than double bottom tanks, are necessarily located adjacent to or within machinery spaces of category A, at least one of their vertical sides is to be contiguous to the machinery space boundaries and they are preferably to have a common boundary with the double bottom tanks and the area of the tank boundary common with the machinery spaces are to be kept to a minimum. Where such tanks are situated within the boundaries of machinery spaces of category A, they are not to contain oil fuel having a flashpoint of less than 60°C. In general, the use of free-standing oil fuel tanks is to be avoided. When such tanks are employed their use is to be prohibited in category A machinery spaces on passenger ships. Where permitted, they are to be placed in an oil-tight spill tray of ample size having a suitable drain pipe leading to a suitably sized spill oil tank.
- c. No oil fuel tank is to be situated from where spillage or leakage can cause a fire or explosion hazard by falling on heated surfaces.
- d. For oil fuel tanks which are situated above the double bottom tanks, the inlet and outlet, pipes which are connected to the tank at a point lower than the outlet of the overflow pipe or below the top of the tanks without an overflow pipe, are to be fitted with shut off valves located on the tank itself.

The engine and boiler spaces, valves, mentioned above, are to be capable of being closed locally and from positions outside these spaces which will always be accessible in the event of fire breaking out in these spaces. Instructions for closing the valves are to be indicated at the valves and at the remote control positions. The controls for remote operation of the quick closing valve for the emergency generator fuel tank are to be in a separate location from other quick closing valves for tanks in the engine room.

Every oil fuel suction pipe which is led into the engine and boiler spaces, from a tank situated above the double bottom, outside these spaces (including shaft tunnel, pipe tunnel or similar spaces), is to be fitted in the machinery space with a valve controlled as above, except where the valve on the tank is already capable of being closed from an accessible position above the bulkhead deck.

- e. Safe and efficient means of ascertaining the amount of oil fuel contained in any oil fuel tank are to be provided.
- f. Where sounding pipes are used, they are not to terminate in any space where the risk of ignition of spillage from the sounding pipe might arise. In particular, they are not to terminate in passenger or crew spaces. As a general rule, they are not to terminate in machinery spaces. However, where INTLREG considers that these latter requirements are impracticable, sounding pipes may terminate in machinery spaces subject to following requirements being met:
 - i. an oil-level gauge is provided meeting the requirements of (g) below;
 - ii. the sounding pipes terminate in locations remote from ignition hazards unless precautions are taken, such as the fitting of effective screens, to prevent the oil fuel in the case of spillage through the terminations of the sounding pipes from coming into contact with a source of ignition; and
 - iii. the termination of sounding pipes are fitted with self-closing blanking devices and with a small- diameter self-closing control cock located below the blanking device for the purpose of ascertaining before the blanking device is opened that oil fuel is not present. Provisions are to be made so as to ensure that any spillage of oil fuel through the control cock involves no ignition hazard.

Oil level gauge referred at f (i) above need not be provided for tanks (other than double bottom tanks) having overflow system.

- g. Other oil-level gauges may be used in place of sounding pipes as per details given below.

Oil level gauges may be used for tanks containing lubricating oil, oil fuel or other flammable liquid in place of sounding pipes, subject to the following conditions:

- In passenger ships, such gauges should not require penetration below the top of the tank and their failure or overfilling of the tanks will not allow release of their contents; and
 - In cargo ships, the failure of level gauges or overfilling of the tank will not allow release of their contents into the space. The use of cylindrical gauge glasses is not acceptable. Flat type glasses may be accepted provided they are of heat resisting quality, adequately supported, protected from mechanical damage and fitted with self-closing valves between the gauges and the tanks.
- h. The means prescribed in Section (g) above are to be maintained in proper condition to ensure their continued accurate functioning in service.

2.1.2.2.4 Prevention of overpressure

Provisions are to be made to prevent overpressure in any oil tank or in any part of the oil fuel system, including the filling pipes served by pumps on board. Air and overflow pipes and relief valves are to discharge to a position where there is no risk of fire or explosion from the emergence of oils and vapor and are not to lead into crew spaces, passenger spaces nor into special category spaces, closed ro-ro cargo spaces, machinery spaces or similar spaces. Also refer in Pt.5A/Ch 9/sect 5

2.1.2.2.5 Oil fuel piping

- a. Oil fuel pipes and their valves and fittings are to be made of steel or other approved material, except that restricted use of flexible pipes are permissible in positions where INTLREG is satisfied that they are necessary. Such flexible pipes and end attachments are to be of approved fire-resisting materials of adequate strength and are to be constructed to the satisfaction of INTLREG. For valves, fitted to oil fuel tanks and which are under static pressure, steel or spheroidal graphite cast iron may be accepted. However, ordinary cast iron valves may be used in piping systems where the design pressure is lower than 7 bars and the design temperature is below 60°C.
- b. All external high-pressure fuel delivery lines between the high-pressure fuel pumps and fuel injectors are to be protected with a jacketed piping system capable of containing fuel from a high-pressure line failure. A jacketed pipe incorporates an outer pipe into which the high-pressure fuel pipe is placed, forming a permanent assembly. The jacketed piping system is to include means for collection of leakages and arrangements provided for an alarm to be given of a fuel line failure. However, this requirement need not be applied for engines intended to be fitted on board non-passenger vessels of less than 500 GT.
- c. Oil fuel lines are not to be positioned immediately above or near units of high temperature including boilers, steam pipelines, exhaust manifolds, silencers or other equipment required to be insulated by 1.2.2.6. As far as practicable, oil fuel lines are to be arranged far away from hot surfaces, electrical installations or other 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.
- d. Components of a diesel engine fuel system is to be designed considering the maximum peak pressure which will be experienced in service, including any high pressure pulses which are generated and transmitted back into the fuel supply and spill lines by the action of fuel injection pumps. Connections within the fuel supply and spill lines are to be constructed taking into account to their ability to prevent pressurized oil fuel leaks while in service and after maintenance.
- e. In multi-engine installations which are supplied from the same fuel source, means of isolating the fuel supply and spill piping to individual engines, shall be provided. The means of isolation shall not affect the operation of

the other engines and shall be operable from a position not rendered inaccessible by a fire on any of the engines.

- f. Where INTLREG may permit the transferring of oil and combustible liquids through accommodation and service spaces, the pipes used for carrying oil or combustible liquids are to be of a material approved by INTLREG having regard to the risk of fire.

2.1.2.2.6 Protection of high temperature surfaces

All surfaces of machinery where the surface temperature may exceed 220°C, e.g., steam and exhaust gas lines, silencers, boilers, exhaust gas boilers, turbo blowers, etc. are to be properly insulated to prevent ignition of combustible materials coming in contact with them. Where insulation covering these surfaces is oil absorbing or may permit penetration of oil, the insulation is to be encased in steel or its equivalent. The insulation is to be of a type and so supported that it will not crack or deteriorate when subjected to vibration.

Oil spillages coming into contact with hot surfaces, electrical installations or other sources of ignition:

- a. Precautions (e.g. shielding) are to be taken to prevent oil that may escape under pressure from any pump, filter or heater or piping from coming into contact with sources of ignition.
- b. Oil tanks, pipes, filters, heaters, etc. are not to be located immediately above or near units of high temperature including boilers, steam pipe lines, exhaust manifolds, silencers or other equipment required to be insulated and electrical equipment, as far as practicable. In particular, oil fuel filters under pressure for diesel engines are to be located such that in the event of leakage, oil cannot be prayed on to the exhaust manifold.
- c. Oil filters fitted in parallel for the purpose of enabling cleaning without disturbing oil supply to engines (e.g. duplex filters) are to be provided with adequate arrangements that will minimize the possibility of a filter under pressure being opened by mistake. Filter/filter chambers are to be provided with suitable means for :
- Venting when put into operation; and
 - Depressurizing before being opened.

Valves or cocks with drain pipes led to a safe location are to be used for this purpose.

Hydraulic units with working pressure above 15 bars are preferably to be placed in separate spaces. If it is impracticable to locate such units in separate space, then adequate shielding is to be provided. Flammable or oil absorbing materials are not to be used in floors, gratings, etc. in boiler and engine rooms, shaft tunnels or in compartments where settling tanks are installed. Oil fuel purifiers for heated oil are to be in separate room enclosed by steel bulkheads extending from deck to deck and provided with self-closing steel doors. The room is to be provided with:

- Independent mechanical ventilation or a ventilation arrangement which can be isolated from the machinery space ventilation;

- Fire detecting system; and
- Fixed fire extinguishing installation.

The extinguishing installation is to be capable of being activated from outside the room. Closing of ventilation openings is to be effected from a position close to where the extinguishing system is activated. The extinguishing system is to be separate for the room, but may be part of the main fire extinguishing system for the machinery spaces.

If it is impracticable to locate the oil fuel purifiers in a separate space, INTLREG will give special consideration with regard to location, containment of possible leakages, shielding and ventilation. A local fixed fire extinguishing system is to be provided which is capable of being activated manually from the machinery control position or from other suitable location. If automatic release is provided, additional manual release is to be arranged.

2.1.2.3 Arrangements for lubricating oil

2.1.2.3.1 The arrangements for the storage, distribution and utilization of oil used in pressure lubrication systems are to be such as to ensure the safety of the ship and people onboard. The arrangements made in machinery spaces of category A and whenever practicable in other machinery spaces are at least to comply with the provisions of Sections Sect 1, except that:

- This does not preclude the use of sight-flow glasses in lubricating systems provided that they are shown by testing to have a suitable degree of fire resistance; and
- Sounding pipes may terminate in machinery spaces; however, the requirements of Sect [2.1.2.2.3]. (f.i) and [2.1.2.2.3]. (f.iii) need not be applied on condition that the sounding pipes are fitted with appropriate means of closure.

2.1.2.3.2 Valves on lubricating oil tanks

The provisions laid out in Pt 5A / Ch 9/ Sec 8/[8.3] are also to apply to lubricating oil tanks except those having a capacity less than 500 liters, storage tanks on which valves are closed during the normal operation mode of the ship, or where it is determined that an unintended operation of a quick closing valve on the oil lubricating tank would endanger the safe operation of the main propulsion and essential auxiliary machinery. Where an engine lubricating oil drain tank extends to the bottom shell plating in ships that are required to be provided with a double bottom, a shutoff valve is to be fitted in the drain pipe between the engine crank case and the double bottom lubricating oil tank. This valve is to be capable of being closed from an accessible position above the level of the lower platform (floor plates).

2.1.2.4 Arrangements for other flammable oils

2.1.2.4.1 The arrangements for the storage, distribution and utilization of other flammable oils employed under pressure in power transmission systems, control and activating systems and heating systems are to be such as to ensure the safety of the ship and people onboard. Suitable oil collecting arrangements for leaks are to be fitted below hydraulic valves and comply with the provisions of Sections [2.1.2.2.3] (c), [2.1.2.2.3] (e), [2.1.2.2.5](c) and [2.1.2.2.6] and with the provisions of [2.1.2.2.4] and [2.1.2.2.5](a) in respect of strength and construction.

2.1.2.5 Arrangements for oil fuel in periodically unattended machinery spaces

In addition to the requirements of Sect [2.1.2.1] to [2.1.2.4], the oil fuel and lubricating oil systems in a periodically unattended machinery space are to comply with the following:

2.1.2.5.1 Where daily service oil fuel tanks are filled automatically, or by remote control, means are to be provided to prevent overflow spillages. Other equipment which treat flammable liquids automatically (e.g. oil fuel purifiers) which, whenever practicable, are to be installed in a special space reserved for purifiers and their heaters are to have arrangements to prevent overflow spillages; and

2.1.2.5.2 Where daily service oil fuel tanks or settling tanks are fitted with heating arrangements, a high temperature alarm is to be provided if the flashpoint of the oil fuel can be exceeded.

2.1.3 Arrangements for gaseous fuel for domestic purpose

2.1.3.1 Gaseous fuel systems used for domestic purposes are to be approved by INTLREG. Storage of gas bottles are to be located on the open deck or in a well-ventilated space which opens only to the open deck.

A portion of open deck, recessed into a deck structure, machinery casing, deck house, etc., utilized for the exclusive storage of gas bottles is considered acceptable for the purpose of Sect [2.1.3.1] provided that:

2.1.3.1.1 Such a recess has an unobstructed opening, except for small appurtenant structures, such as opening corner radii, small sills, pillars, etc. The opening may be provided with grating walls and door;

2.1.3.1.2 The depth of such a recess is not greater than 1 m.

2.1.4 Miscellaneous items of ignition sources and ignitability

2.1.4.1 Electric radiators

Primary deck coverings, if applied, within accommodation and service spaces and control stations or if applied on cabin balconies of passenger ships constructed on or after 1 July 2008 are to be of an approved material which will not readily ignite, or give rise to toxic or explosive hazards at elevated temperatures, this being determined in accordance with the Fire Test Procedures Code.

2.1.4.2 Waste receptacles

Waste receptacles are to be constructed of non-combustible materials with no openings in the sides or bottom. Waste receptacles of combustible materials may however be used in galleys, pantries, bars, garbage handling or storage spaces and incinerator rooms provided they are intended purely for the carriage of wet waste, glass bottles and metal cans and are suitably marked.

2.1.4.3 Insulation surfaces protected against oil penetration

In spaces where penetration of oil products is possible, the surface of insulation is to be impervious to oil or oil vapors. Also refer Sect [2.1.2.2.6].

2.1.4.4 Primary deck coverings

Primary deck coverings, if applied, within accommodation and service spaces and control stations are to be of an approved material which will not readily ignite, or give rise to toxic or explosive hazards at elevated temperatures, this being determined in accordance with the Fire Test Procedures Code.

2.1.4.5 Films

Cellulose-nitrate based films are not to be used for cinematograph installations.

2.1.5 Cargo areas of tankers

2.1.5.1 Separation of cargo oil tanks

2.1.5.1.1 Cargo pump-rooms, cargo tanks, slop tanks and cofferdams (Refer Note below) are to be positioned forward of machinery spaces. However, oil fuel bunker tanks need not be ahead of machinery spaces. Cargo tanks and slop tanks are to be isolated from machinery spaces by cofferdams, cargo pump-rooms, oil bunker tanks or ballast tanks. Pump-rooms containing pumps and their accessories for ballasting those spaces situated adjacent to cargo tanks and slop tanks and pumps for oil fuel transfer are to be considered as equivalent to a cargo pump-room within the context of these requirements provided that such pump-rooms have the same safety standard as that required for cargo pump-rooms. The lower portion of the pump-room may be recessed into machinery spaces of category A to accommodate pumps, provided that the deck head of the recess is in general not more than one third of the moulded depth above the keel, except that in the case of ships of not more than 25,000 tons deadweight, where it can be demonstrated that for reasons of access and satisfactory piping arrangements this is Impracticable a recess in excess of such height, but not exceeding one half of the moulded depth above the keel may be permitted.

2.1.5.1.2 Pump rooms intended solely for ballast transfer or fuel oil transfer are also not required to comply with the requirement of Section 5.9. Within the context of the requirements for isolation between the cargo/slop tanks and the machinery spaces mentioned in Sect [2.1.5.1.1], this is considered having 'same safety standard' as cargo pump rooms.

2.1.5.1.3 Main cargo control stations, control stations, accommodation and service spaces (excluding isolated cargo handling gear lockers) are to be positioned aft of cargo tanks, slop tanks and spaces which isolate cargo or slop tanks from machinery spaces, but not necessarily aft of the oil fuel bunker tanks and ballast tanks and are to be arranged in such a way that a single failure of a deck or bulkhead will not permit the entry of gas or fumes from the cargo tanks into an accommodation space, main cargo control stations, control station, or service spaces. A recess provided in accordance with Sect [2.1.5.1.1] need not be taken into account when the position of these spaces is being determined.

2.1.5.1.4 Void space or ballast water tank protecting fuel oil tank as shown in Fig13.2.1.1 need not be considered as 'cargo area' defined in this chapter, section 1[1.3.6] even though they have a cruciform contact with the cargo oil tank or slop tank.

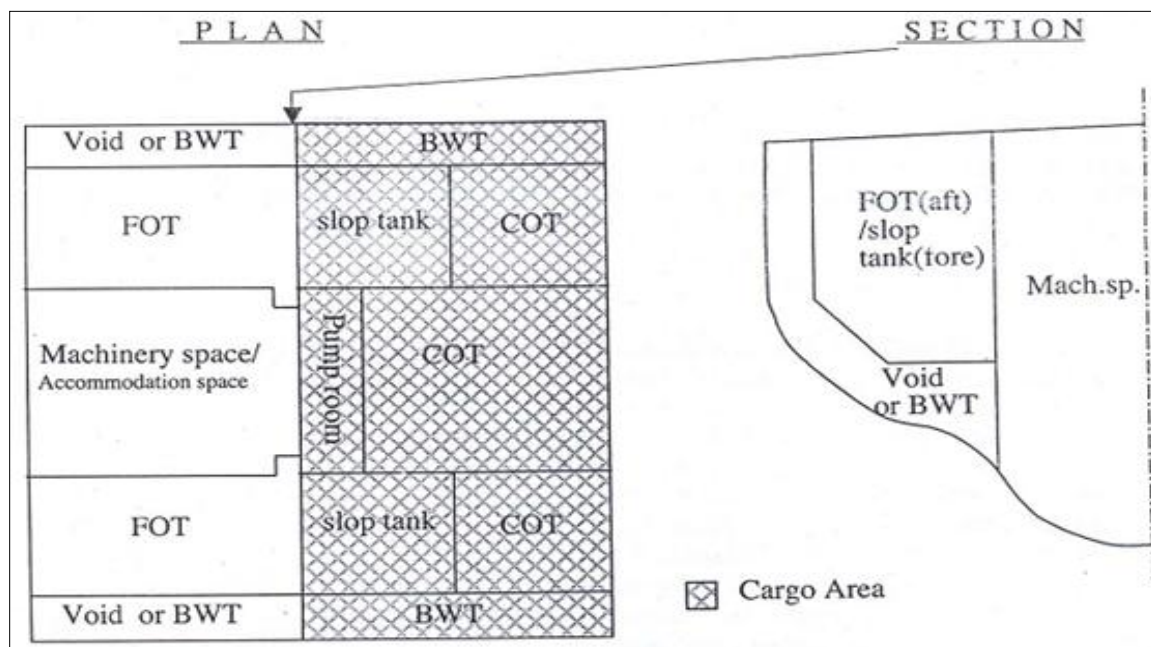


Figure 13.2.1

- 2.1.5.1.5 However, where deemed necessary, INTLREG may permit main cargo control stations, control stations, accommodation and service spaces forward of the cargo tanks, slop tanks and spaces which isolate cargo and slop tanks from machinery spaces, but not necessarily forward of oil fuel bunker tanks or ballast tanks. Machinery spaces, other than those of category A, may be permitted forward of the cargo tanks and slop tanks provided they are isolated from the cargo tanks and slop tanks by cofferdams, (Refer Note below) cargo pump-rooms, oil fuel bunker tanks or ballast tanks and have at least one portable fire extinguisher. In cases where they contain internal combustion machinery, one approved foam-type extinguisher of at least 45 l capacity or equivalent is to be arranged in addition to portable fire extinguishers. If operation of a semi-portable fire extinguisher is impracticable, this fire extinguisher may be replaced by two additional portable fire extinguishers. Accommodation spaces, main cargo control spaces, control stations and service spaces are to be arranged in such a way that a single failure of a deck or bulkhead will not permit the entry of gas or fumes from the cargo tanks into such spaces. In addition, where deemed necessary for the safety or navigation of the ship, INTLREG may permit machinery spaces containing internal combustion machinery not being main propulsion machinery having an output greater than 375 kW to be located forward of the cargo area provided the arrangements are in accordance with the provisions of this clause.
- 2.1.5.1.6 Paint lockers, regardless of their use are not to be located above the cargo tanks, slop tanks and spaces which isolate cargo or slop tanks from machinery spaces for oil tankers (refer Sect [2.1.5.1.3] and the cargo area for chemical tankers and liquefied gas carriers.
- 2.1.5.1.7 The void space protecting fuel oil tank is not considered as cofferdam and the void space as shown in Fig. 13.2.1 is considered acceptable although it has cruciform contact with the slop tank.

2.1.5.1.8 These requirements are applicable to combination carriers where oil residues are retained in the slop tanks and the ship is otherwise gas free. The slop tanks are to be surrounded by cofferdams except where the boundaries are the hull, main cargo deck, cargo pump-room bulkhead or oil fuel bunker tank. These cofferdams are not to be open to a double bottom, pipe tunnel, pump room or other enclosed spaces nor they are to be used for cargo or ballast and are not to be connected to piping systems serving oil cargo or ballast. Means are to be provided for filling the cofferdams with water and draining them. Where the boundary of a slop tank is the cargo pump room bulkhead, the pump room should not be open to the double bottom, pipe tunnel or other enclosed spaces except when they are closed gastight by bolted plates. Means are to be provided for isolating the piping connecting the pump room with the slop tanks. The means of isolation is to consist of a valve followed by a spectacle flange or a spool piece with appropriate blank flanges. This arrangement is to be located adjacent to the slop tanks, but where this is unreasonable or impracticable it may be located within the pump room directly after the piping penetrates the bulkhead. A separate pumping and piping arrangement is to be provided for discharging the contents of the slop tanks directly over the open deck when the ship is in the dry cargo mode. When the transfer system is used for slop transfer in the dry cargo mode, it is to have no connection to other systems. Separation from other systems by means of removal of spool pieces may be accepted. Hatches and tank cleaning openings to slop tanks are to be provided only on the open deck and are to be fitted with closing arrangements. Except when they are closed watertight by bolted plates, these closing arrangements are to be provided with locking arrangements, under the control of a responsible ship's officer. Slop tanks are to be provided with an approved independent venting system.

2.1.5.1.9 Where the fitting of a navigation position above the cargo area is shown to be necessary, it is to be for navigation purposes only and it is to be separated from the cargo tank deck by means of an open space with a height of at least 2 m. The fire protection for such a navigation position is to be that required for control stations and other provisions for tankers, as applicable.

2.1.5.1.10 Means are to be provided to keep deck spills away from the accommodation and service areas. This may be accomplished by provision of a permanent continuous coaming of a height of at least 300 [mm], extending from side to side. Special consideration will be given to the arrangements associated with stern loading.

Note: For the purpose of clause Sect [2.1.5.1] the expression 'cofferdam' means an isolating space between two adjacent steel bulkheads or decks. The minimum distance between the two bulkheads or decks is to be sufficient for safe access and inspection. In order to meet the single failure principle, in particular case when a corner-to-corner situation occurs, this principle may be met by welding a diagonal plate across the corner. No cargo, wastes or other goods are to be contained in cofferdams.

2.1.6 Restriction on boundary openings

2.1.6.1 Except as permitted by Sect [2.1.6.2], access doors, air inlets and openings to accommodation spaces, service spaces, control stations and machinery spaces are not to face the cargo area. They are to be located on the transverse bulkhead not facing the cargo area or on the outboard side of the superstructure or deckhouse at a distance of at least 4% of the length of the ship but not less than 3 [m] from the end of the superstructure or deckhouse facing the cargo area. This distance need not exceed 5 [m].

2.1.6.2 INTLREG may permit access doors in boundary bulkheads facing the cargo area or within the 5 [m] limits specified in Sect [2.1.6.1], to main cargo control stations and to such service spaces used as provision rooms, store-rooms and lockers, provided they do not give access directly or indirectly to any other space containing or providing for accommodation, control stations or service spaces such as galleys, pantries or workshops, or similar spaces containing sources of vapor ignition. The boundary of such a space is to be insulated to "A-60" standard, with the exception of the boundary facing the cargo area. Bolted plates for the removal of machinery may be fitted within the limits specified in Sect [2.1.6.1] Wheelhouse doors and windows may be located within the limits specified in Sect [2.1.6.1] so long as they are designed to ensure that the wheelhouse can be made rapidly and efficiently gas and vapor tight.

- a. An access to a deck foam system room (including the foam tank and the control station) can be located within the limits mentioned in clause Sect [2.1.6.1], provided that the conditions listed in clause [2.1.6.2] are satisfied and that the door is located flush with the bulkhead.
- b. The navigation bridge external doors and windows which are located within the limits of clause Sect [2.1.6.1] are to be tested for gas-tightness. If a water hose test is applied, the following may be taken as a guide:
 - Nozzle diameter: minimum 12 [mm];
 - Water pressure just before the nozzle: not less than 0.2 [N/mm²]; and
 - Distance between the nozzles and the doors or windows: max.1.5 [m].
- c. Access to forecastle spaces containing sources of ignition may be permitted through doors facing cargo area provided the doors are located outside hazardous areas as defined in IEC Publication 60092502.

2.1.6.3 Windows and side scuttles facing the cargo area and on the sides of the superstructures and deckhouses within the limits specified in Sec [2.1.6.1] are to be of a fixed (non-opening) type. Such windows and side scuttles, except wheelhouse windows are to be constructed to "A-60" class standard except that "A-0" class standard is acceptable for windows and side scuttles outside the limit given below:

The distance of 3 [m] is to be measured horizontally and parallel to the middle line of the ship from the boundary which faces the cargo area at each deck level. In the case of the sides of those superstructures and deckhouses, such insulation is to be carried up to the underside of the deck of the navigation bridge.

2.1.6.4 Where there is permanent access from a pipe tunnel to the main pump-room, a watertight door is to be fitted. (Openings in the collision bulkhead above the bulkhead deck / freeboard deck are to have weather tight doors or an equivalent arrangement.) and in addition, with the following:

- In addition to the bridge operation, the watertight door is to be capable of being manually closed from outside the main pump-room entrance; and
- The watertight door is to be kept closed during normal operations of the ship except when access to the pipe tunnel is required.

2.1.6.5 Where the pump room is illuminated through glazed ports, these are to be effectively protected from mechanical damage and are to have strong covers secured from the side of the safe space. Glazed ports are to be so constructed that glass and sealing will not be impaired by the working of the ship. The glass and the protection of the light fitting are not to impair the integrity of the bulkhead and are to be of equivalent strength. The fitting is to have the same resistance to fire and smoke as the unpierced bulkhead.

2.1.6.6 The arrangement of ventilation inlets and outlets and other deckhouse and superstructure boundary space openings are to be such as to complement the provisions of Cargo Tank Venting and Section 3.5. Such vents, especially for machinery spaces are to be situated as far aft as practicable. Due consideration in this regard is to be given when the ship is equipped to load or discharge at the stern. Sources of ignition such as electrical equipment are to be so arranged as to avoid an explosion hazard.

2.1.7 Ventilation

2.1.7.1 Ventilation systems in cargo pump-rooms

Cargo pump-rooms are to be mechanically ventilated and discharges from the exhaust fans are to be led to a safe place on the open deck. The ventilation of these rooms is to have sufficient capacity to minimize the possibility of accumulation of flammable vapors. The number of air changes is to be at least 20 per hour, based upon the gross volume of the space. The air ducts are to be arranged so that all of the space is effectively ventilated. The ventilation is to be of the suction type using fans of the non-sparking type.

2.1.8 Ventilation systems in combination carriers

In combination carriers, cargo spaces and any enclosed spaces adjacent to cargo spaces are to be capable of being mechanically ventilated. The mechanical ventilation may be provided by portable fans. An approved fixed gas warning system capable of monitoring flammable vapors is to be provided in cargo pump-rooms, pipe ducts and cofferdams, as referred to in Sect [2.1.5.1.8], adjacent to slop tanks. Suitable arrangements are to be made to facilitate measurement of flammable vapors in all other spaces within the cargo area. Such measurements are to be made possible from the open deck or easily accessible position.

2.1.9 Inert gas systems

2.1.9.1 Application

- a. These requirements apply where an inert gas system, based on flue gas, is fitted for inerting tanks and void spaces within the cargo area. Oil tankers of 20,000 tons dwt and above intended for the carriage of oil cargoes having a flash point not exceeding 60°C (closed cup test) and all vessels fitted with crude oil washing arrangements regardless of size are to be fitted with a permanently installed inert gas system complying with the requirements of this Section.
- b. On tankers required to be fitted with inert gas systems:
 - Double hull spaces are to be fitted with suitable connections for the supply of inert gas;
 - Where hull spaces are connected to a permanently fitted inert gas distribution system, means are to be provided to prevent hydrocarbon gases from the cargo tanks entering the double hull spaces through the system;
 - Where such spaces are not permanently connected to an inert gas distribution system, appropriate means are to be provided to allow connection to the inert gas main.

2.1.10 Inert gas systems of chemical tankers and gas carriers

The requirements for inert gas systems contained in Sect [2.1.9.1](a) need not be applied to:

- a. Chemical tankers and gas carriers when carrying cargoes should comply with the requirements for inert gas systems on chemical tankers approved by the National Statutory Authority (refer to the regulations for inert gas systems on chemical tankers adopted by IMO Resolution A.567(14) Corr.1) or
- b. Chemical tankers and gas carriers when carrying flammable cargoes other than crude oil or petroleum products, provided that the capacity of tanks used for their carriage does not exceed 3,000 [m³] and the individual nozzle capacities of tank washing machines do not exceed 17.5 [m³/h] and the total combined throughput from the number of machines in use in a cargo tank at any one time does not exceed 110 [m³/h].

2.1.11 General requirements for inert gas systems

- a. The inert gas system is to be capable of inerting, purging and gas-freeing empty tanks and maintaining the atmosphere in cargo tanks with the required oxygen content.
- b. The inert gas system referred to in (a) is to be designed, constructed and tested in accordance with the Fire Safety System Code.
- c. Tankers fitted with a fixed inert gas system are to be provided with a closed ullage system.

2.1.12 Requirements for equivalent systems

Where an installation equivalent to a fixed inert gas system is installed, it is to:

- a. 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
- b. Be so designed as to minimize the risk of ignition from the generation of static electricity by the system itself.

2.1.13 Inerting, purging and gas-freeing

- a. Arrangements for purging and/or gas-freeing are to be such as to minimize the hazards due to dispersal of flammable vapors in the atmosphere and to flammable mixtures in a cargo tank.
- b. When the ship is provided with an inert gas system, the cargo tanks are first to be purged in accordance with the provisions of Sect [2.1.13] until the concentration of hydrocarbon vapors in the cargo tanks has been reduced to less than 2% by volume. Thereafter, gas-freeing may take place at the cargo tank deck level.

2.1.14 Gas measurement**2.1.14.1 Portable instrument**

All tankers are to be equipped with at least two portable instruments for measuring flammable vapor concentrations. Suitable means are to be provided for the calibration of such instruments.

2.1.14.2 Arrangements for gas measurement in double hull and double bottom spaces

At least two suitable portable instruments for measuring oxygen and flammable vapor concentrations are to be provided. In selecting these instruments, due attention shall be given to their use in combination with the fixed gas-sampling-line systems referred to in Section. Where the atmosphere in double hull spaces cannot be reliably measured using flexible gas sampling hoses, such spaces are to be fitted with permanent gas sampling lines. The configuration of such line systems are to be adapted to the design of such spaces. The materials of construction and the dimensions of gas sampling lines are to be such as to prevent restriction. Where plastic materials are used, they should be electrically conductive.

2.1.15 Air supply to double hull and double bottom spaces

Double hull and double bottom spaces are to be fitted with suitable connections for the supply of air.

2.1.16 Protection of cargo area

Drip pans of suitable material for collecting cargo residues in cargo lines and hoses are to be provided in the area of pipe and hose connections under the manifold area. Cargo hoses and tank washing hoses are to have electrical continuity over their entire lengths including couplings and flanges (except shore connections) and are to be earthed for removal of electrostatic charges.

2.1.17 Protection of cargo pump rooms

2.1.17.1 Proper measures are to be taken to prevent explosions in cargo pump rooms. Cargo pumps, ballast pumps and stripping pumps, installed in cargo pump rooms and driven by shafts passing through pump room bulkheads are to be fitted with temperature sensing devices for bulkhead shaft glands, bearing, and pump casings. Alarms are to be initiated in the cargo control room or the pump control station.

2.1.17.2 All pump rooms are to be provided with bilge level monitoring devices together with audio-visual alarms in the wheel house, pump control station and other appropriate locations.

2.1.17.3 The above requirements are only applicable to the pump-rooms where pumps for cargo, such as cargo pumps, stripping pumps, pumps for slop tanks, pumps for COW or similar pumps are provided.

2.2 FIRE GROWTH POTENTIAL

2.2.1 Purpose

2.2.1.1. The sole purpose of this regulation is to limit the fire growth potential in every surface of the ship. For this purpose, the following functional requirements are to be met:

- a. Means of control for the air supply to the space are to be provided;
- b. Means of control for flammable liquids in the space are to be provided; and
- c. The use of combustible materials is to be restricted.

2.2.2 Control of air supply and flammable liquid to the space

2.2.2.1 Closing appliances and stopping devices of ventilation

- 2.2.2.1.1. The main inlets and outlets of all ventilation system are to be capable of being closed from outside the spaces being ventilated. The means of closing are to be easily accessible as well as prominently and permanently marked that clearly indicate whether the shut-off is open or closed.
- 2.2.2.1.2. Power ventilation of accommodation spaces, service spaces, cargo spaces, control stations and machinery spaces should be capable of being stopped from an easily accessible position outside the space being served. This place is not to be readily cut off in the event of a fire in the spaces served.
- 2.2.2.1.3. In passenger ships carrying more than 36 passengers, power ventilation, except machinery space and cargo space ventilation and any alternative system, is to be fitted with controls so grouped that all fans may be stopped from either of two different points which are to be located as far apart as practicable. Fans serving power ventilation systems to cargo spaces are to be capable of being stopped from a safe position outside such spaces.

(Note: The fan in a cabin HVAC temperature control unit is not required to be stopped if it is not capable of supplying outside air to the cabin).

2.2.3 Means of control in machinery spaces

- 2.2.3.1 Means of control are to be provided for opening and closure of skylights, closure of openings in funnels which normally allow exhaust ventilation and closure of ventilator dampers.
Ventilation inlets and outlets located at outside boundaries are to be fitted with closing appliances as required by Sect [2.2.2.3] but need not comply with the details of duct penetration. The controls are to be easily accessible as well as prominently and permanently marked and are to indicate whether the shut-off is open or closed.
- 2.2.3.2 Means of control are to be provided for stopping ventilating fans. Controls provided for the power ventilation serving machinery spaces are to be grouped so as to be operable from two positions, one of which is to be outside such spaces. The means provided for stopping the power ventilation of the machinery spaces are to be entirely separate from the means provided for stopping ventilation of other spaces.
- 2.2.3.3 Means of control are to be provided for stopping forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pumps, lubricating oil service pumps, thermal oil circulating pumps and oil separators (purifiers). However, Sect [2.2.3.4] and [2.2.3.5] need not apply to oily water separators.
- 2.2.3.4 The controls required in 2.2.3.1 to 2.2.3.3 are to be located outside the space concerned so they will not be cut off in the event of fire in the space they serve.
- 2.2.3.5 In passenger ships, the controls required in Sect [2.2.3.1] to [2.2.3.4] and Means of control are to be provided for permitting the release of smoke and such controls are to be located outside the space concerned so that, in the event of fire, they will not be cut off from the space they serve. Means of control are to be provided for closing power-operated doors or actuating release mechanisms on doors other than power-operated watertight doors. The control is to be located outside the space concerned, where they will not be cut off in the event of fire in the space it serves, and the controls for any required fire-extinguishing system are to be situated at one control position or grouped in as few positions as possible to the satisfaction of INTLREG. Such positions are to have a safe access from the open deck.

2.2.4 Additional requirements for means of control in periodically unattended machinery spaces

2.2.4.1 For periodically unattended machinery spaces, special consideration will be given to maintaining the fire integrity of the machinery spaces, the location and centralization of the fire-extinguishing system controls, the required shutdown arrangements (e.g. ventilation, fuel pumps, etc.) and that additional fire-extinguishing appliances and other fire-fighting equipment and breathing apparatus may be required.

2.2.4.2 In passenger ships, these requirements are to be at least equivalent to those of machinery spaces normally attended.

2.2.5 Fire protection materials

2.2.5.1 Use of non-combustible materials

2.1.5.1.1 Insulating materials

- a. Insulating materials are to be non-combustible, except in cargo spaces, mail rooms, baggage rooms and refrigerated compartments of service spaces. Vapor barriers and adhesives used in conjunction with insulation, as well as the insulation of pipe fittings for cold service systems, need not be of noncombustible materials, but they are to be kept to the minimum quantity practicable and their exposed surfaces are to have low flame-spread characteristics.
- b. Cold service is understood to mean refrigeration systems and chilled water piping for air-conditioning systems.

2.2.6 Ceilings and linings

2.2.6.1 In passenger ships, all linings, grounds, draught stops and ceilings are to be of non-combustible material in the following spaces except in mailrooms, baggage rooms and saunas and refrigerated compartments of service spaces:

- Accommodation spaces, service spaces and control stations
- Stairways, open deck spaces
- Machinery spaces.

2.2.6.2 In cargo ships, all linings, ceilings, draught stops and their associated grounds are to be of noncombustible materials in the following spaces:

- In accommodation and service spaces and control stations for ships where Method IC is specified.
- In corridors and stairway enclosures serving accommodation and service spaces and control stations for ships where Method IIC and IIIC.

2.2.6.3 Partial bulkheads and decks on passenger ships

- a. Partial bulkheads or decks used to subdivide a space for utility or artistic treatment are to be of non-combustible material.
- b. Linings, ceilings or partial bulkheads or decks used to screen or to separate adjacent cabin balconies are to be made of non-combustible materials. Cabin balconies on passenger ships constructed before 1 July 2008 are to comply with the requirements of this clause by the first survey after 1 July 2008.

2.2.7 Use of combustible materials

2.2.7.1. General

- a. In passenger ships, "A", "B" or "C" class divisions in accommodation and services spaces and cabin balconies which are faced with combustible materials, facings, mouldings, decorations and veneers are to comply with the provisions of Sect [2.2.8] to [2.2.10]. However, traditional wooden benches and wooden linings on bulkheads and ceilings are permitted in saunas and such materials need not be subject to the calculations prescribed in 2.3.2.2 and 2.3.2.3. Sect [2.2.8] and [2.2.9]. However, the provisions of [2.2.9] need not be applied to cabin balconies.
- b. In cargo ships, non-combustible bulkheads, ceilings and linings fitted in accommodation and service spaces may be faced with combustible materials, facings, mouldings, decorations and veneers provided such spaces are bounded by non-combustible bulkheads, ceilings and linings in accordance with the provisions of [2.2.8] to [2.2.10] and section 3.

2.2.8 Maximum calorific value of combustible materials

Combustible materials used on the surfaces and linings specified in [2.2.7.1] are to have a calorific value not exceeding 45 [MJ/m²] of the area for the thickness used. The requirements of this Section are not applicable to the surfaces of furniture fixed to linings or bulkheads. (Refer ISO 1716:1973 on Determination of Calorific value).

2.2.9 Total volume of combustible materials

Where combustible materials are used in accordance with [2.2.7.1], they are to comply with the following requirements:

- a. The total volume of combustible facings, mouldings, decorations and veneers in accommodation and service spaces are not to exceed a volume equivalent to 2.5 [mm] veneer on the combined area of the walls and ceiling linings. Furniture fixed to linings, bulkheads or decks need not be included in the calculation of the total volume of combustible materials; and
- b. In the case of ships fitted with an automatic sprinkler system complying with the provisions of the Fire Safety Systems Code, the above volume may include some combustible material used for erection of "C" class divisions.

2.2.10 Low flame-spread characteristics of exposed surfaces

The following surfaces are to have low flame-spread characteristics in accordance with the Fire Test Procedures Code:

- a. In passenger ships:
 - Exposed surfaces in corridors and stairway enclosures and of bulkhead and ceiling linings in accommodation and service spaces (except saunas) and control stations; and
 - Surfaces and grounds in concealed or inaccessible spaces in accommodation and service spaces and control stations.
 - Exposed surfaces of cabin balconies, except for natural hard wood decking systems.

b. In cargo ships:

- Exposed surfaces in corridors and stairway enclosures and of ceilings in accommodation and service spaces (except saunas) and control stations; and
- Surfaces and grounds in concealed or inaccessible spaces in accommodation and service spaces and control stations.

2.2.11 Furniture in stairway enclosures of passenger ships

Furniture in stairway enclosures is to be restricted to seating purpose only. It is to be fixed, limited to six seats on each deck in each stairway enclosure, be of restricted fire risk determined in accordance with the Fire Test Procedure Code, and is not to restrict the passenger escape route. Additional seating may be permitted in the main reception area within a stairway enclosure if it is fixed, non-combustible and does not restrict the passenger escape route. Furniture is not to be fixed in passenger and crew corridors forming escape routes in cabin areas. In addition to the above, lockers of non-combustible material, providing storage for non-hazardous safety equipment required by these rules, may be permitted. Drinking water dispensers and ice cube machines may be fixed in corridors provided they are fixed and do not restrict the width of the escape routes. This applies as well to decorative flower or plant arrangements, statues or other objects of art such as paintings and tapestries in corridors and stairways.

2.2.12 Furniture and furnishings on cabin balconies of passenger ships

On passenger ships, furniture and furnishings on cabin balconies are to comply with requirements of Ch13/Sect 3[3.1.5.2] unless such balconies are protected by a fixed pressure water-spraying and fixed fire detection and fire alarm systems. Passenger ships constructed before 1 July 2008 are to comply with the requirements of this clause by the first survey after 1 July 2008.

2.3 SMOKE GENERATION POTENTIAL AND TOXICITY

2.3.1. Purpose

The purpose of this section is to reduce the hazard to life from smoke and toxic products generated during a fire in spaces where persons normally work or live. For this purpose, the quantity of smoke and toxic products released from combustible materials, including surface finishes, during fire is to be limited.

2.3.2. Paints, varnishes and other finishes

The following requirements apply to accommodation spaces, service spaces and control stations as well as stairway enclosures.

2.3.2.1 Paints, varnishes and other finishes used on exposed interior surfaces are not be capable of producing excessive quantities of smoke and toxic products, this being determined in accordance with the Fire Test Procedures Code.

2.3.2.2 On passenger ships constructed on or after 1 July 2008, paints, varnishes and other finishes used on exposed surfaces of cabin balconies, excluding natural hard wood decking systems, are not to be capable of producing excessive quantities of smoke and toxic products, this being determined in accordance with the Fire Test Procedures Code. Anticipation

2.3.3. Primary deck coverings

2.3.3.1 Primary deck coverings, if applied within accommodation and service spaces and control stations are to be of approved material which will not give rise to smoke or toxic or explosive hazards at elevated temperatures, this being determined in accordance with the Fire Test Procedures Code.

2.3.3.2 On passenger ships constructed on or after 1 July 2008, primary deck coverings on cabin balconies are not to give rise to smoke, toxic or explosive hazards at elevated temperatures, this being determined in accordance with the Fire Test Procedures Code.

2.3.4. Asbestos

For all ships, new installations of materials which contain asbestos are prohibited.

SECTION 3 SUPPRESSION OF FIRE

Contents

3.1 Detection And Alarm 618

3.2 Control Of Smoke Spread 622

3.3 Containment Of Fire 623

3.4 Fire Fighting 657

3.5 Structural Integrity 672

3.1 DETECTION AND ALARM**3.1.1 Purpose**

The purpose of this rule is aimed at detecting a fire in the space of origin and providing an alarm for safe escape and fire fighting activity. For this, the following functional requirements have to be met:

- 3.1.1.1. Fire alarm system installations and fixed fire detection shall be suitable for the nature of the space, fire growth potential and potential generation of smoke and gases.
- 3.1.1.2. Call points, operated manually shall provide an effective means for the detection and location of fires and alerting the navigation bridge and fire teams.
- 3.1.1.3. Fire patrols should also provide an effective means for the detection and location of fires and alerting the navigation bridge and fire teams.

3.1.2 General requirements

- 3.1.2.1. In accordance with the provisions of this chapter, a fixed fire detection and fire alarm system shall be provided.
- 3.1.2.2. As per the requirement of this and other chapters, a fixed fire detection and fire alarm system along with a sample extraction smoke detection system should be an approved one and at the same time comply with the Fire Safety Systems Code.
- 3.1.2.3. Places requiring a fixed fire detection and fire alarm system for protecting the spaces other than those mentioned in Section Sect [3.1.5.1], at least one detector complying with the Fire Safety Systems Code shall be installed in each such space.

3.1.3 Initial and periodical tests

- 3.1.3.1. As per the requirement of the relevant regulations of this chapter, the function of fixed fire detection and fire alarm systems shall be tested under varying conditions of ventilation after the installation.
- 3.1.3.2. It is necessary for fixed fire detection and fire alarm systems to undergo periodical test to the INTLREG's satisfaction by means of equipment producing hot air at the appropriate temperature or smoke or aerosol particles having the appropriate range of density or particle size, or other phenomena associated with incipient fires to which the detector is designed to respond.

3.1.4 Protection of machinery spaces**3.1.4.1. Installation**

- 3.1.4.1.1. A fixed fire detection and fire alarm system is required to be installed in:
 - a. Periodically unattended machinery spaces
 - b. Machinery spaces where:
 - i. The installation of automatic and remote control systems and equipment has been approved in lieu of continuous manning of the space.

- ii. The primary propulsion and associated machinery, including the main sources of electrical power are offered with various degrees of automatic or remote control and is subjected to continuous manned supervision from a control room.

3.1.4.2. Design

The fixed fire detection and fire alarm system as mentioned in the Section [3.1.4.1] shall be so designed and the detectors positioned appropriately that it helps in detecting the onset of fire rapidly in any part of those spaces and under any normal conditions of operation of the machinery and variations of ventilation as required by the possible range of ambient temperatures. Apart from spaces of restricted height and where their use is especially appropriate, detection systems using only thermal detectors are not permitted.

Audible and visual alarms are to be initiated by the detection system and they should be distinct in both respects from the alarms of any other system not indicating fire and in sufficient places for ensuring that the alarms can be heard and observed by a responsible engineer officer on the navigation bridge. In case the navigation bridge is unmanned, the alarm should sound in a place where a responsible crew member is on duty.

3.1.5 Protection of accommodation and service spaces and control stations

3.1.5.1. Smoke detectors in accommodation spaces

All corridors, stairways and escape routes within the accommodation spaces as specified in Sections [3.1.5.2], [3.1.5.3] and [3.1.5.4] should have smoke detectors installed. The installation of special purpose smoke detectors within ventilation ducting is to be given special consideration.

3.1.5.2. Requirements for passenger ships carrying more than 36 passengers

The installation and arrangement of a fixed fire detection and fire alarm system is to be made such that it provides smoke detection in service spaces, control stations accommodation spaces including stairways, escape routes and corridors within the accommodation spaces. Private bathrooms and galleys do not necessarily need smoke detectors. Spaces with no or little fire risks like public toilets, voids, carbon dioxide rooms and similar spaces does not require to be fitted with a fixed fire detection and alarm system.

3.1.5.3. Requirements for passenger ships carrying not more than 36 passengers

There should be installation throughout each separate zone, whether it is vertical or horizontal, in all service and accommodation spaces and where it is deemed necessary by the INTLREG, in control stations except spaces which are not prone to substantial fire risk which includes sanitary and void spaces, either of:

- 3.1.5.3.1. A fixed fire detection and fire alarm system installed and arranged in a manner for detecting the presence of fire in such spaces and providing detection of smoke in stairways, corridors and escape routes within accommodation spaces; or
- 3.1.5.3.2. An approved automatic sprinkler, fire detection and fire alarm system in compliance with the relevant requirements of the fire safety systems code and installed and arranged in such a manner so as to protect such spaces and additionally a fixed fire detection and fire alarm system and installed and arranged in such a manner so as to carry out smoke detection in stairways, escape routes and corridors within accommodation spaces.

3.1.5.4. Protection of atriums in passenger ships

A smoke detection system has to be installed throughout to protect the entire primary vertical zone.

3.1.5.5. Cargo ships

In case of cargo ships, accommodation and service spaces as well as control stations are to be protected by fixed fire detection and fire alarm system and/or an automatic sprinkler, fire detection and fire alarm system as follows, depending on a protection method that has been adopted in accordance with Section 3,[3.2.3.1].

3.1.5.5.1. Method IC- According to this, a fixed fire detection and fire alarm system is to be installed and arranged such that smoke can be detected in all corridors, stairways and escape routes within accommodation spaces.

3.1.5.5.2. Method IIC- An approved automatic sprinkler, fire detection and fire alarm system in compliance with the relevant requirements of the Fire Safety Systems Code has to be so installed and arranged that it guarantees protection to accommodation spaces, galleys and other service spaces, apart from the spaces which are devoid of any substantial fire risk such as sanitary and void spaces etc. Additionally, a fixed fire detection and fire alarm system has to be so installed and arranged as to provide smoke detection in all corridors, stairways and escape routes within accommodation spaces.

3.1.5.5.3. Method IIIC- A fixed fire detection and fire alarm system has to be so installed and arranged for detecting the presence of fire in all accommodation spaces and service spaces, providing smoke detection in stairways, corridors and escape routes within accommodation spaces, apart from spaces which has no substantial fire risk such as void spaces, sanitary spaces, etc. Additionally, a fixed fire detection and fire alarm system shall be so installed and arranged as to provide smoke detection in all corridors, stairways and escape routes within accommodation spaces.

3.1.6 Protection of cargo spaces in passenger ships

Any cargo space has to have fixed fire detection and fire alarm system or a sample extraction smoke detection system which according to the INTLREG is not accessible except where it is pointed out to the satisfaction of the INTLREG that the ship is occupied on voyages of short duration which does not necessarily require the application of this requirement.

3.1.7 Manually operated call points

Manually operated call points complying with the Fire Safety Systems Code are to be installed throughout the accommodation spaces, service spaces and control stations. Each exit should have a manually operated call point installed. Manually operated call points shall be readily accessible in the corridors of each deck so as to ensure that no part of the corridor is more than 20 m from a manually operated call point.

3.1.8 Fire patrols in passenger ships

3.1.8.1. Fire patrols

For the detection of an outbreak of fire an efficient patrol system has to be maintained for ships carrying more than 36 passengers. Individual members of the fire patrol should be trained in order to be familiar with the arrangements of the ship and the location and operation of any equipment that he might be required to use.

3.1.8.2. Inspection hatches

The construction of bulkheads and ceilings should be such that it will be easier and possible for the fire patrols, without harming the efficiency of the fire protection, to detect any smoke from inaccessible and concealed places except where according to the INTLREG such places have no risk of fire.

3.1.8.3. Two-way portable radiotelephone apparatus

Individual member of the fire patrol shall be provided with a two-way portable radiotelephone apparatus.

3.1.9 Fire alarm signaling systems in passenger ships

3.1.9.1. Passenger ships at all times for example at sea or in port (except when not in service) should be so manned or equipped that any initial fire alarm can be received immediately by a responsible member of the crew.

3.1.9.2. The fail-safe principle (for example, an open detector circuit shall cause an alarm condition) shall be followed in designing the control panel of fixed fire detection and fire alarm systems.

3.1.9.3. Passenger ships with more than 36 passengers on board shall have fire detection alarms for the systems as per the requirements in Section 5.2 centralized in a continuously manned central control station. Additionally, controls for remote closing of the fire doors and shutting down the ventilation fans shall be centralized in the same location. The ventilation fans should be in such a position that it could be reactivated by the crew at the continuously manned control station. In the central control station, the control panels should be functional enough in indicating open or closed positions of fire doors and closed or off status of the alarms, fans and detectors. In case of loss of normal power supply, the control panel shall be continuously powered and shall have an automatic change-over to standby power supply. It is necessary for the control panel to be powered continuously. It should also have an automatic change-over to standby power supply in case of loss of normal power supply. The main source of electrical power should provide power to the control panel apart from the emergency source of electrical power defined by SOLAS regulation II-1/42 unless other arrangements are permitted by the regulations, as applicable.

3.1.9.4. A special alarm operated from the fire control station or Navigation Bridge is to be fitted for summoning the crew. The special alarm might be part of the general alarm system of the ship and shall be capable of being sounded independently of the alarm to the passenger spaces.

3.1.10 Protection of cabin balconies on passenger ships

A fixed fire detection and fire alarm system complying with the provisions of the Fire Safety Systems Code shall be installed on cabin balconies of ships to which Section 2/[2.2.7] applies, when furniture and furnishings on such balconies are not as defined in section 1[1.3.40]

3.2 CONTROL OF SMOKE SPREAD

3.2.1 Purpose

The aim of this regulation is to control the smoke from spreading in order to minimize the hazards from smoke. For this purpose, provisions for controlling smoke in control stations, atriums, concealed and machinery spaces shall be made.

3.2.2 Protection of control stations outside machinery spaces

Practicable measures shall be taken for control stations outside machinery spaces for ensuring that visibility, ventilation and freedom from smoke are maintained so that in case there is a fire, the machinery and equipment contained therein may be supervised and they continue to function efficiently. Provisions for alternative and separate means of air supply are to be made and air inlets of the two sources of supply shall be disposed in a manner that the risk of both inlets drawing in smoke simultaneously is reduced. At the INTLREG's discretion, such requirements are not necessarily applicable to control stations situated on and opening onto, an open deck or where local closing arrangements would be equally effective.

3.2.3 Release of smoke from machinery spaces

3.2.3.1. The provisions of this Section are applicable to machinery spaces of category A and as per desirable by the INTLREG, to other machinery spaces.

3.2.3.2. Appropriate arrangements are to be made for releasing the smoke in the event of a fire breakout, from the space to be protected, subject to the provisions of Sect [3.1.4] For this purpose, the normal ventilation systems are acceptable.

For permitting the release of smoke, means of control shall be provided. Such controls shall be located outside the space concerned so that they will not be cut off in the event of fire in the space they serve.

3.2.3.3. In case of passenger ships, the required controls as specified in Section 3.3 shall be situated either at one control position or grouped in as few positions as possible to the INTLREG's satisfaction. Positions as such should have a safe access from the open deck.

3.2.4 Draught stops

Air spaces enclosed behind ceilings, paneling or linings shall be divided by close-fitting draught stops spaced not more than 14 m apart. In the vertical direction, such enclosed air spaces, including those behind linings of stairways, trunks, etc., shall be closed at each deck.

3.2.5 Smoke extraction systems in atriums of passenger ships

Atriums should come with a smoke extraction system. The smoke extraction system shall be activated by the required smoke detection system and be capable of manual control. The fans shall be of such size that the entire volume within the space can be exhausted in 10 min or less than that.

3.3 CONTAINMENT OF FIRE**3.3.1 Purpose**

The aim of this regulation is to keep the fire contained in the space of its origin. For this, the following functional requirements are to be taken care of:

3.3.1.1. The ship shall be subdivided by thermal and structural boundaries; thermal insulation of boundaries shall have due regard to the fire risk of the space and adjacent spaces; and

3.3.1.2. The fire integrity of the divisions shall be maintained at openings and penetrations.

3.3.2 Thermal and structural boundaries

3.3.2.1. Thermal and structural subdivision

All types of ships are to be subdivided into spaces by thermal and structural divisions having regard to the fire risks of the spaces.

3.3.2.2. Passenger ships

3.3.2.2.1. Main vertical zones and horizontal zones

- i. The hull, superstructure and deckhouses shall be subdivided into main vertical zones by "A-60" class divisions in ships carrying more than 36 passengers. Steps and recesses are to be kept to a minimum but where necessary, they shall also be "A-60" class divisions. Where a category (5), (9) or (10) space defined in Section [3.3.2.3].ii.b) is on one side or where fuel oil tanks are on both sides of the division the standard may be reduced to "A-0".
- ii. The hull, superstructure and deckhouses in way of accommodation and service spaces shall be subdivided into main vertical zones by "A" class divisions in ships carrying not more than 36 passengers. These divisions shall have insulation values in accordance with tables in Section [3.3.2.2.3].
- iii. As far as practicable, the bulkheads forming the boundaries of the main vertical zones above the bulkhead deck shall be in line with watertight subdivision bulkheads situated immediately below the bulkhead deck. The length and width of main vertical zones may be extended to a maximum of 48 m in order to bring the ends of main vertical zones to coincide with watertight subdivision bulkheads or in order to accommodate a large public space extending for the whole length of the main vertical zone provided that the total area of the main vertical zone is not greater than 1,600 m² on any deck. The length or width of a main vertical zone is the maximum distance between the furthestmost points of the bulkheads bounding it.
- iv. Such bulkheads shall extend from deck to deck and to the shell or other boundaries.
- v. Where horizontal "A" class divisions subdivides a main vertical zone into horizontal zones for the purpose of providing a suitable barrier between a zone with sprinklers and a zone without sprinklers, the divisions shall extend between adjacent main vertical zone bulkheads and to the shell or exterior boundaries of the ship and shall be insulated in accordance with the fire insulation and integrity values specified in SOLAS table 9.4.
- vi. On ships designed for special purposes for example as automobile or railroad car ferries and where the provision of the primary vertical zone bulkheads would not work in favor of the purpose for which the ship is designed, equivalent means for limiting and controlling a fire shall be substituted and duly approved by the INTLREG. Service spaces and ship stores shall not be located on ro-ro decks unless protected in accordance with the applicable regulations.

- vii. In a ship with special category spaces, it is required that such spaces should be in compliance with the applicable provisions of SOLAS regulation 20 and were such compliance would be incompatible with other requirements for passenger ships specified in this chapter, the requirements of regulation 20 shall prevail.

3.3.2.2.2. Bulkheads within a main vertical zone

- i. In ships with more than 36 passengers, bulkheads which do not necessarily have to be “A” class divisions shall be at least “B” or “C” class divisions according to the tables in Section [3.3.2.2.3].
- ii. In ships carrying not more than 36 passengers, bulkheads within accommodation and service spaces which do not necessarily be “A” class divisions, should at least be “B” class or “C” class divisions as per the specifications in the tables in Section [3.3.2.2.4]. Additionally, corridor bulkheads where it is not required to be “A” class, shall be “B” class divisions which shall extend from deck to deck except:
 - a. When on both sides of the bulkhead, continuous “B” class ceilings or linings are fitted, the portion of the bulkhead behind the continuous ceiling or lining shall be of such a material both in thickness and composition that it is acceptable in the construction of “B” class divisions but which requires to meet the “b” class integrity standards only in so far as is reasonable and practicable according to the INTLREG and;
 - b. In case a ship protected by an automatic sprinkler system which complies with the provisions of the Fire Safety Systems Code, the corridor bulkheads may terminate at a ceiling in the corridor provided that the bulkheads and the ceilings are of “B” class standard and are in compliance with Section [3.3.2.2.4]. In such bulkheads, all doors and frames should be of non-combustible materials and requires having the same fire integrity as the bulkhead in which they are fitted.
- iii. As per the specifications in Section [3.3.2.2.2] (ii), bulkheads except corridor bulkheads are required to be “B” class divisions and should extend from deck to deck and to the shell or other boundaries. However, where a continuous “B” class ceiling or lining is fitted on both sides of a bulkhead and where it has the same free resistance as the adjoining bulkhead, the bulkhead may terminate at the continuous ceiling or lining.

3.3.2.2.3. Fire integrity of bulkheads and decks in ships carrying more than 36 passengers

- i. In addition to complying with the particular provisions for fire integrity of bulkheads and decks of passenger ships, the minimum fire integrity of all bulkheads and decks should be in compliance with what is specified in Tables 13.3.1 and 13.3.2. If there is any difficulty in determining from the tables the minimum fire integrity value of any divisions owing to any particular structural arrangements in the ship, such values are generally determined to the satisfaction of the INTLREG.

- ii. The following requirements are to be followed in the application of the tables:
- a. Table 13.3.1 is applicable to bulkheads not bounding either main vertical zones or horizontal zones. Table 13.3.2 is applicable to decks not forming steps in main vertical zones nor bounding horizontal zones.
 - b. For the determination of appropriate fire integrity standards applicable to boundaries between adjacent spaces, such spaces are classified according to their fire risk as outlined in categories (1) to (14) below. Where the contents and use of a space are such that there is a doubt as to its classification for the purpose of this regulation or where it is possible to assign two or more classifications to a space, it shall be treated as a space within the relevant category having the most stringent boundary requirements. Smaller, enclosed rooms within a space with less than 30% communicating openings to that space are counted as separate spaces. The fire integrity of the boundary bulkheads and decks of such smaller rooms shall be in compliance with the specification in Tables 13.3.1 and 13.3.2. The title of each category should be typical rather than restrictive. The number in parentheses preceding each category refers to the applicable column or row in the tables.

1) Control stations

- Wheelhouse and chartroom
- Spaces containing the ship's radio equipment
- Fire control stations
- Spaces containing emergency sources of power and lighting
- Control room for propulsion machinery when located outside the propulsion machinery space.
- Spaces containing centralized emergency public address system stations and equipment.
- Spaces containing centralized fire alarm equipment.

2) Stairways

- Interior stairways, lifts, totally enclosed emergency escape trunks, and escalators (other than those wholly contained within the machinery spaces) for passengers and crew and enclosures thereto.

In regard to this, a stairway enclosed at only one level is considered as part of the space from which it is not separated by a fire door.

3) Corridors

Passenger and crew corridors and lobbies

4) Evacuation stations and external escape routes

- Survival craft stowage area
- Assembly stations, internal and external
- External stairs and open decks used as escape routes

- Open deck spaces and enclosed promenades forming lifeboat and life raft embarkation and lowering stations.
- The ship's side to the waterline in the lightest seagoing condition, superstructure and deckhouse sides situated below and adjacent to the life raft and evacuation slide embarkation areas.

5) Open deck spaces

Open deck spaces and enclosed promenades clear of lifeboat and life raft embarkation and lowering stations. To be counted under this category, enclosed promenades shall have no significant fire risk, meaning that furnishings shall only consist of deck furniture. Additionally, such spaces shall be naturally ventilated by permanent openings.

Air spaces (the space outside superstructures and deckhouses).

6) Accommodation spaces of minor fire risk

- Dispensaries and offices containing furniture and furnishings of restricted fire risk.
- Cabins containing furniture and furnishings of restricted fire risk.
- Public spaces containing furniture and furnishings of restricted fire risk and having deck area of less than 50 m².

7) Accommodation spaces of moderate fire risk

Spaces mentioned in category 6 above but containing furniture and furnishings of other than restricted fire risk.

Public spaces containing furniture and furnishings of restricted fire risk and having a deck area of 50 m² or more.

Isolated lockers and small store-rooms in accommodation spaces having areas less than 4 m² (in which flammable liquids are not stowed).

Sale shops, Motion picture projection and film stowage rooms and Diet kitchens (with no open flame).

Table 13.3.1- Bulkheads not bounding either main vertical zones or horizontal zones

8) Accommodation spaces of greater fire risk

- Barber shops, saunas and beauty parlors.
- Public spaces containing furniture and furnishings of other than restricted fire risk and having a deck area of 50 m² or more.

- 9) Sanitary and similar spaces
 - Small laundry rooms
 - Indoor swimming pool area
 - Communal sanitary facilities, showers, baths, water closets, etc
 - Isolated pantries containing no cooking appliances in accommodation spaces
 - Private sanitary facilities shall be considered a portion of the space of their location
- 10) Tanks, voids and auxiliary machinery spaces having little or no fire risk
 - Voids and cofferdams
 - Water tanks forming part of the ship's structure
 - Auxiliary machinery spaces which do not contain machinery having a pressure lubrication system and where storage of combustibles is prohibited, such as:
 - steering gear room; windlass room stabilizer equipment room; ventilation and air-conditioning rooms; electrical propulsion motor room; rooms containing section switchboards and purely electrical equipment other than oil-filled electrical transformers (above 10 kVA); shaft alleys and pipe tunnels; and spaces for pumps and refrigeration machinery (not handling or using flammable liquids).
 - Closed trunks serving the spaces listed above.
 - Other closed trunks such as pipe and cable trunks
- 11) Auxiliary machinery spaces, cargo spaces, cargo and other oil tanks and other similar spaces of moderate fire risk
 - Oil fuel tanks (where installed in a separate space with no machinery).
 - Shaft alleys and pipe tunnels allowing storage of combustibles
 - Auxiliary machinery spaces as in category (10) which contain machinery having a pressure lubrication system or where storage of combustibles is permitted.
 - Oil fuel filling stations
 - Cargo oil tanks
 - Cargo holds, trunkways and hatchways
 - Refrigerated chambers
 - Spaces containing oil-filled electrical transformers (above 10 kVA)
 - Spaces containing turbine and reciprocating steam engine driven auxiliary generators and small internal combustion engines of power output up to 110 kW driving generators, sprinkler, drencher or fire pumps, bilge pumps, etc.
 - Closed trunks serving the spaces listed above.

12) Machinery spaces and main galleys

- Auxiliary machinery spaces other than those in categories (10) and (11) which contain internal combustion machinery or other oil-burning, heating or pumping units
- Main propulsion machinery rooms (other than electric propulsion motor rooms) and boiler rooms
- Main galleys and annexes
- Trunks and casings to the spaces listed above

13) Store-rooms, workshops, pantries, etc.

- Main pantries not annexed to galleys
- Large drying rooms (having a deck area of more than 4 m²)
- Main Laundry
- Mail and baggage rooms
- Miscellaneous stores
- Garbage rooms
- Workshops (not part of machinery spaces, galleys, etc.)
- Lockers and store-rooms having areas greater than 4m², other than those spaces that have provisions for the storage of flammable liquids.

14) Other spaces in which flammable liquids are stowed

- Paint lockers
- Store-rooms containing flammable liquids (including dyes, medicines, etc.)
- Laboratories (in which flammable liquids are stowed)

c. Where a single value is shown for the fire integrity of a boundary between two spaces, that value shall apply in all cases.

d. Notwithstanding the provisions of Section [3.3.2.2.2], there are no special requirements for material or integrity of boundaries where only a dash appears in the tables.

e. The INTLREG shall determine in respect of category (5) spaces whether the insulation values in table 13.3.1 shall apply to ends of deckhouses and superstructures, and whether the insulation values in table 13.3.2 shall apply to weather decks. In no case shall the requirements of category (5) of tables 13.3.1 or 13.3.2 necessitate enclosure of spaces which in the opinion of the INTLREG need not be enclosed.

TABLE 13.3.1 Bulkheads not bounding either main vertical zones or horizontal zones

Spaces	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Control stations 1)	B - 0'	A - 0	A-0	A-0	A-0	A-60	A-60	A-60	A-0	A-0	A-60	A-60	A-60	A-60
Stairways 2)		A - 0'	A-0	A-0	A-0	A-0	A-15	A-15	A-0C	A-0	A-15	A-30	A-15	A-30
Corridors 3)			B - 1	A - 6	A - 0	B-15	B - 1	B-15	B - 1	A - 0	A-15	A-30	A-0	A-30
Evacuation stations and external 4) escape					A - 0	A-60 ^K _d	A-60 ^K _d	A-6() ^K _d	A - 0"	A - 0	A-60 _b	A-6() _b	A-60 _b	A-6() _b
Open deck spaces 5)						A-0	A-0	A-0	A - 0	A - 0	A-0	A - 0	A-0	A-0
Accommodation spaces of minor 6) fire risk						B-0	B-0	B-0	C	A - 0	A-0	A - 30	A-0	A-30
Accommodation spaces of moderate 7) fire risk							B-0	B-0	c	A - 0	A-15	A - 60	A-15	A-60
Accommodation spaces of greater fire (8) risk								B-0	c	A - 0	A-30	A-60	A-15	A-60
Sanitary and similar spaces 9)									c	A - 0	A-0	A - 0	A-0	A-0
Spaces	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Tanks, voids and auxiliary machinery (10) spaces having little or no fire risk										A - 0'	A-0	A - 0	A-0	A-0
Auxiliary machinery spaces, cargo (11)											A - 0'	A - 0	A-0	A-15

INTLREG Rules for Building and Classing Steel Vessels

Machinery spaces and main galleys (12)												A-0' ₁	A-0	A-60
Store-rooms, workshops, pantries, (13) etc.													A-0'	A-0
Other spaces in which flammable (14) liquids are stowed														A-30

TABLE 13.3.2 Decks not forming steps in main vertical zones nor bounding horizontal zones

Space below J, Space above —>	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14
Control stations 1)	A-30	A-30	A-15	A-0	A-0	A-0	A-15	A-30	A-0	A-0	A-0	A-60	A-0	A-60
Stairways 2)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30	A-0	A-30
Corridors 3)	A-15	A-0	A-0 ^a	A-60	A-0	A-0	A-15	A-15	A-0	A-0	A-0	A-30	A-0	A-30
Evacuation stations and external escape 4) routes	A-0	A-0	A-0	A-0	-	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0
Open deck spaces 5)	A-0	A-0	A-0	A-0	-	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0
Accommodation spaces of minor fire 6) risk	A-60	A-15	A-0	A-60	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0
Space below J, Space above —>	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14
Accommodation spaces of moderate 7) fire risk	A-6	A-1	A-1	A-6	A-0	A-0	A-1	A-1	A-0	A-0	A-0	A-0	A-0	A-0
Accommodation spaces of greater fire 8) risk	A-6	A-1	A-1	A-6	A-0	A-1	A-1	A-3	A-0	A-0	A-0	A-0	A-0	A-0
Sanitary and similar spaces 9)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0

Space below J, Space above —>	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14
Tanks, voids and auxiliary machinery 10) spaces having little or no fire risk	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0 ^a	A-0	A-0	A-0	A-0
Auxiliary machinery spaces, cargo 11) spaces, cargo and other oil tanks and other similar spaces of moderate fire risk	A-60	A-60	A-60	A-60	A-0	A-0	A-15	A-30	A-0	A-0	A-0 ^a	A-0	A-0	A-30
Machinery spaces and main galleys 12)	A-60	A-60	A-60	A-60	A-0	A-60	A-60	A-60	A-0	A-0	A-30 ^a	A-0	A-0	A-60
Store-rooms, workshops, pantries, etc. 13)	A-60	A-30	A-15	A-60	A-0	A-15	A-30	A-30	A-0	A-0	A-0	A-0	A-0	A-0
Store-rooms, workshops, pantries, etc. 14)	A-60	A-30	A-15	A-60	A-0	A-15	A-30	A-30	A-0	A-0	A-0	A-0	A-0	A-0

Notes: To be applied to tables 13.3.1 and 13.3.2, as appropriate.

- If it is deemed unnecessary by the INTLREG, then in places where adjacent spaces are in the same numerical category and superscript "a" appears, a bulkhead or deck between such spaces need not be fitted. For example in category (12) a bulkhead is not really required between a galley and its annexed pantries under circumstances that the pantry bulkhead and decks maintain the integrity of the galley boundaries. A bulkhead is, however a requirement between a galley and machinery space even though both spaces are in category (12).
- The ship's side, to the waterline in the lightest seagoing condition, superstructure and deckhouse sides situated below and adjacent to liferafts and evacuation slides may be reduced to "A-30".
- The public toilet bulkhead within the stairway enclosure can be of "B" class integrity, where public toilets are installed completely within the stairway enclosure.
- Where spaces of categories (6), (7), (8) and (9) are located completely within the outer perimeter of the assembly station, the bulkheads of these spaces are allowed to be of "B - 0" class

integrity. Control positions for audio, video and light installations may be considered as part of the assembly station. Cleaning gear lockers (in which flammable liquids are not stowed)

- Laboratories (in which flammable liquids are not stowed)
- Pharmacies
- Small drying rooms (having a deck area of 4 m² or less)
- Specie rooms
- Operating rooms

iii. Continuous "B" class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing, wholly or in part, to the required insulation and integrity of a division.

iv. Construction and arrangement of saunas

- a. The perimeter of the sauna shall be of "A" class boundaries and may include changing rooms, showers and toilets. The sauna shall be insulated to "A-60" standard against other spaces except those inside of the perimeter and spaces of categories (5), (9) and (10).
- b. Bathrooms with direct access to saunas may be considered as part of them. In such cases, it is not a necessity that the door between sauna and the bathroom has to comply with fire safety requirements.
- c. The traditional wooden lining on the bulkheads and ceiling are permitted in the sauna. The ceiling above the oven shall be lined with a non-combustible plate with an air gap of at least 30 mm. The distance from the hot surfaces to combustible materials shall be at least 5.00 mm or the combustible materials shall be protected (e.g., non-combustible plate with an air gap of at least 30 mm).
- d. The sauna door shall open outwards by pushing.
- e. The traditional wooden benches are permitted to be used in the sauna.
- f. Electrically heated ovens shall be provided with a timer

3.3.2.2.4. Fire integrity of bulkheads and decks in ships carrying not more than 36 passengers

- i. In addition to complying with the specific provisions for fire integrity of bulkheads and decks of passenger ships, the minimum fire integrity of bulkheads and decks shall be as prescribed in tables 13.3.3 and 13.3.4.
- ii. The following requirements shall govern application of the tables:
 - a. Tables 13.3.3 and 13.3.4 shall apply respectively to the bulkheads and decks separating adjacent spaces.
 - b. For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, such spaces are classified according to their fire risk as shown in categories (1) to

(11) below. Where the contents and use of a space are such that there is a doubt as to its classification for the purpose of this regulation, or where it is possible to assign two or more classifications to a space, it shall be treated as a space within the relevant category having the most stringent boundary requirements. Smaller, enclosed rooms within a space that have less than 30% communicating openings to that space are considered separate spaces. The fire integrity of the boundary bulkheads and decks of such smaller rooms shall be as prescribed in tables 13.3.3 and 13.3.4. The title of each category is intended to be typical rather than restrictive. The number in parentheses preceding each category refers to the applicable column or row in the tables.

- 1) Control stations
 - Spaces containing emergency sources of power and lighting
 - Fire control stations
 - Wheelhouse and chartroom
 - Spaces containing the ship's radio equipment
 - Control room for propulsion machinery when located outside the machinery space. Spaces containing centralized fire alarm equipment

- 2) Corridors
 - Passenger and crew corridors and lobbies

- 3) Accommodation spaces
 - Spaces as defined in Section [3.3.1.1] excluding corridors

- 4) Stairways

Interior stairways, lifts, totally enclosed emergency escape trunks, and escalators (other than those wholly contained within the machinery spaces) and enclosures thereto.

In this connection, a stairway which is enclosed only at one level shall be regarded as part of the space from which it is not separated by a fire door.

- 5) Service spaces (low risk)

Lockers and store-rooms with no provisions for the storage of flammable liquids and having areas less than 4 m² and drying rooms and laundries.

- 6) Machinery spaces of category A Spaces as defined in Section 1[1.3.31]

- 7) Other machinery spaces
Electrical equipment rooms (auto-telephone exchange, air-conditioning duct spaces). Spaces as defined in Section 1, [1.3.30] excluding machinery spaces of category A.

- 8) Cargo spaces

All spaces used for cargo (including cargo oil tanks) and trunk ways and hatchways to such spaces, other than special category spaces.

- 9) Service spaces (high risk)
Galleys, pantries containing cooking appliances, paint lockers, lockers and store-rooms having areas of 4 m² or more, spaces for the storage of flammable liquids, saunas and workshops other than those forming part of the machinery spaces.
- 10) Open decks
Open deck spaces and enclosed promenades having little or no fire risk. To be considered in this category, enclosed promenades shall have no significant fire risk, meaning that furnishing shall be restricted to deck furniture. In addition, such spaces shall be naturally ventilated by permanent openings.
spaces (the space outside superstructures and deckhouses).

- 11) Special category and Ro—Ro spaces

Spaces as defined in Section 1[1.3.41]

Table 13.3.3 — Fire integrity of bulkheads separating adjacent spaces

Spaces		1)	2)	3)	4)	5)	6)	7)	8)	9)	10)	11)
Control stations	1)	A -	A - 0	A - 0	A - 0	A 1 5	A - 60	A - 1 5	A -	A -	*	A - 60
Corridors	2)		C ^c	B - 0	A - 0 A B	B - 0	A - 60	A - 0	A - 0	A - 1 5	*	A - 15
Accommodation spaces	3)			C ^e	A - 0 A B-	B - 0	A - 60	A - 0	A - 0	A - 1 5	*	A A - 0 d
Stairways	4)				A - 0 A B - 0	A B - 0	A - 60	A - 0	A - 0	A A - 0 d	*	A - 15
Service spaces (low risk)	5)					C ^e	A - 0	A - 0	A - 0	A - 0	*	A - 0
Machinery spaces of category A	6)						*	A - 0	A - 0	A - 0	*	A - 60
Other machinery spaces	7)							A - 0 ^B	A - 0	A - 0	*	A - 0
Cargo spaces	8)								*	A - 0	*	A - 0

PART 5A
CHAPTER 13

INTLREG Rules and Regulations for Classification of Steel Vessels

Service spaces (high risk)	9)									A-0	*	A-30
Open decks	10)											A-0
Special category and Ro—Ro spaces	11)											A-0

Table 13.3.4 - Fire integrity of decks separating adjacent spaces

Space below /	Space above	1)	2)	3)	4)	5)	6)	7)	8)	9)	10)	11)
Control stations	1)	A-0	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0	*	A-30
Corridors	2)	A-0	*	*	A-0	*	A-60	A-0	A-0	A-0	*	A-0
Accommodation spaces	3)	A-60	A-0	*	A-0	*	A-60	A-0	A-0	A-0	*	A-30 A-0 ^d
Stairways	4)	A-0	A-0	A-0	*	A-0	A-60	A-0	A-0	A-0	*	A-0
Service spaces (low risk)	5)	A-15	A-0	A-0	A-0	*	A-60	A-0	A-0	A-0	*	A-0
Machinery spaces of category A	6)	A-60	A-60	A-60	A-60	A-60	*	A-60	A-30	A-60	*	A-60
Other machinery	7)	A-0	A-0	A-0	A-0	A-0	A-0	*	A-0	A-0	*	A-0
Cargo spaces	8)	A-60	A-0	A-0	A-0	A-0	A-0	A-0	*	A-0	*	A-0
Service spaces (high risk)	9)	A-60	A-30	A-30	A-30	A-0	A-60	A-0	A-0	A-0	*	A-30
Open decks	10)	*	*	*	*	*	*	*	*	*	-	A-0
Special category and Ro—Ro spaces	11)	A-60	A-15	A-30	A-15	A-0	A-30	A-0	A-0	A-30	A-0	A-0

Notes: To be applied to both tables 13.3.3 and 13.3.4 as appropriate.

- For clarification as to which applies, Refer Sections [3.3.2.2.2] and [3.3.2.2.5].
- Where spaces are of the same numerical category and superscript "b" appears, a bulkhead or deck of the rating shown in the tables is only required when the adjacent spaces are for a different purpose (e.g., in category (9)). A bulkhead is not required for a galley next to a galley, but a galley next to a paint room requires an "A-0" bulkhead,
- Bulkheads separating the wheelhouse and chartroom from each other may have a "B-0" rating,
- If the machinery space in category (7), in the opinion of the INTLREG, has little or no fire risk, then there is no need to fit fire insulation.

* Where an asterisk appears in the tables, the division is required to be of steel or other equivalent material, but is not required to be of "A" class standard. However, where a deck, except in a category (10) space, is penetrated for the passage of electric cables, pipes and vent ducts, such penetrations shall be made tight to prevent the passage of flame and smoke.

Divisions between control stations (emergency generators) and open decks may have air intake openings without means for closure; unless a fixed gas fire-extinguishing system is fitted.

For the application of Section [3.3.2.2.1]., an asterisk, where appearing in table 13.3.4, except for categories (8) and (10), shall be read as "A-0".

- c. In determining the applicable fire integrity standard of a boundary between two spaces within a main vertical zone or horizontal zone which is not protected by an automatic sprinkler system complying with the provisions of the Fire Safety Systems Code or between such zones neither of which is so protected, the higher of the two values given in the tables shall apply.
- d. In the determination of the applicable fire integrity standard of a boundary between two spaces within a main vertical zone or horizontal zone which is protected by an automatic sprinkler system complying with the provisions of the Fire Safety Systems Code or between such zones both of which are so protected, the lesser of the two values given in the tables shall apply. Where a zone with sprinklers and a zone without sprinklers meet within accommodation and service spaces, the higher of the two values given in the tables shall apply to the division between the zones.
- iii. Continuous "B" class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing, wholly or in part, to the required insulation and integrity of a division.
- iv. External boundaries which are required in Chapter 2 Section 3, 2 to be of steel or other equivalent material may be pierced for the fitting

of windows and side scuttles provided that there is no requirement for such boundaries of passenger ships to have "A" class integrity. Similarly, in such boundaries which are not required to have "A" class integrity, doors may be constructed of materials which are to the satisfaction of the INTLREG.

- v. Saunas shall comply with Section [3.3.2.2.3].(iv).

3.3.2.2.5. Protection of stairways and lifts in accommodation area

- i. Stairways shall be within enclosures formed of "A" class divisions, with positive means of closure at all openings, except that:
 - a. A stairway connecting only two decks is not required to be enclosed, on the condition that the integrity of the deck is maintained by proper bulkheads or self-closing doors in one 'tween-deck space. When a stairway is closed in one 'tween-deck space, the stairway enclosure shall be protected in accordance with the tables for decks in Sections [3.3.2.2.3] or [3.3.2.2.4]; and
 - b. Stairways may be fitted in the open in a public space, provided they lie wholly within the public space.
- ii. Lift trunks should be fitted in such a manner that the passage of smoke and flame from one 'tween-deck to another can be prevented and shall be provided with means of closing so as to permit the control of draught and smoke. Machinery for lifts located within stairway enclosures shall be arranged in a separate room, surrounded by steel boundaries, except that small passages for lift cables are permitted. Lifts which open into spaces other than public spaces, special category spaces, corridors, stairways and external areas shall not open into stairways included in the means of escape.

3.3.2.2.6. Arrangement of cabin balconies

For the purpose of fighting fires on passenger ships constructed on or after 1 July 2008, non-load-bearing partial bulkheads which separate adjacent cabin balconies shall be capable of being opened by the crew from each side.

3.3.3 Cargo ships except tankers

3.3.3.1 Methods of protection in accommodation area

- i. One of the following methods of protection shall be adopted in accommodation and service spaces and control stations:
 - a. Method IC - The construction of internal divisional bulkheads of non-combustible "B " or "C" class divisions generally without the installation of an automatic sprinkler, fire detection and fire alarm system in the accommodation and service spaces, except as required by Section [3.1.5.5.1] or
 - b. Method IIC — The fitting of an automatic sprinkler, fire detection and fire alarm system as required by Section [3.1.5.5.2] for the detection and extinction of fire

in all spaces in which fire might be expected to originate, generally with no restriction on the type of internal divisional bulkheads; or

- c. Method IIIC - The fitting of a fixed fire detection and fire alarm system as required by Section [3.1.5.5.3] in spaces in which a fire might be expected to originate, generally with no restriction on the type of internal divisional bulkheads, except that in no case shall the area of any accommodation space or spaces bounded by an "A" or "B" class division exceed 50 m. However, consideration may be given by the INTLREG to increasing this area for public spaces.

- ii. The requirements for the use of non-combustible materials in the construction and insulation of boundary bulkheads of machinery spaces, control stations, service spaces, etc., and the protection of the above stairway enclosures and corridors will be common to all three methods outlined in Section [3.3.3.1.i].

3.3.3.2 Bulkheads within accommodation area

- i. Bulkheads required to be "B" class divisions shall extend from deck to deck and to the shell or other boundaries. However, where a continuous "B" class ceiling or lining is fitted on both sides of the bulkhead, the bulkhead may terminate at the continuous ceiling or lining.
- ii. Method IC — Bulkheads not required by this or other regulations for cargo ships to be "A" or "B" class divisions shall be of at least "C" class construction.
- iii. Method IIC — There shall be no restriction on the construction of bulkheads not required by this or other regulations for cargo ships to be "A" or "B" class divisions except in individual cases where "C" class bulkheads are required in accordance with table 13.3.5.
- iv. Method IIIC — There shall be no restriction on the construction of bulkheads not required for cargo ships to be "A" or "B" class divisions except that the area of any accommodation space or spaces bounded by a continuous "A" or "B" class division shall in no case exceed 50 m², except in individual cases where "C" class bulkheads are required in accordance with table 13.3.5. However, consideration may be given by the INTLREG to increasing this area for public spaces.

3.3.3.3 Fire integrity of bulkheads and decks

- i. In addition to complying with the specific provisions for fire integrity of bulkheads and decks of cargo ships, the minimum fire integrity of bulkheads and decks shall be as prescribed in tables 13.3.5 and 13.3.6.
- ii. The following requirements shall govern application of the tables:
 - a. Tables 13.3.5 and 13.3.6 shall apply respectively to the bulkheads and decks separating adjacent spaces.
 - b. For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, such spaces are classified according to their fire risk as shown in categories (1) to (11) below. Where the contents and use of a space are such that there is a doubt as to its classification for the purpose of this regulation, or where it is possible to assign two or more classifications to a space, it shall be treated as a space within the relevant category having the most stringent boundary requirements. Smaller, enclosed rooms within a space that have less than 30% communicating openings to

that space are considered separate spaces. The fire integrity of the boundary bulkheads and decks of such smaller rooms shall be as prescribed in tables 13.3.5 and 13.3.6. The title of each category is intended to be typical rather than restrictive. The number in parentheses preceding each category refers to the applicable column or row in the tables.

- iii. Continuous "B" class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing, wholly or in part, to the required insulation and integrity of a division.
- iv. External boundaries which are required in Section 3[3.5.2]. to be of steel or other equivalent material may be pierced for the fitting of windows and side scuttles provided that there is no requirement for such boundaries of cargo ships to have "A" class integrity. Similarly, in such boundaries which are not required to have "A" class integrity, doors may be constructed of materials which are to the satisfaction of the INTLREG.
- v. Saunas shall comply with Section [3.3.2.2.3].(iv).

Table 13.3.5 — Fire integrity of bulkheads separating adjacent spaces

Spaces		1)	2)	3)	4)	5)	6)	7)	8)	9)	10)	11)
Control stations	1)	A-0	A-0	A-60	A-0	A-15	A-60	A-0	A-0	A-60	*	A-60
Corridors	2)		C	B-0	B-0 A-0 ^c	B-0	A-60	A-0	A-0	A-0	*	A-30
Accommodation spaces	3)			c a, b	B-0 A-0 ^c	B-0	A-60	A-0	A-0	A-0	*	A-30
Stairways	4)				B-0 A-0 ^c	B-0 A-0 ^c	A-60	A-0	A-0	A-0	*	A-30
Service spaces (low risk)	5)					C	A-60	A-0	A-0	A-0	*	A-0
Machinery spaces of category A	6)						*	A-0	A-0	A-60	*	A-60 ^f
Other machinery spaces	7)							A-0 ^d	A-0	A-0	*	A-0
Cargo spaces	8)								*	A-0	*	A-0
Service spaces (high risk)	9)									A-0 ^d	*	A-30
Open decks	10)										-	A-0
Ro-ro and vehicle	11)											

Table 13.3.6 - Fire integrity of decks separating adjacent spaces

Space below j	Space above—>	1)	2)	3)	4)	5)	6)	7)	8)	9)	10)	11)
Control stations	1)	A-0	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0	*	A-60
Corridors	2)	A-0	*	*	A-0	*	A-60	A-0	A-0	A-0	*	A-30
Accommodation spaces	3)	A-60	A-0	*	A-0	*	A-60	A-0	A-0	A-0	*	A-30
Stairways	4)	A-0	A-0	A-0	*	A-0	A-60	A-0	A-0	A-0	*	A-30
Service spaces (low risk)	5)	A-15	A-0	A-0	A-0	*	A-60	A-0	A-0	A-0	*	A-0
Machinery spaces of category A	6)	A-60	A-60	A-60	A-60	A-60	*	A-60 ¹	A-30	A-60	*	A-60
Other machinery spaces	7)	A-15	A-0	A-0	A-0	A-0	A-0	*	A-0	A-0	*	A-0
Cargo spaces	8)	A-60	A-0	A-0	A-0	A-0	A-0	A-0	*	A-0	*	A-0
Service spaces (high risk)	9)	A-60	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0*	*	A-30
Open decks	10)	*	*	*	*	*	*	*	*	*	*	*
Ro—ro and vehicle spaces	11)	A-60	A-30	A-30	A-30	A-0	A-60	A-0	A-0	A-30	*	*h

Notes: To be applied to tables 13.3.5 and 13.3.6, as appropriate.

- No special requirements are imposed upon bulkheads in methods IIC and IIIC fire protection.
- In case of method IIIC, "B" class bulkheads of "B-0" rating shall be provided between spaces or groups of spaces of 50 m² and over in area,
- For clarification as to which applies, Refer Sections [3.3.3.2] and [3.3.3.4].
- Where spaces are of the same numerical category and superscript "d" appears, a bulkhead or deck of the rating shown in the tables is only required when the adjacent spaces are for a different purpose (e.g., in category (9)). A galley next to a galley does not require a bulkhead, but a galley next to a paint room requires an "A-0" bulkhead,
- Bulkheads separating the wheelhouse, chartroom and radio room from each other may have a "B-0" rating.
- An "A-0" rating may be used if no dangerous goods are intended to be carried or if such goods are stowed not less than 3 m horizontally from such a bulkhead,
- For cargo spaces in which dangerous goods are intended to be carried, rules in chapter 5 is to be followed.
- Bulkheads and decks separating Ro—Ro spaces shall be capable of being closed reasonably gastight and such divisions shall have "A" class integrity in so far as reasonable and practicable, if in the opinion of the INTLREG it has little or no fire risk,

- i. Fire insulation need not be fitted in the machinery space in category (7) if, in the opinion of the INTLREG, it has little or no fire risk.

*Where an asterisk appears in the tables, it is a requirement for the division to be of steel or other equivalent material but not necessarily enough to be of "A" class standard. However, where a deck, apart from an open deck, is penetrated for the passage of electric cables, pipes and vent ducts, such penetrations shall be made tight to prevent the passage of flame and smoke. Divisions between control stations (emergency generators) and open decks may have air intake openings without means for closure; unless a fixed gas fire-extinguishing system is fitted.

1) Control stations

- Wheelhouse and chartroom
- Spaces containing the ship's radio equipment
- Spaces containing emergency sources of power and lighting
- Fire control stations
- Control room for propulsion machinery when located outside the machinery space
- Spaces containing centralized fire alarm equipment

2) Corridors

Corridors and lobbies

3) Accommodation spaces

Spaces as defined in Section [1.3.1], excluding corridors

4) Stairways

Interior stairway, lifts, totally enclosed emergency escape trunks, and escalators (other than those wholly contained within the machinery spaces) and enclosures there to. In this connection, a stairway which is enclosed only at one level shall be regarded as part of the space from which it is not separated by a fire door.

5) Service spaces (low risk)

Lockers and store-rooms not having provisions for the storage of flammable liquids and having areas less than 4 m² and drying rooms and laundries.

6) Machinery spaces of category A Spaces as defined in Section [1.3.31].

7) Other machinery spaces

Electrical equipment rooms (auto-telephone exchange, air-conditioning duct spaces). Spaces as defined in Section , [1.3.30]. excluding machinery spaces of category A.

8) Cargo spaces

All spaces used for cargo (including cargo oil tanks) and trunk ways and hatchways to such spaces.

9) Service spaces (high risk)

Galley, pantries containing cooking appliances, saunas, paint lockers and store-rooms having areas of 4m² or more, spaces for the storage of flammable liquids, and workshops other than those forming part of the machinery spaces.

10) Open decks

Open deck spaces and enclosed promenades and open deck spaces having little or no fire risk. To be considered in this category, enclosed promenades shall have no significant fire risk, meaning that furnishings shall be restricted to deck furniture. In addition, such spaces should have natural openings for permitting natural ventilation.

Air spaces (the space outside superstructures and deckhouses)

11) Ro-ro and vehicle spaces

Ro-Ro spaces as defined in Section [1.3.41]

Vehicle spaces as defined in Section [1.3.49]

3.3.3.4 Protection of stairways and lift trunks in accommodation spaces, service spaces and control stations

- i. Stairways which penetrate only a single deck shall be protected, at a minimum, at one level by at least "B-0" class divisions and self-closing doors. Lifts which penetrate only a single deck shall be surrounded by "A-0" class divisions with steel doors at both levels. Stairways and lift trunks which penetrate more than a single deck shall be surrounded by at least "A-0" class divisions and be protected by self-closing doors at all levels.
- ii. On ships having accommodation for 12 persons or less, where stairways penetrate more than a single deck and where there are at least two escape routes direct to the open deck at every accommodation level, the "A-0" requirements of Section [3.3.3.4](i) may be reduced to "B-0".

3.3.4 Tankers

3.3.4.1 Application

For tankers, only method IC as defined in Section [3.3.3.1].(i) shall be used.

3.3.4.2 Fire integrity of bulkheads and decks

- i. In lieu of Section 3.2.3 and in addition to complying with the specific provisions for fire integrity of bulkheads and decks of tankers, the minimum fire integrity of bulkheads and decks shall be as prescribed in tables 3.3.7 and 3.3.8.
- ii. The following requirements shall govern application of the tables:
 - a. Tables 13.3.7 and 13.3.8 shall apply respectively to the bulkhead and decks separating adjacent spaces.
 - b. For determining the appropriate fire integrity standards applicable to divisions between adjacent spaces, such spaces are classified according to their fire risk as shown in categories (1) to (10) below. Where the contents and use of a space are such that there is a doubt as to its classification for the purpose of this regulation, or where it is possible to assign two or more classifications to a space, it shall be treated as a space within the relevant category having the most stringent boundary requirements. Smaller, enclosed areas within a space that have less than 3 0% communicating openings to that space are considered separate areas. The fire integrity of the boundary bulkheads and decks of such smaller spaces shall be as prescribed in tables 13.3.7 and 13.3.8. The title of each category is intended to be typical rather than restrictive. The

number in parentheses preceding each category refers to the applicable column or row in the tables.

- 1) Control stations
 - Spaces containing emergency sources of power and lighting
 - Spaces containing the ship's radio equipment
 - Wheelhouse and chartroom
 - Fire control stations
 - Control room for propulsion machinery when located outside the machinery space. Spaces containing centralized fire alarm equipment.
- 2) Corridors
Corridors and lobbies
- 3) Accommodation spaces
Spaces as defined in SOLAS regulation [1.3.1], excluding corridors
- 4) Stairways
Interior stairways, lifts, totally enclosed emergency escape trunks, and escalators (other than those wholly contained within the machinery spaces) and enclosures thereto.

Table 13.3.7 Fire integrity of bulkheads separating adjacent spaces

Spaces	1)	2)	3)	4)	5)	6)	7)	8)	9)	10)
Control stations 1)	A-0 ^c	A-0	A-60	A-0	A-15	A-60	A-15	A-60	A-60	*
Corridors 2)		C	B-0	B-0 A-0 ^A	B-0	A-60	A-0	A-60	A-0	*
Accommodation spaces 3)			C	B-0 A-0 ^A	B-0	A-60	A-0	A-60	A-0	*
Stairways (4)				B-0 A-0' A-0''	B-0 A-0''	A-60	A-0	A-60	A-0	*
Service spaces (low risk) (5)					C	A-60	A-0	A-60	A-0	*
Machinery spaces of category A (6)						*	A-0	A-0 ^D	A-60	*
Other machinery spaces (7)							A-0 ^B	A-n	A-0	*
Cargo pump-rooms (8)								*	A-60	*

Service spaces (high risk) (9)									A-0 ^B	
Open decks (10)										-

Table 13.3.8 - Fire integrity of decks separating adjacent spaces

Space below J.	Space above— *	1)	2)	3)	4)	5)	6)	7)	8)	9)	10)
Control stations	1)	A-0	A-0	A-0	A-0	A-0	A-60	A-0		A-0	*
Corridors	2)	A-0	*	*	A-0	*	A-60	A-0		A-0	*
Accommodation spaces	3)	A-60	A-0	*	A-0	*	A-60	A-0		A-0	*
Stairways	4)	A-0	A-0	A-0	*	A-0	A-60	A-0		A-0	*
Service spaces (low risk)	5)	A-15	A-0	A-0	A-0	*	A-60	A-0		A-0	*
Machinery spaces of category A	6)	A-60	A-60	A-60	A-60	A-60	*	A-60 ^e	A-0	A-60	*
Other machinery spaces	7)	A-15	A-0	A-0	A-0	A-0	A-0	*	A-0	A-0	*
Space below J.	Space above— *	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Cargo pump-rooms	8)						A-0*	A-0	*		*
Service spaces (high risk)	9)	A-60	A-0	A-0	A-0	A-0	A-60	A-0		A-0"	*
Open decks	10)	*	*	*	*	*	*	*	*	*	

Notes: To be applied to tables 13.3.7 and 13.3.8 as appropriate.

- For clarification as to which applies, refer to Sections [3.3.3.2] and [3.3.3.4].
- Where spaces have the same numerical category and superscript "b" appears, a bulkhead or deck of the rating shown in the tables is only required when the adjacent spaces are for a different purpose (e.g., in category (9)). A galley next to a galley does not require a bulkhead but a galley next to a paint room requires an "A-0" bulkhead.
- Bulkheads separating the wheelhouse, chartroom and radio room from each other may have a "B-0" rating.
- Cargo Pump shaft glands and similar gland penetrations can penetrate bulkheads and decks between cargo pump-rooms and machinery spaces of category A, on the condition that gastight seals

with efficient lubrication or other means of ensuring the permanence of the gas seal are fitted in way of the bulkheads or deck.

- e. In the machinery space in category (7), there is no requirement to fit fire insulation if in the opinion of the INTLREG, it has little or no fire risk.

* Where an asterisk appears in the table, the division is required to be of steel or other equivalent material, but is not required to be of "A" class standard. However, where a deck, except an open deck, is penetrated for the passage of electric cables, pipes and vent ducts, such penetrations shall be made tight to prevent the passage of flame and smoke. Divisions between control stations (emergency generators) and open decks may have air intake openings without means for closure, unless a fixed gas fire-extinguishing system is fitted. In this connection, a stairway which is enclosed only at one level shall be regarded as part of the space from which it is not separated by a fire door.

5) Service spaces (low risk)

Lockers and store-rooms not having provisions for the storage of flammable liquids and having areas less than 4 m² and drying rooms and laundries.

6) Machinery spaces of category A Spaces as defined in Section[1.3.31]

7) Other machinery spaces

Electrical equipment rooms (auto-telephone exchange and air-conditioning duct spaces). Spaces as defined in Section [1.3.31], excluding machinery spaces of category A.

8) Cargo pump-rooms

Spaces containing cargo pumps and entrances and trunks to such spaces.

9) Service spaces (high risk)

Galleys, pantries containing cooking appliances, saunas, paint lockers and store-rooms having areas of 4 m² or more, spaces for the storage of flammable liquids and workshops other than those forming part of the machinery spaces.

10) Open decks

Open deck spaces and enclosed promenades having little or no fire risk. To be considered in this category, enclosed promenades shall have no significant fire risk, meaning that furnishings shall be restricted to deck furniture. In addition, such spaces should have permanent openings for natural ventilation.

Air spaces (the space outside superstructures and deckhouses).

- i. Continuous "B" class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing, wholly or in part, to the required insulation and integrity of a division.

- ii. External boundaries which are required in Section 3, [3.5.2], to be of steel or other equivalent material may be pierced for the fitting of windows and side scuttles provided that there is no requirement for such boundaries of tankers to have "A" class integrity. Similarly, in such boundaries which are not required to have "A" class integrity, doors may be constructed of materials which are to the satisfaction of the INTLREG.
- iii. Exterior boundaries of superstructures and deckhouses enclosing accommodation and including any overhanging decks which support such accommodation shall be constructed of steel and insulated to "A-60" standard for the whole of the portions which face the cargo area and on the outward sides for a distance of 3 m from the end boundary facing the cargo area. The distance of 3 m shall be measured horizontally and parallel to the middle line of the ship from the boundary which faces the cargo area at each deck level. In the case of the sides of those superstructures and deckhouses, such insulation shall be carried up to the underside of the deck of the navigation bridge.
- iv. Skylights to cargo pump-rooms shall be of steel, shall not contain any glass and shall be capable of being closed from outside the pump-room.
- v. Construction and arrangement of saunas shall comply with Section [3.3.2.2.3].(iv).

3.3.5 Penetrations in fire-resisting divisions and prevention of heat transmission

- 3.3.5.1 Where "A" class divisions are penetrated, such penetrations shall be tested in accordance with the Fire Test Procedures Code, subject to [3.3.6.1.1](v). In the case of ventilation ducts, Sections [3.3.10.1.2] and [3.3.10.3.1] apply. However, where a pipe penetration is made of steel or equivalent material having a thickness of 3 mm or greater and a length of not less than 900 mm (preferably 450 mm on each side of the division), and there are no openings, testing is not required. Such penetrations shall be suitably insulated by extension of the insulation at the same level of the division.
- 3.3.5.2 Where "B" class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for the fitting of ventilation terminals, lighting fixtures and similar devices, arrangements shall be made to ensure that the fire resistance is not impaired, subject to the provisions of Section [3.3.10.3.2]. Pipes other than steel or copper that penetrate "B" class divisions shall be protected by either:
 - a. a fire-tested penetration device suitable for the fire resistance of the division pierced and the type of pipe used; or
 - b. a steel sleeve, having a thickness of not less than 1.8 mm and a length of not less than 900 mm for pipe diameters of 150 mm or more and not less than 600 mm for pipe diameters of less than 150 mm (preferably equally divided to each side of the division). The pipe shall be connected to the ends of the sleeve by flanges or couplings; or the clearance between the sleeve and the pipe shall not exceed 2.5 mm; or any clearance between pipe and sleeve shall be made tight by means of non-combustible or other suitable material.

- 3.3.5.3 Un-insulated metallic pipes penetrating "A" or "B" class divisions shall be of materials having a melting temperature which exceeds 950°C for "A-0" and 850°C for "B - 0" class divisions.
- 3.3.5.4 In approving structural fire protection details, the INTLREG shall have regard to the risk of heat transmission at intersections and terminal points of required thermal barriers. The insulation of a deck or bulkhead shall be carried past the penetration, intersection or terminal point for a distance of at least 450 mm in the case of steel and Aluminium structures. If a space is divided with a deck or a bulkhead of "A" class standard having insulation of different values, the insulation with the higher value shall continue on the deck or bulkhead with the insulation of the lesser value for a distance of at least 450 mm.
- 3.3.6 Protection of openings in fire-resisting divisions
- 3.3.6.1 Openings in bulkheads and decks in passenger ships
- 3.3.6.1.1. Openings in "A" class divisions
- i. Except for hatches between cargo, special category, store, and baggage spaces, and between such spaces and the weather decks, openings shall be provided with permanently attached means of closing which shall be at least as effective for resisting fires as the divisions in which they are fitted.
 - ii. The construction of doors and door frames in "A" class divisions, with the means of securing them when closed, shall provide resistance to fire as well as to the passage of smoke and flame equivalent to that of the bulkheads, in which the doors are situated, this being determined in accordance with the Fire Test Procedures Code. Such doors and door frames shall be constructed of steel or other equivalent material. Watertight doors need not be insulated.
 - iii. It shall be possible for each door to be opened and closed from each side of the bulkhead by one person only.
 - iv. Fire doors in main vertical zone bulkheads, galley boundaries and stairway enclosures other than power-operated watertight doors and those which are normally locked shall satisfy the following requirements:
 - a. The doors shall be self-closing and be capable of closing with an angle of inclination of up to 3.5° opposing closure;
 - b. The approximate time of closure for hinged fire doors shall be no more than 40 second and no less than 10 second from the beginning of their movement with the ship in upright position. The approximate uniform rate of closure for sliding doors shall be of no more than 0.2 m/s and no less than 0.1 m/s with the ship in upright position;
 - c. The doors, except those for emergency escape trunks, shall be capable of remote release from the continuously manned central control station, either simultaneously or in groups, and shall be capable of release also individually from a position at both sides of the door. Release switches shall have an on—off function to prevent automatic resetting of the system;

- d. Hold-back hooks not subject to central control station release are prohibited;
- e. A door closed remotely from the central control station shall be capable of being re-opened from both sides of the door by local control. After such local opening, the door shall automatically close again;
- f. Indication shall be provided at the fire door indicator panel in the continuously manned central control station whether each door is closed;
- g. The release mechanism shall be so designed that the door will automatically close in the event of disruption of the control system or central power supply;
- h. Local power accumulators for power-operated doors shall be provided in the immediate vicinity of the doors to enable the doors to be operated at least ten times (fully opened and closed) after disruption of the control system or central power supply using the local controls;
- i. Disruption of the control system or central power supply at one door shall not impair the safe functioning of the other doors;
- j. Remote-released sliding or power-operated doors shall be equipped with an alarm that sounds at least 5 s but no more than 10 s, after the door is released from the central control station and before the door begins to move and continues sounding until the door is completely closed;
- k. A door designed to re-open upon contacting an object in its path shall re-open not more than 1 m from the point of contact;
- l. Double-leaf doors equipped with a latch necessary for their fire integrity shall have a latch that is automatically activated by the operation of the doors when released by the system;
- m. Doors giving direct access to special category spaces which are power-operated and automatically closed need not be equipped with the alarms and remote-release mechanisms required in Sections [3.3.6.1.1](iv).(m) and [3.3.6.1.1j];
- n. The components of the local control system shall be accessible for maintenance and adjusting;
- o. Power-operated doors shall be provided with a control system of an approved type which shall be able to operate in case of fire and be in accordance with the fire test procedures code. This system shall satisfy the following requirements:
 - The control system shall be able to operate the door at the temperature of at least 200°C for at least 60 min, served by the power supply;
 - The power supply for all other doors not subject to fire shall not be impaired; and

- At temperatures exceeding 200°C the control system shall be automatically isolated from the power supply and shall be capable of keeping the door closed up to at least 945°C.
- v. In ships carrying not more than 36 passengers, where a space is protected by an automatic sprinkler fire detection and fire alarm system complying with the provisions of the Fire Safety Systems Code or fitted with a continuous " B " class ceiling, openings in decks not forming steps in main vertical zones nor bounding horizontal zones shall be closed reasonably tight and such decks shall meet the "A" class integrity requirements in so far as is reasonable and practicable in the opinion of the INTLREG.
- vi. The requirements for "A" class integrity of the outer boundaries of a ship shall not apply to glass partitions, windows and side scuttles provided that there is no requirement for such boundaries to have "A" class integrity in Section [3.3.6.1.3] (iii). requirements for "A" class integrity of the outer boundaries of the ship shall not apply to exterior doors, except for those in superstructures and deckhouses facing life-saving appliances, embarkation and external assembly station areas, external stairs and open decks used for escape routes. Stairway enclosure doors need not meet this requirement.
- vii. Except for watertight doors, weather tight doors (semi-watertight doors), doors leading to the open deck and doors which need to be reasonably gastight, all "A" class doors located in stairways, public spaces and main vertical zone bulkheads in escape routes shall be equipped with a self-closing hose port. The material, construction and fire resistance of the hose port shall be equivalent to the door into which it is fitted, and shall be a 150 mm square clear opening with the door closed and shall be inset into the lower edge of the door, opposite the door hinges or, in the case of sliding doors, nearest the opening.
- viii. Where it is necessary that a ventilation duct passes through a main vertical zone division, a fail-safe automatic closing fire damper shall be fitted adjacent to the division. The damper shall also be capable of being manually closed from each side of the division. The operating position shall be readily accessible and be marked in red light-reflecting colour. The duct between the division and the damper shall be of steel or other equivalent material and, if necessary, insulated to comply with the requirements of Section [3.3.5.1]. The damper shall be fitted on at least one side of the division with a visible indicator showing whether the damper is in the open position.

3.3.6.1.2. Openings in "B" class divisions

- i. Doors and door frames in "B" class divisions and means of securing them shall provide a method of closure which shall have resistance to fire equivalent to that of the divisions, this being determined in accordance with the Fire Test Procedures Code except that ventilation openings may be permitted in the lower portion of such doors. Where such opening is in or under a door, the total net area of any such opening or openings shall not exceed 0.05m. Alternatively, a non-combustible air balance duct routed between the cabin and the corridor, and located below the sanitary unit, is permitted where the cross- sectional area of the duct does not exceed 0.05 m². All

ventilation openings shall be fitted with a grill made of non-combustible material. Doors shall be non-combustible.

- ii. Cabin doors in "B" class divisions shall be of a self-closing type. Hold-back hooks are not permitted.
- iii. The requirements for "B" class integrity of the outer boundaries of a ship shall not apply to glass partitions, windows and side scuttles. Similarly, the requirements for "B" class integrity shall not apply to exterior doors in superstructures and deckhouses. For ships carrying not more than 36 passengers, the INTLREG may permit the use of combustible materials in doors separating cabins from the individual interior sanitary spaces such as showers.
- iv. In ships carrying not more than 36 passengers, where an automatic sprinkler system complying with the provisions of the Fire Safety Systems Code is fitted:
 - a. Openings in decks not forming steps in main vertical zones nor bounding horizontal zones shall be closed reasonably tight and such decks shall meet the " B " class integrity requirements in so far as is reasonable and practicable in the opinion of the INTLREG; and
 - b. Openings in corridor bulkheads of "B" class materials shall be protected in accordance with the provisions of Section [3.3.2.2.2].

3.3.6.1.3. Windows and side scuttles

- i. Windows and side scuttles in bulkheads within accommodation and service spaces and control stations other than those to which the provisions of Sections [3.3.6.1.1](vi) and [3.3.6.1.2](iii) apply shall be so constructed as to preserve the integrity requirements of the type of bulkheads in which they are fitted, this being determined in accordance with the Fire Test Procedures Code.
- ii. Notwithstanding the requirements of tables 13.3.1 to 13.3.4 windows and side scuttles in bulkheads separating accommodation and service spaces and control stations from weather shall be constructed with frames of steel or other suitable material. The glass shall be retained by a metal glazing bead or angle.
- iii. Windows facing life-saving appliances, embarkation and assembly stations, external stairs and open decks used for escape routes, and windows situated below life raft and escape slide embarkation areas shall have fire integrity as required in table 13.3.1. Where automatic dedicated sprinkler heads are provided for windows, "A-0" windows may be accepted as equivalent. To be considered under this Section, the sprinkler heads shall either be:
 - a. Dedicated heads located above the windows, and installed in addition to the conventional ceiling sprinklers;
 - b. Conventional ceiling sprinkler heads arranged such that the window is protected by an average application rate of at least 5 //min/m~ and the additional window area is included in the calculation of the area of coverage.

Windows located in the ship's side below the lifeboat embarkation area shall have fire integrity at least equal to "A-0" class.

3.3.7 Doors in fire-resisting divisions in cargo ships

3.3.7.1 The fire resistance of doors shall be equivalent to that of the division in which they are fitted, this being determined in accordance with the Fire Test Procedures Code. Doors and door frames in "A" class divisions shall be constructed of steel. Doors in "B" class divisions shall be non-combustible. Doors fitted in boundary bulkheads of machinery spaces of category A shall be reasonably gastight and self-closing. In ships constructed according to method IC, the INTLREG may permit the use of combustible materials in doors separating cabins from individual interior sanitary accommodation such as showers.

3.3.7.2 Doors required to be self-closing shall not be fitted with hold-back hooks. However, hold-back arrangements fitted with remote release devices of the fail-safe type may be utilized.

3.3.7.3 In corridor bulkheads, ventilation openings may be permitted in and under the doors of cabins and public spaces. Ventilation openings are also permitted in "B" class doors leading to lavatories, offices, pantries, lockers and store-rooms. Except as permitted below, the openings shall be provided only in the lower half of a door. Where such an opening is in or under a door, the total net area of any such opening or openings shall not exceed 0.05 m². Alternatively, a non-combustible air balance duct routed between the cabin and the corridor, and located below the sanitary unit, is permitted where the cross-sectional area of the duct does not exceed 0.05 m². Ventilation openings, except those under the door, shall be fitted with a grill made of non-combustible material.

3.3.7.4 Watertight doors need not be insulated.

3.3.8 Protection of openings in machinery space boundaries

3.3.8.1 Application

The provision of this Section shall apply to machinery spaces of category A and, where the INTLREG considers it desirable, to other machinery spaces.

3.3.8.2 Protection of openings in machinery space boundaries

3.3.8.2.1 The number of skylights, doors, ventilators, openings in funnels to permit exhaust ventilation and other openings to machinery spaces shall be reduced to a minimum consistent with the needs of ventilation and the proper and safe working of the ship.

3.3.8.2.2 Skylights shall be of steel and shall not contain glass panels.

3.3.8.2.3 Means of control shall be provided for closing power-operated doors or actuating release mechanisms on doors other than power-operated watertight doors. The controls shall be located outside the space concerned, where they will not be cut off in the event of fire in the space it serves.

3.3.8.2.4 In passenger ships, the means of control required in Section 3.3.8.2.3 shall be situated at one control position or grouped in as few positions as possible, to the satisfaction of the INTLREG. Such positions shall have safe access from the open deck.

3.3.8.2.5 In passenger ships, doors, other than power-operated watertight doors, shall be so arranged that positive closure is assured in case of fire in the space by power-operated closing arrangements or by the provision of self-closing doors capable of closing against an inclination of 3.5° opposing closure, and having a fail-safe hold-back arrangement, provided with a remotely operated release device. Doors for emergency escape trunks need not be fitted with a fail-safe hold-back facility and a remotely operated release device.

3.3.8.2.6 Windows shall not be fitted in machinery space boundaries. However, this does not preclude the use of glass in control rooms within the machinery spaces.

3.3.9 Protection of cargo space boundaries

3.3.9.1 In passenger ships carrying more than 36 passengers, the boundary bulkheads and decks of special category and Ro-Ro spaces shall be insulated to "A-60" class standard. However, where a category (5), (9) or (10) space, as defined in Section [3.3.2.2.3], is on one side of the division, the standard may be reduced to "A-0". Where fuel oil tanks are below a special category space, the integrity of the deck between such spaces may be reduced to "A - 0" standard.

3.3.9.2 In passenger ships carrying not more than 36 passengers, the boundary bulkheads of special category spaces shall be insulated as required for category (11) spaces in table 13.3.3 and the horizontal boundaries as required for category (11) spaces in table 13.3.4.

3.3.9.3 In passenger ships carrying not more than 36 passengers, the boundary bulkheads and decks of closed and open ro-ro spaces shall have fire integrity as required for category (8) spaces in table 13.3.3 and the horizontal boundaries as required for category (8) spaces in table 13.3.4.

3.3.9.4 In passenger ships, indicators shall be provided on the navigation bridge which shall indicate when any fire door leading to or from the special category spaces is closed.

3.3.9.5 In tankers, for the protection of cargo tanks carrying crude oil and petroleum products having a flashpoint not exceeding 60°C, materials readily rendered ineffective by heat shall not be used for valves, fittings, tank opening covers, cargo vent piping, and cargo piping so as to prevent the spread of fire to the cargo.

3.3.10 Ventilation systems

3.3.10.1 Ducts and dampers

3.3.10.1.1 Ventilation ducts shall be of non-combustible material. However, short ducts, not generally exceeding 2 m in length and with a free cross-sectional area not exceeding 0.02 m², need not be non-combustible, subject to the following conditions:

- a) The ducts are made of a material which has low flame-spread characteristics;
- b) The ducts are only used at the end of the ventilation device; and

- c) The ducts are not situated less than 600 mm, measured along the duct, from an opening in an "A" or " B " class division, including continuous "B" class ceiling.

3.3.10.1.2 The following arrangements shall be tested in accordance with the Fire Test Procedures Code:

- a) Fire dampers, including their relevant means of operation; and
- b) Duct penetrations through "A" class divisions. However, the test is not required where steel sleeves are directly joined to ventilation ducts by means of riveted or screwed flanges or by welding.

3.3.10.2 Arrangement of ducts

3.3.10.2.1 The ventilation systems for machinery spaces, vehicle spaces, Ro—Ro spaces, galleys, special category spaces and cargo spaces shall, in general, be separated from each other and from the ventilation systems serving other spaces, except that the galley ventilation systems on cargo ships of less than 4,000 gross tonnage and in passenger ships carrying not more than 36 passengers need not be completely separated, but may be served by separate ducts from a ventilation unit serving other spaces. In any case, an automatic fire damper shall be fitted in the galley ventilation duct near the ventilation unit. Ducts provided for the ventilation of machinery spaces of category A, galleys, vehicle spaces, Ro-Ro spaces or special category spaces shall not pass through accommodation spaces, service spaces or control stations unless they comply with the conditions specified in Sections [5.4.3.3][3.3.10.2.1] (i) to(v))

- i. The ducts are constructed of steel having a thickness of at least 3 mm and 5 mm for ducts the widths or diameters of which are up to and including 300 mm and 760 mm and over respectively and, in the case of such ducts, the widths or diameters of which are between 300 mm and 760 mm, having a thickness obtained by interpolation;
- ii. The ducts are suitably supported and stiffened;
- iii. The ducts are fitted with automatic fire dampers close to the boundaries penetrated; and
- iv. The ducts are insulated to "A-60" class standard from the machinery spaces, galleys, vehicle spaces, Ro—Ro spaces or special category spaces to a point at least 5 m beyond each fire damper; or
- v. The ducts are constructed of steel in accordance with Sections [3.3.10.2.1] (i)
- vi. The ducts are insulated to "A-60" class standard throughout the accommodation spaces, service spaces or control stations;

Except that penetrations of main zone divisions shall also comply with the requirements of Section [3.3.6.1](viii)

3.3.10.2.2 Ducts provided for ventilation to accommodation spaces, service spaces or+ control stations shall not pass through machinery spaces of category A, galleys, vehicle spaces, Ro-Ro spaces or special category spaces unless they comply with the conditions specified in Sections [3.3.10.2.2] (i) to (v)

- i. The ducts, where they pass through a machinery space of category A, galley, vehicle space, Ro—Ro space or special category space, are constructed of steel in accordance with Sections [3.3.10.2.1](i)
- ii. Automatic fire dampers are fitted close to the boundaries penetrated; and
- iii. The integrity of the machinery space, galley, vehicle space, Ro-Ro space or special category space boundaries is maintained at the penetrations; or
- iv. The ducts, where they pass through a machinery space of category A, galley, vehicle space, Ro—Ro space or special category space, are constructed of steel in accordance with Section [3.3.10.2.1]
- v. The ducts are insulated to "A-60" standard within the machinery space, galley, vehicle space, Ro-Ro space or special category space; except that penetrations of main zone divisions shall also comply with the requirements of Section [3.3.6.1viii]

3.3.10.3 Details of duct penetrations

3.3.10.3.1 Where a thin plated duct with a free cross-sectional area equal to, or less than, 0.02 m² passes through "A" class bulkheads or decks, the opening shall be lined with a steel sheet sleeve having a thickness of at least 3 mm and a length of at least 200 mm, divided preferably into 100 mm on each side of the bulkhead or, in the case of the deck, wholly laid on the lower side of the decks pierced. Where ventilation ducts with a free cross-sectional area exceeding 0.02 m² pass through "A" class bulkheads or decks, the opening shall be lined with a steel sheet sleeve. However, where such ducts are of steel construction and pass through a deck or bulkhead, the ducts and sleeves shall comply with the following:

- i. The sleeves shall have a thickness of at least 3 mm and a length of at least 900 mm. When passing through bulkheads, this length shall be divided preferably into 450 mm on each side of the bulkhead. These ducts, or sleeves lining such ducts, shall be provided with fire insulation. The insulation shall have at least the same fire integrity as the bulkhead or deck through which the duct passes; and
- ii. Ducts with a free cross-sectional area exceeding 0.075 m² shall be fitted with fire dampers in addition to the requirements of Section 3.3.10.3.1i The fire damper shall operate automatically, but shall also be capable of being closed manually from both sides of the bulkhead or deck. The damper shall be provided with an indicator which shows whether the damper is open or closed. Fire dampers are not required, however, where ducts pass through spaces surrounded by "A" class divisions, without serving those spaces, provided those ducts have the same fire integrity as the divisions which they pierce. Fire dampers shall be easily accessible. Where they are placed behind ceilings or linings, these ceilings or linings shall be provided with an inspection

door on which a plate reporting the identification number of the fire damper is provided. The fire damper identification number shall also be placed on any remote controls required.

3.3.10.3.2 Ventilation ducts with a free cross-sectional area exceeding 0.02 m² passing through "B" class bulkheads shall be lined with steel sheet sleeves of 900 mm in length, divided preferably into 450 mm on each side of the bulkheads unless the duct is of steel for this length.

3.3.10.4 Ventilation systems for passenger ships carrying more than 36 passengers

3.3.10.4.1 The ventilation system of a passenger ship carrying more than 36 passengers shall be in compliance with the following additional requirements.

3.3.10.4.2 In general, the ventilation fans shall be so disposed that the ducts reaching the various spaces remain within the main vertical zone.

3.3.10.4.3 Where ventilation systems penetrate decks, precautions shall be taken, in addition to those relating to the fire integrity of the deck required by Sections [3.3.5.1] and [3.3.6.1.1].(v), to reduce the likelihood of smoke and hot gases passing from one 'tween-deck space to another through the system. In addition to insulation requirements contained in Section . [3.3.10.4], vertical ducts shall, if necessary, be insulated as required by the appropriate tables 13.3.1 and 13.3.2.

3.3.10.4.4 Except in cargo spaces, ventilation ducts shall be constructed of the following materials:

- i. Ducts not less than 0.075 m² in free cross-sectional area and all vertical ducts serving more than a single 'tween-deck space shall be constructed of steel or other equivalent material;
- ii. Ducts less than 0.075 m² in free cross-sectional area, other than the vertical ducts referred to in Section [3.3.10.4.4](i) shall be constructed of non-combustible materials. Where such ducts penetrate "A" or "B" class divisions, due regard shall be given to ensuring the fire integrity of the division; and
- iii. Short lengths of duct, not in general exceeding 0.02 m² in free cross-sectional area nor 2 m in length, need not be non-combustible provided that all of the following conditions are met:
 - a) The duct is constructed of a material which has low flame-spread characteristics;
 - b) The duct is used only at the terminal end of the ventilation system; and
 - c) The duct is not located closer than 600 mm measured along its length to a penetration of an "A" or "B" class division, including continuous "B" class ceilings.

3.3.10.4.5 Stairway enclosures shall be ventilated and served by an independent fan and duct system which shall not serve any other spaces in the ventilation systems.

3.3.10.4.6 Exhaust ducts shall be provided with hatches for inspection and cleaning. The hatches shall be located near the fire dampers.

3.3.10.5 Exhaust ducts from galley ranges

3.3.10.5.1 Requirements for passenger ships carrying more than 36 passengers

Exhaust ducts from galley ranges shall meet the requirements of Sections [3.3.10.2.1] and shall be fitted with:

- i. A grease trap readily removable for cleaning unless an alternative approved grease removal system is fitted;
- ii. A fire damper located in the lower end of the duct which is automatically and remotely operated and, in addition, a remotely operated fire damper located in the upper end of the duct;
- iii. A fixed means for extinguishing a fire within the duct;
- iv. Remote-control arrangements for shutting off the exhaust fans and supply fans, for operating the fire dampers mentioned in Section [3.3.10.5.1](ii) and for operating the fire-extinguishing system, which shall be placed in a position close to the entrance to the galley. Where a multi-branch system is installed, a remote means located with the above controls shall be provided to close all branches exhausting through the same main duct before an extinguishing medium is released into the system; and
- v. Suitably located hatches for inspection and cleaning

3.3.10.5.2 Requirements for cargo ships and passenger ships carrying not more than 36 passengers

- i. Where they pass through accommodation spaces or spaces containing combustible materials, the exhaust ducts from galley ranges shall be constructed of "A" class divisions. Each exhaust duct shall be fitted with:
 - a) A grease trap readily removable for cleaning;
 - b) A fire damper located in the lower end of the duct;
 - c) Arrangements, operable from within the galley, for shutting off the exhaust fans; and
 - d) Fixed means for extinguishing a fire within the duct.

3.4 FIRE FIGHTING

3.4.1 Purpose

The main aim of the regulation is to suppress and gradually extinguish a fire in the space where it has originated. For this purpose, it is essential that the following requirements are fulfilled.

- a) Installation of fixed fire extinguishing systems, having due regard to the fire growth potential of the protected spaces.
- b) Ready availability of fire extinguishing appliances.

3.4.2 Water supply systems

In compliance with the applicable requirements of this regulation, ships shall be provided with fire mains, hydrants, hoses and fire pumps.

3.4.3 Fire mains and hydrants

3.4.3.1 General

Unless adequately protected, materials readily rendered ineffective by heat shall not be used for fire mains and hydrants. The pipes and hydrants shall be so placed that the fire hoses may be easily coupled to them. To avoid the possibility of freezing, the arrangement of the pipes and hydrants should be suitably done. Appropriate drainage provisions shall be provided for fire main piping. For all open deck fire main branches used for purposes apart from firefighting, it is necessary to install isolation valves. In ships carrying deck cargo, the hydrants shall be such positioned that they can be accessed anytime and the pipes shall be arranged as far as practicable for avoiding the risk of damage by such cargo.

3.4.3.2 Ready availability of water supply

The arrangements for the ready availability of water supply shall be:

- i. In passenger ships:
 - a) Of 1,000 gross tonnage and upwards such that at least one effective jet of water is immediately available from any hydrant in an interior location and so as to ensure the continuation of the output of water by the automatic starting of one required fire pump;
 - b) Of less than 1,000 gross tonnage by automatic start of at least one fire pump or by remote starting from the navigation bridge of at least one fire pump. If the pump starts automatically or if the bottom valve cannot be opened from where the pump is remotely started, the bottom valve shall always be kept open; and
 - c) If fitted with periodically unattended machinery spaces in accordance with SOLAS regulation ii-1/54, the INTLREG shall determine provisions for fixed water fire-extinguishing arrangements for such spaces equivalent to those required for normally attended machinery spaces;
- ii. In cargo ships
 - a. To the satisfaction of the INTLREG; and
 - b. With a periodically unattended machinery space or when only one person is required on watch, there shall be immediate water delivery from the fire main system at a suitable pressure, either by remote starting of one of the main fire pumps with remote starting from the navigation bridge and fire control station, if any, or permanent pressurization of the fire main system by one of the main fire pumps, except that the INTLREG may waive this requirement for cargo ships of less than 1,600 gross tonnage if the fire pump starting arrangement in the machinery space is in an easily accessible position.

3.4.3.3 Diameter of fire mains

The diameter of the fire main and water service pipes shall be sufficient for the effective distribution of the maximum required discharge from two fire pumps operating simultaneously, except that in the case of cargo ships the diameter need only be sufficient for the discharge of 140 m³/h.

3.4.3.4 Isolating valves and relief valves

- i. Isolating valves to separate the section of the fire main within the machinery space containing the main fire pump or pumps from the rest of the fire main shall be fitted in an easily accessible and tenable position outside the machinery spaces. The arrangement of the fire main shall be such that when the isolating valves are shut, all the hydrants on the ship apart from those in the machinery space as referred above can be supplied with water by either another fire pump or an emergency fire pump. The outside of the machinery space should have the emergency fire pump, its seawater inlet and suction and delivery pipes as well as the isolating valves. If such an arrangement is not possible, then the sea chest may be fitted in the machinery space if the valve is controlled remotely from a position in the same compartment as the emergency fire pump and provided that the suction pipe is as short as practicable. Short lengths of suction or discharge piping may penetrate the machinery space, on the condition that they are enclosed in a substantial steel casing or are insulated to "A-60" class standards. The pipes shall have substantial wall thickness, but in no case less than 11 mm, and shall be welded except for the flanged connection to the sea inlet valve.
- ii. Each fire hydrant shall be served by a valve fitted for the purpose so that any fire hose may be removed while the fire pumps are in operation.
- iii. Fire pumps shall come with relief valves if the pumps are capable of developing a pressure beyond the design pressure of the water service pipes, hoses and hydrants. These valves should be so placed and adjusted that the excessive pressure in any part of the fire main system can be prevented.
- iv. In tankers, isolation valves shall be fitted in the fire main at the poop front in a protected position and on the tank deck at intervals of not more than 40 m for preserving the integrity of the fire main system in case of fire or explosion.

3.4.3.5 Number and position of hydrants

- i. The number and position of hydrants shall be such that at least two jets of water not emanating from the same hydrant, one of which shall be from a single length of hose, may reach any part of the ship normally accessible to the passengers or crew while the ship is being navigated and any part of any cargo space when empty, any Ro-Ro space or any vehicle space, in which latter case the two jets shall reach any part of the space, each from a single length of hose. Furthermore, such hydrants shall be positioned near the accesses to the protected spaces.
- ii. In addition to the requirements stated in Section [3.4.3.5].(i), passenger ships need to comply with the following:
 - a) In the accommodation, service and machinery spaces, the number and position of hydrants shall be such that the requirements of Section [3.4.3.5].(i), may be complied with when all watertight doors and all doors in main vertical zone bulkheads are closed; and

- b) Where access is provided to a machinery space of category at a low level from an adjacent shaft tunnel, two hydrants shall be provided external to, but near the entrance to, that machinery space. Where such access is provided from other spaces, in one of those spaces two hydrants shall be provided near the entrance to the machinery space of category a. Such provision need not be made where the tunnel or adjacent spaces are not part of the escape route.

3.4.3.6 Pressure at hydrants

With the two pumps simultaneously delivering water through the nozzles as outlined in Section 3.4.5.3. with the quantity of water as specified in Section [3.4.5.3], through any adjacent hydrants, the following minimum pressures shall be maintained at all hydrants:

- i. For passenger ships:

4,000 gross tonnage and upwards 0.40 N/mm², less than 4,000 gross tonnage 0.30 N/mm²

- ii. For cargo ships:

6,000 gross tonnage and upwards 0.27 N/mm²
less than 6,000 gross tonnage 0.25 N/mm² and

- iii. The maximum pressure at any hydrant shall not go beyond that at which the effective control of a fire hose can be demonstrated.

3.4.3.7 International shore connection

- i. At least one international shore connection complying with the Fire Safety Systems Code is to be provided for ships of 500 gross tonnage and upwards.
- ii. Facilities would be available for enabling the use of such a connection on either side of the ship.

3.4.4 Fire pumps

3.4.4.1 Pumps accepted as fire pumps

On the condition that they are not normally used for pumping oil and that if they are subject to occasional duty for the transfer or pumping of oil fuel, suitable change-over arrangements are fitted, sanitary, ballast, bilge or general service pumps may be accepted as fire pumps.

3.4.4.2 Number of fire pumps

Ships shall be provided with independently driven fire pumps as follows:

- i. In passenger ships of:
4,000 gross tonnage and upwards at least three less than 4,000 gross tonnage at least two
- ii. In cargo ships of:
1,000 gross tonnage and upwards at least two less than 1,000 gross tonnage at least two power-driven pumps, one of which shall be driven independently

3.4.4.3 Arrangement of fire pumps and fire mains

(i) Fire pumps

The arrangement of sea connections, fire pumps and their sources of power shall be as to ensure that:

- a. In passenger ships of 1,000 gross tonnage and upwards, in the event of a fire in any one compartment, all the fire pumps will not be put out of action; and
- b. If a fire in any one compartment could put all the pumps out of action, in passenger ships of less than 1,000 gross tonnage as well as in cargo ships, there shall be an alternative means consisting of an emergency fire pump complying with the provisions of the fire safety systems code with its source of power and sea connection located outside the space where the main fire pumps or their sources of power are located.

(ii) Requirements for the space containing the emergency fire pump

a) Location of the space

The space containing the fire pump shall not be contiguous to the boundaries of machinery spaces of category A or those spaces containing main fire pumps. Where this is not possible, the common bulkhead between the two spaces requires to be insulated to a standard of structural fire protection which equals to that required for a control station.

b) Access to the emergency fire pump

Direct access is not permitted between the machinery space and the space consisting of the emergency fire pump and its source of power. When this is not possible, an arrangement might be accepted by the INTLREG where the access is by means of an airlock with the door of the machinery space being of "A-6 0" class standard and the other door being at least steel, both reasonably gastight, self-closing and without any hold-back arrangements. Alternatively, the access may be through a watertight door which can be operated from a space remote from the machinery space and the space containing the emergency fire pump and unlikely to be cut off in the event of fire in those spaces. In such cases, a second means of access to the space containing the emergency fire pump and its source of power shall be provided.

c) Ventilation of the emergency fire pump space

Ventilation arrangements to the space containing the independent source of power for the emergency fire pump shall be such as to preclude, as far as practicable, the possibility of smoke from a machinery space fire entering or being drawn into that space.

(iii) Additional pumps for cargo ships

In addition, in cargo ships where other pumps, such as general service, bilge and ballast, etc., are fitted in a machinery space, arrangements shall be made for ensuring that at least one of these pumps, having the capacity and pressure as specified in Sections [3.4.3.6] (ii) and [3.4.4.4] (ii), is capable of providing water to the fire main.

3.4.4.4 Capacity of fire pumps

i. Total capacity of required fire pumps

The required fire pumps shall be capable of delivering for fire-fighting purposes a quantity of water, at the pressure specified in Section [3.4.3.6], as follows:

- a. pumps in passenger ships: the quantity of water is not less than two thirds of the quantity required to be dealt with by the bilge pumps when employed for bilge pumping; and
- b. pumps in cargo ships, other than any emergency pump: the quantity of water is not less than four thirds of the quantity required under SOLAS regulation II-1/35-1 to be dealt with by each of the independent bilge pumps in a passenger ship of the same dimension when employed in bilge pumping, provided that in no cargo ship need the total required capacity of the fire pumps exceed 180 m³/h.

ii. Capacity of each fire pump

Each of the required fire pumps (other than any emergency pump specified in Section [3.4.4.3].(i).(b) for cargo ships) shall have a capacity not less than 80 % of the total required capacity divided by the minimum number of required fire pumps, but in any case not less than 25 m³/h, and each such pump shall in any event be capable of delivering at least the two required jets of water. These fire pumps shall be capable of supplying the fire main system under the required conditions. Where more pumps than the minimum of required pumps are installed, such additional pumps shall have a capacity of at least 25 m³/h and shall be capable of delivering at least the two jets of water required in Section [3.4.3.5] (i).

3.4.5 Fire hoses and nozzles

3.4.5.1 General specifications

- i. Fire hoses approved by the INTLREG should be of non perishable material and should have a sufficient length to project a jet of water to any of the spaces in which they may be required to be used. Each hose shall be provided with a nozzle and the necessary couplings. In this chapter, hoses specified as "fire hoses" shall together with any necessary fittings and tools, be kept ready for use in conspicuous positions near the water service hydrants or connections. Additionally, fire hoses shall be connected to the hydrants at all times in interior locations in passenger ships carrying more than 36 passengers. Fire hoses shall have a length of at least 10 m, but not more than:
 - a. 15 m in machinery spaces;
 - b. 20 m in other spaces and open decks; and
 - c. 25 m for open decks on ships with a maximum breadth in excess of 30 m.
- ii. Unless one hose and nozzle is provided for each hydrant in the ship, there shall be complete interchangeability of hose couplings and nozzles.

3.4.5.2 Number and diameter of fire hoses

- i. Ships shall be provided with fire hoses, the number and diameter of which shall be to the satisfaction of the INTLREG.
- ii. In passenger ships, there shall be at least one fire hose for each of the hydrants as specified in Section [3.4.3.5] and these hoses shall be used only for the purposes of extinguishing fires or testing the fire- extinguishing apparatus at fire drills and surveys.
- iii. In cargo ships:
 - a. Of 1,000 gross tonnage and upwards, the number of fire hoses to be provided shall be one for each 30 m length of the ship and one spare, but in no case less than five in all. This number does not include any hoses required in any engine-room or boiler room. The number of hoses required might be increased by the INTLREG for ensuring that hoses in sufficient number are available and accessible at all times, having regard to the type of ship and the nature of trade in which the ship is employed. Ships carrying dangerous goods in accordance with regulation 19 shall be provided with three hoses and nozzles, in addition to those required above; and
 - b. Of less than 1,000 gross tonnage, the number of fire hoses to be provided shall be calculated in accordance with the provisions of Section [3.4.5.2](iii)(a) However, the number of hoses shall in no case be less than three.

3.4.5.3 Size and types of nozzles

- i. For the purposes of this chapter, standard nozzle sizes shall be 12 mm, 16 mm and 19 mm or as near thereto as possible. It is at the discretion of the INTLREG to permit larger diameter nozzles.
- ii. For accommodation and service spaces, a nozzle size greater than 12 mm need not be used.
- iii. The nozzle size for machinery spaces and exterior locations shall be such so as to obtain the maximum discharge possible from two jets at the pressure specified in Section [3.4.3.6] from the smallest pump, provided that a nozzle size greater than 19 mm need not be used.
- iv. Nozzles shall be of an approved dual-purpose type (i.e. spray/jet type) incorporating a shutoff.

3.4.6 Portable fire extinguishers

3.4.6.1 Type and design

Portable fire extinguishers shall comply with the requirements of the Fire Safety Systems Code.

3.4.6.2 Arrangement of fire extinguishers

3.4.6.2.1 Accommodation spaces, control stations and service spaces shall be provided with portable fire extinguishers of appropriate types and in sufficient number to the satisfaction of the INTLREG. At least five portable fire extinguishers should be carried by ships of 1,000 gross tonnages.

3.4.6.2.2 One of the portable fire extinguishers intended for use in any space shall be stowed near the entrance to that space.

- 3.4.6.2.3 Accommodation spaces will not have Carbon dioxide fire extinguishers. In control stations and other spaces containing electrical or electronic equipment or appliances necessary for the safety of the ship, fire extinguishers shall be provided whose extinguishing media are neither electrically conductive nor harmful to the equipment and appliances.
- 3.4.6.2.4 Fire extinguishers shall be situated ready for use at places which are easily visible and which can be reached quickly and easily at any time in the event of a fire, and in such that their serviceability is not impaired by the weather, vibration or other external factors. Portable fire extinguishers shall be provided with devices which indicate whether they have been used.
- 3.4.6.3 Spare charges
 - 3.4.6.3.1 Spare charges shall be provided for 100% of the first ten extinguishers and 50% of the remaining fire extinguishers which can be recharged on board. Not more than sixty total spare charges are required. Instructions for recharging shall be carried on board.
 - 3.4.6.3.2 For fire extinguishers which are not rechargeable on board, additional portable fire extinguishers of the same quantity, type, capacity and number as specified in Section [3.4.6.3.1] above shall be provided in lieu of spare charges.
- 3.4.7 Fixed fire-extinguishing systems
 - 3.4.7.1 Types of fixed fire-extinguishing systems
 - 3.4.7.1.1 A fixed fire-extinguishing system required by Section [3.4.8]below may be any of the following systems:
 - a. A fixed gas fire-extinguishing system complying with the provisions of the Fire Safety Systems Code;
 - b. A fixed high-expansion foam fire-extinguishing system complying with the provisions of the Fire Safety Systems Code; and
 - c. A fixed pressure water-spraying fire-extinguishing system complying with the provisions of the Fire Safety Systems Code.
 - 3.4.7.1.2 Where a fixed fire-extinguishing system not required by this chapter is installed, it shall meet the requirements of the relevant regulations of this chapter and the Fire Safety Systems Code.
 - 3.4.7.1.3 Fire-extinguishing systems using Halon 1211, 1301 and 2402 and perfluorocarbons shall be prohibited.
 - 3.4.7.1.4 In general, it is not permitted by the INTLREG to use steam as a fire-extinguishing medium in fixed fire-extinguishing systems. Where the use of steam is permitted by the INTLREG, it shall be used only in restricted areas as an addition to the required fire-extinguishing system and should be in compliance with the requirements of the Fire Safety System Code.

3.4.7.2 Closing appliances for fixed gas fire-extinguishing systems

Where a fixed gas fire-extinguishing system is used, openings which may admit air to, or allow gas to escape from; a protected space shall be capable of being closed from outside the protected space.

3.4.7.3 Storage rooms of fire-extinguishing medium

In case the fire extinguishing medium is stored outside a space that is protected, it is required to store it in a room which is located behind the forward collision bulkhead, and is used for no other purpose. The entrance to such a storage room is preferred to be from the open deck and shall be independent of the protected space. In case the location of the storage space is below the deck, it shall be located no more than one deck below the open deck. It should also easily accessible directly by a ladder or a stairway from the open deck. Spaces located below deck or spaces and not having access from the open deck shall be fitted with a mechanical ventilation system designed to take exhaust air from the bottom of the space and shall be sized to provide at least 6 air changes per hour. Access doors shall open outwards. Bulkheads and decks, including doors and other means of closing any opening therein, which form the boundaries between such rooms and adjacent enclosed spaces requires to be gastight. For the purpose of the application of Tables 13.3.1 to 13.3.8, such storage rooms shall be treated as fire control stations.

3.4.7.4 Water pumps for other fire-extinguishing systems

Pumps, apart from the ones serving the fire main, required for the provision of water for fire-extinguishing systems required by this chapter, their sources of power and their controls shall be installed outside the space or spaces protected by such systems and shall be so arranged that a fire in the space or spaces protected will not put any such system out of action.

3.4.8 Fire-extinguishing arrangements in machinery spaces

3.4.8.1 Machinery spaces containing oil-fired boilers or oil fuel units

3.4.8.1.1 Fixed fire-extinguishing systems

Machinery spaces of category A containing oil-fired boilers or oil fuel units shall be provided with any one of the fixed fire-extinguishing systems as specified in Section [3.4.7.1] In each case, if the engine-room and boiler room are not entirely separate, or if fuel oil can drain from the boiler room into the engine-room, the combined engine and boiler rooms shall be considered as one compartment.

3.4.8.1.2 Additional fire-extinguishing arrangements

- i. 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.
- ii. There shall be at least two portable foam extinguishers or equivalent in each firing space in each boiler room and in each space in which a part of the oil fuel installation is situated. There shall be not less than one approved foam-type extinguisher of at least 13 5/ capacity or equivalent in each boiler room. These extinguishers should come with hoses on reels suitable for reaching any part of the boiler room. In the case of

domestic boilers of less than 175 kW an approved foam-type extinguisher of at least 135 / capacity is not required.

- iii. Each firing space should be provided with a receptacle containing 0.1 m³ sand at least, sawdust impregnated with soda, or other approved dry material, along with a suitable shovel for spreading the material. As an alternative, an approved portable extinguisher may be used as a substitute.

3.4.8.2 Machinery spaces containing internal combustion machinery

3.4.8.2.1 Fixed fire-extinguishing systems

Machinery spaces containing internal combustion machinery shall be provided with one of the fixed fire-extinguishing systems in Section [3.4.7.1]

3.4.8.2.2 Additional fire-extinguishing arrangements *

- i. There shall be at least one portable foam applicator unit complying with the provisions of the Fire Safety Systems Code.
- ii. Each such space should have approved foam-type fire extinguishers, each of at least 45 / capacity 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. In addition, a sufficient number of portable foam extinguishers or equivalent shall be provided which shall 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. The INTLREG may consider relaxing this requirement in case of smaller spaces in cargo ships.

3.4.8.3 Machinery spaces containing steam turbines or enclosed steam engines

3.4.8.3.1 Fixed fire-extinguishing systems

In spaces containing steam turbines or enclosed steam engines used for main propulsion or other purposes having in the aggregate a total output of not less than 375 kW, one of the fire-extinguishing systems specified in Section [3.4.1] shall be provided if such spaces are periodically unattended.

3.4.8.3.2 Additional fire-extinguishing arrangements

- i. There shall be approved foam fire extinguishers, each of at least 45 / capacity or equivalent, sufficient in number to enable foam or its equivalent to be directed on to any part of the pressure lubrication system, on to any part of the casings enclosing pressure-lubricated parts of the turbines, engines or associated gearing, and any other fire hazards. However, such extinguishers shall not be required if protection, at least equivalent to that required by this subSection, is provided in such spaces by a fixed fire-extinguishing system fitted in compliance with Section [3.4.7.1].

- ii. There shall be a sufficient number of portable foam extinguishers or equivalent which shall be located such 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, except that such extinguishers shall not be required in addition to any provided in compliance with Section [3.4.8.2.2]

3.4.8.4 Other machinery spaces

Where, in the opinion of the INTLREG, a fire hazard exists in any machinery space for which no specific provisions for fire-extinguishing appliances are prescribed in Sections [3.4.8.1], [3.4.8.2] and [3.4.8.3], there shall be provided in, or adjacent to, that space such a number of approved portable fire extinguishers or other means of fire extinction as the INTLREG may deem sufficient.

3.4.8.5 Additional requirements for passenger ships

Each machinery space of category "A" shall be provided with at least two suitable water fog applicators in passenger ships carrying more than 36 passengers.

3.4.8.6 Fixed local application fire-extinguishing systems

3.4.8.6.1 Section [3.4.8.6] is applicable to passenger ships of 500 gross tonnage and above and cargo ships of 2,000 gross tonnage and above.

3.4.8.6.2 Machinery spaces of category A above 500 m³ in volume shall, in addition to the fixed fire-extinguishing system required in Section [3.4.8.1.1], be protected by an approved type of fixed water-based or equivalent local application fire-extinguishing system, based on the guidelines developed by the Organization. In the case of periodically unattended machinery spaces, the fire-extinguishing system shall have both automatic and manual release capabilities. In the case of continuously manned machinery spaces, the fire-extinguishing system is only required to have a manual release capability.

3.4.8.6.3 Fixed local application fire-extinguishing systems are to protect areas such as the following without the necessity of engine shutdown, personnel evacuation, or sealing of the spaces:

- i. The fire hazard portions of internal combustion machinery used for the ship's main propulsion and power generation;
- ii. purifiers for heated fuel oil
- iii. Boiler fronts;
- iv. the fire hazard portions of incinerators; and

3.4.8.6.4 In case the local application system is activated, it shall give a visual and distinct audible alarm in the protected space and at continuously manned stations. The activation of the specific system should be indicated by the alarm. The system alarm requirements described within this Section are in addition to, and not a substitute for, the detection and fire alarm system required elsewhere in this chapter.

3.4.9 Fire-extinguishing arrangements in control stations, accommodation and service spaces

3.4.9.1 Sprinkler and water-spraying systems in passenger ships

3.4.9.1.1 Passenger ships carrying more than 36 passengers shall be equipped with an automatic sprinkler, fire detection and fire alarm system of an approved type complying with the requirements of the Fire Safety Systems

Code in all control stations, accommodation and service spaces, including corridors and stairways. Alternatively, control stations, may be fitted with an approved fixed fire-extinguishing system of another type in case there are chances of water causing damage to essential equipment. An automatic sprinkler system is not essential in spaces with little or no fire risks such as voids, carbon dioxide rooms and public toilets.

3.4.9.1.2 In passenger ships carrying not more than 36 passengers, when a fixed smoke detection and fire alarm system complying with the provisions of the Fire Safety Systems Code is provided only in corridors, stairways and escape routes within accommodation spaces, an automatic sprinkler system shall be installed in accordance with regulation [3.1.5.3.2].

3.4.9.1.3 the provisions of the Fire Safety Systems Code shall be installed on cabin balconies of ships to which [2.2.12] applies, where furniture and furnishings on such balconies are not as defined in ,Sect 1,[1.3.40] (a,b,c,f) and (g)

3.4.9.2 Sprinkler systems for cargo ships

In cargo ships in which method IIC specified in Sect [3. 3.3.1].(i).(b) is adopted, an automatic sprinkler, fire detection and fire alarm system shall be fitted in accordance with the requirements specified in Sect [3.1.5.5.2].

3.4.9.3 Spaces containing flammable liquid

3.4.9.3.1 Paint lockers shall be protected by:

- i. A carbon dioxide system, designed to give a minimum volume of free gas equal to 40% of the gross volume of the protected space;
- ii. A water spraying or sprinkler system, designed for 5 //m² min. Water spraying systems may be connected to the fire main of the ship; or
- iii. A dry powder system, designed for at least 0.5 kg powder/m³;
- iv. A system providing equivalent protection, as determined by the INTLREG

In all cases, the system shall be operable from outside the protected space.

3.4.9.3.2 Flammable liquid lockers shall be protected by an appropriate fire-extinguishing arrangement approved by the INTLREG.

3.4.9.3.3 For lockers of a deck area of less than 4 m², which do not give access to accommodation spaces, a portable carbon dioxide fire extinguisher sized to provide a minimum volume of free gas equal to 40% of the gross volume of the space may be accepted in lieu of a fixed system. A discharge port shall be arranged in the locker to allow the discharge of the extinguisher without having to enter into the protected space. The required portable fire extinguisher shall be stowed adjacent to the port. Alternatively, a port or hose connection may be provided to facilitate the use of fire main water.

3.4.9.4 Deep-fat cooking equipment

Deep-fat cooking equipment shall be fitted with the following:

- 3.4.9.4.1 An automatic or manual fire-extinguishing system tested to an international standard acceptable to the Organization;
 - 3.4.9.4.2 A primary and backup thermostat with an alarm to alert the operator in the event of failure of either thermostat;
 - 3.4.9.4.3 An alarm for indicating operation of the fire-extinguishing system in the galley where the equipment is installed; and
 - 3.4.9.4.4 Arrangements for shutting off the electrical power automatically upon activation of the fire- extinguishing system;
 - 3.4.9.4.5 Controls for manually operating the fire-extinguishing system which are clearly labeled to be used readily by the crew.
- 3.4.10 Fire-extinguishing arrangements in cargo spaces
- 3.4.10.1 Fixed gas fire-extinguishing systems for general cargo
- 3.4.10.1.1 Except as provided for in Section [3.4.10.2] the cargo spaces of passenger ships of 1,000 gross tonnage and upwards shall be protected by a fixed carbon dioxide or inert gas fire-extinguishing system complying with the provisions of the Fire Safety Systems Code or by a fixed high-expansion foam fire-extinguishing system which gives equivalent protection.
 - 3.4.10.1.2 Where it is shown to the satisfaction of the INTLREG that a passenger ship is engaged on voyages of such short duration that it would be unreasonable to apply the requirements of Section [3.4.10.1.1] and also in ships of less than 1,000 gross tonnage, the arrangements in cargo spaces shall be to the satisfaction of the INTLREG, provided that the ship is fitted with steel hatch covers and effective means of closing all ventilators and other openings leading to the cargo spaces.
 - 3.4.10.1.3 Cargo spaces on cargo ships of 2,000 gross tonnage and upwards shall be protected by a fixed carbon dioxide or inert gas fire-extinguishing system complying with the provisions of the Fire Safety Systems Code, or by a fire-extinguishing system which gives equivalent protection Except for ro-ro and vehicle spaces.
 - 3.4.10.1.4 The INTLREG may exempt from the requirements of Sections [3.4.10.1.3] and [3.4.10.2] cargo spaces of any cargo ship if constructed, and solely intended, for the carriage of ore, coal, grain, unseasoned timber, non- combustible cargoes or cargoes which, in the opinion of the INTLREG, constitute a low fire risk. Such exemptions 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. When such exemptions are granted, the INTLREG shall issue an Exemption Certificate, irrespective of the date of construction of the ship concerned, in accordance with Solas regulation I/12(a)(vi), and shall ensure that the list of cargoes the ship is permitted to carry is attached to the Exemption Certificate.
- 3.4.10.2 Fixed gas fire-extinguishing systems for dangerous goods
- A ship employed in the carriage of dangerous goods in any cargo spaces shall be provided with a fixed carbon dioxide or inert gas fire-extinguishing system complying with the provisions of the Fire Safety Systems Code or with a fire-extinguishing

system which gives equivalent protection for the cargoes carried, in the opinion of the INTLREG.

3.4.11 Cargo tank protection

3.4.11.1 Fixed deck foam fire-extinguishing systems

3.4.11.1.1 A fixed deck foam fire-extinguishing system shall be provided complying with the provisions of the Fire Safety Systems Code for tankers of 20,000 tonnes deadweight and upwards, except that, in lieu of the above, the INTLREG, after having given consideration to the ship's arrangement and equipment, may accept other fixed installations if they afford protection equivalent to the above, in accordance with Solas regulation 1/5. The requirements for alternative fixed installations shall comply with the requirements in Section [3.4.11.1.2].

3.4.11.1.2 In accordance with Section [3.4.11.1.1], where the INTLREG accepts an equivalent fixed installation in lieu of the fixed deck foam fire-extinguishing system, the installation shall:

- i. Be capable of extinguishing spill fires and also preclude ignition of spilled oil not yet ignited; and
- ii. Be capable of combating fires in ruptured tanks

3.4.11.1.3 Tankers of less than 20,000 tonnes deadweight shall be provided with a deck foam fire-extinguishing system complying with the requirements of the Fire Safety Systems Code.

3.4.12 Protection of cargo pump-rooms in tankers

3.4.12.1 Fixed fire-extinguishing systems

Each cargo pump-room shall be provided with one of the following fixed fire-extinguishing systems operated from a readily accessible position outside the pump-room. Cargo pump-rooms shall be provided with a system suitable for machinery spaces of category A.

3.4.12.1.1 A carbon dioxide fire-extinguishing system in compliance with the provisions of the Fire Safety Systems Code and with the following:

- i. The alarms giving audible warning of the release of fire-extinguishing medium shall be safe for use in a flammable cargo vapour/air mixture; and
- ii. A notice stating that, due to the electrostatic ignition hazard, the system is to be used only for fire extinguishing and not for inerting purposes should be exhibited at the controls.

3.4.12.1.2 A high-expansion foam fire-extinguishing system complying with the provisions of the Fire Safety Systems Code, provided that the foam concentrate supply is suitable for extinguishing fires involving the cargoes carried.

3.4.12.1.3 A fixed pressure water-spraying fire-extinguishing system complying with the provisions of the Fire Safety Systems Code.

3.4.12.2 Quantity of fire-extinguishing medium

Where the fire-extinguishing medium used in the cargo pump-room system is also used in systems serving other spaces, the quantity of medium provided or its delivery rate shouldn't go beyond the maximum required for the largest compartment.

3.4.13 Fire-fighter's outfits

3.4.13.1 Types of fire-fighter's outfits

Fire-fighter's outfits shall comply with the Fire Safety Systems Code.

3.4.13.2 Number of fire-fighter's outfits

3.4.13.2.1 Ships shall carry at least two fire-fighter's outfits.

3.4.13.2.2 In addition, in passenger ships there shall be provided:

- i. For every 80 m, or part thereof, of the aggregate of the lengths of all passenger spaces and service spaces on the deck which carries such spaces or, if there is more than one such deck, on the deck which has the largest aggregate of such lengths, two fire-fighter's outfits and, in addition, two sets of personal equipment, each set comprising the items stipulated in the Fire Safety Systems Code. In passenger ships carrying more than 36 passengers, two additional fire-fighter's outfits shall be provided for each main vertical zone. However, for stairway enclosures which constitute individual main vertical zones and for the main vertical zones in the fore or aft end of a ship which do not contain spaces of categories (6), (7), (8) or (12) no additional fire-fighter's outfits are required; and
- ii. On ships carrying more than 36 passengers, for each pair of breathing apparatus, one water fog applicator which shall be stored adjacent to such apparatus.

3.4.13.2.3 In addition, in tankers, two fire-fighter's outfits shall be provided.

3.4.13.2.4 The INTLREG may require additional sets of personal equipment and breathing apparatus, having due regard to the size and type of the ship.

3.4.13.2.5 Two spare charges shall be provided for each required breathing apparatus. Passenger ships carrying not more than 36 passengers and cargo ships that are equipped with suitably located means for fully recharging the air cylinders free from contamination need carry only one spare charge for each required apparatus. In passenger ships carrying more than 36 passengers, at least two spare charges for each breathing apparatus shall be provided.

3.4.13.3 Storage of fire-fighter's outfits

3.4.13.3.1 The fire-fighter's outfits or sets of personal equipment shall be kept ready for use in an easily accessible location that is permanently and clearly marked and, where more than one fire-fighter's outfit or more

than one set of personal equipment is carried, they shall be stored in widely separated positions.

- 3.4.13.3.2 In passenger ships, at least two fire-fighter's outfits and, in addition, one set of personal equipment shall be available at any one position. At least two fire-fighter's outfits shall be stored in each main vertical zone.

3.5 STRUCTURAL INTEGRITY

3.5.1 Purpose

Maintaining the structural integrity of the ship, preventing partial or whole collapse of the ship structures due to strength deterioration by heat is the main purpose of this regulation. For this purpose, materials used in the ships' structure shall ensure that the structural integrity is not degraded due to fire.

3.5.2 Material of hull, superstructures, structural bulkheads, decks and deckhouses

The hull, structural bulkheads, superstructures, decks and deckhouses shall be constructed of steel or other equivalent material. For applying the definition of steel or other equivalent material as given in Sect [1.3.41], the "applicable fire exposure" shall be according to the integrity and insulation standards given in tables 13.3.1 to 13.3.4. For example, the "applicable fire exposure" shall be half an hour where divisions such as decks or sides and ends of deckhouses are permitted to have "B-0" fire integrity.

3.5.3 Structure of aluminium alloy

Unless otherwise specified in Section [3.5.2], in cases where any part of the structure is of aluminium alloy, the following shall apply:

- 3.5.3.1 In the opinion of the INTLREG, the insulation of aluminium alloy components of "A" or "B" class divisions, except structure which, is non-load-bearing, shall be such that the temperature of the structural core does not rise beyond 200°C above the ambient temperature at any time during the applicable fire exposure to the standard fire test; and

- 3.5.3.2 Special attention shall be given to the insulation of aluminium alloy components of columns, stanchions and other structural members required to support lifeboat and liferaft stowage, launching and embarkation areas, and "A" and "B" class divisions to ensure:

- a) That for such members supporting lifeboat and liferaft areas and "A" class divisions, the temperature rise limitation specified in Section [3.5.3.1] shall apply at the end of one hour; and
- b) That for such members required to support "B" class divisions, the temperature rise limitation specified in Section [3.5.3.1] shall apply at the end of half an hour.

3.5.4 Machinery spaces of category A

3.5.4.1 Crowns and casings

Crowns and casings of machinery spaces of category A shall be constructed out of steel and shall be insulated according to the requirements in Tables 13.3.5 and 13.3.7, as appropriate.

3.5.4.2 Floor plating

The floor plating of normal passageways in machinery spaces of category A shall be made of steel.

3.5.5 Materials of overboard fittings

Materials already rendered as ineffective by heat is not used for sanitary discharges, overboard scuppers and other outlets situated close to the waterline and where the material's failure in the event of fire raises gives rise to danger of flooding.

3.5.6 Protection of cargo tank structure against pressure or vacuum in tankers

3.5.6.1 General

The venting arrangements shall be designed and operated in a manner to ensure that neither pressure nor vacuum in cargo tanks shall exceed design parameters and be such as to provide for:

3.5.6.1.1 The flow of the small volumes of vapour, air or inert gas mixtures caused by thermal variations in a cargo tank in all cases through pressure/vacuum valves; and

3.5.6.1.2 The passage of large volumes of vapour, air or inert gas mixtures during discharging or during cargo loading and ballasting.

3.5.6.2 Openings for small flow by thermal variation

Openings for pressure release required by Section [3.5.6.1.1] shall:

3.5.6.2.1 Have as great a height as is practicable above the cargo tank deck to obtain maximum dispersal of flammable vapours, but in no case less than 2 m above the cargo tank deck; and

3.5.6.2.2 Be arranged at the furthest distance practicable, but not less than 5 m, from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery and equipment which may constitute an ignition hazard. Chain locker and anchor windlass openings constitute an ignition hazard.

3.5.6.3 Safety measures in cargo tanks

3.5.6.3.1 Preventive measures against liquid rising in the venting system

Provisions shall be made in the venting system to guard against liquid rising to a height which would go beyond the design head of cargo tanks. This shall be accomplished by high-level alarms or overflow control systems or other equivalent means, together with independent gauging devices and cargo tank filling procedures. Spill valves are not considered equivalent to an overflow system for the purposes of this regulation.

3.5.6.3.2 Secondary means for pressure/vacuum relief

In the event of failure of the arrangements specified in Section [3.5.6.1.2], a secondary means of allowing full flow relief of vapour, air or inert gas mixtures shall be provided to prevent over-pressure or under-pressure. Alternatively, each tank protected by the arrangement specified in Section [3.5.6.1.2] is to be fitted with pressure sensors, with a monitoring system in the ship's cargo control room or the position from which cargo operations are normally carried out. An alarm facility shall also be provided by such monitoring equipment which is activated by detection of over-pressure or under-pressure conditions within a tank.

3.5.6.3.3 Bypasses in vent mains

Pressure/vacuum valves required by Section [3.5.6.1.1] may be provided with a bypass arrangement when they are located in a vent main or masthead riser. Where such an arrangement is provided suitable indicators should be present to show whether the bypass is open or closed.

3.5.6.3.4 Pressure/vacuum-breaking devices

One or more pressure/vacuum-breaking devices shall be provided for preventing the cargo tanks from being subjected to:

- i. A positive pressure, in excess of the test pressure of the cargo tank, if the cargo were to be loaded at the maximum rated capacity and all other outlets are left shut; and
- ii. A negative pressure in excess of 700 mm water gauge if the cargo were to be discharged at the maximum rated capacity of the cargo pumps and the inert gas blowers were to fail.

Such devices shall be installed on the inert gas main unless they are installed in the venting system required by SOLAS 4.5.3.1 or on individual cargo tanks. The location and design of the devices shall be in accordance with SOLAS regulation 4.5.3

3.5.6.4 Size of vent outlets

Vent outlets for cargo loading, discharging and ballasting according to the requirements of Section [3.5.6.1.2] shall be designed on the basis of the maximum designed loading rate multiplied by a factor of at least 1.25 to take account of gas evolution, in order to prevent the pressure in any cargo tank from exceeding the design pressure. The master shall be provided with information regarding the maximum permissible loading rate for each cargo tank and, in the case of combined venting systems, for each group of cargo tanks.

SECTION 4 ESCAPE AND OPERATIONAL REQUIREMENTS

Contents

4.1 Notification Of Crew And Passengers	676
4.2 Means Of Escape.....	676
4.3 Operational Readiness And Maintenance	684
4.4 Operations	686

4.1 NOTIFICATION OF CREW AND PASSENGERS

4.1.1 Purpose

The purpose of this guideline is to alert the crew and passengers in case of a fire and for their safe evacuation. For this purpose, a general emergency alarm system and a public address system shall be provided.

4.1.2 General emergency alarm system

A general emergency alarm system required by SOLAS Regulation III/6.4.2 shall be used for alerting the crew and passengers in case of a fire.

4.1.3 Public address systems in passenger ships

A public address system or other effective means of communication conforming to the requirements of SOLAS Regulation III/6.5 shall be accessible throughout the accommodation and service spaces including control stations and open decks as well.

4.2 MEANS OF ESCAPE

4.2.1 Purpose

The purpose of this chapter is to make available means of escape in case of fire so as to safely and swiftly evacuate persons on board to the lifeboat and liferaft embarkation deck. The underlying functional requirements shall be met for this purpose:

4.2.1.1 Safe escape routes shall be accessible;

4.2.1.2 Escape routes shall be maintained in proper condition and cleared of obstacles; and

4.2.1.3 Additional aids for escape shall be there, as necessary, to ensure accessibility, clear marking and accurate design during emergency situations.

4.2.2 General requirements

4.2.2.1 Unless expressly provided otherwise in this section, minimum two widely divided and complete means of escape shall be provided from all spaces or groups of spaces.

4.2.2.2 As per the requisites of this guideline, lifts shall not be considered as part of the means of escape.

4.2.3 Means of escape from control stations, accommodation spaces and service spaces

4.2.3.1 General requirements

4.2.3.1.1 Ladders and stairways shall be so set so as to make ready means of escape to the lifeboat and life raft embarkation deck available from passenger and crew accommodation spaces and from spaces where the crew is normally employed, excluding machinery spaces.

- 4.2.3.1.2 Unless expressly provided otherwise in this guideline, a lobby, corridor or part of a corridor from which there is just one route of escape shall be forbidden. The essential dead-end corridors used in service areas due to their practical utility on the ship, such as fuel oil stations and a thwart ship supply corridors shall only be allowed, provided such dead-end corridors are set apart from crew accommodation areas and are inaccessible from those areas. Also, a part of a corridor that has a depth not more than its width is considered a recess or local extension and is allowed.
- 4.2.3.1.3 All the stairways in service and accommodation spaces and control stations shall be made of steel frame except where the Administration allow the use of other equivalent material.
- 4.2.3.1.4 If a radio-telegraph station has no direct access to the open deck, two means of escape from, or access to, the station shall be provided, one of which may be a window of sufficient size or porthole and some other means if considered satisfactory by the Administration can also be provided.
- 4.2.3.1.5 In general, doors in escape routes shall open in direction of escape, except :
- i Individual cabin doors that may open into the cabins so as to avoid injury to persons in the corridor when the door is opened; and
 - ii Doors in vertical emergency escape trunks that may open out of the trunk so as to let the trunk be used both for access and escape.
- 4.2.3.2 Means of escape in passenger ships
- 4.2.3.2.1 Escape from spaces below the bulkhead deck
- i Below the bulkhead deck, two means of escape, one of which shall be independent of watertight doors, shall be provided, as a minimum, from each watertight compartment or similarly confined space or group of spaces. Exceptionally, the Administration may give one of the means of escape for crew spaces that enter only occasionally, if the required escape route is independent of watertight doors.
 - ii Where the Administration has permitted dispensation under the requirements of Section [4.2.3.2.1].(i), the only means of escape shall provide safe escape. However, stairways shall not be of minimum 800 mm in clear width with handrails on both sides.
- 4.2.3.2.2 Escape from spaces above the bulkhead deck
- From each main vertical zone or confined space or group of spaces situated above the bulkhead deck, there shall be minimum two means of escape out of which, at least one of shall give access to a stairway forming a vertical escape.

4.2.3.2.3 Direct access to stairway enclosures

Stairway enclosures in service as well as accommodation spaces shall be directly accessible from the corridors and be of adequate area to prevent congestion, keeping in mind, the number of persons likely to use them in an emergency. Within the outer limits of such stairway enclosures, only public toilets, lockers of non-combustible material providing storage for non-hazardous safety equipment and open information counters are allowed. The permission to have direct access to these stairway enclosures is given to other escape stairways required by Section [4.2.3.2.4].(i) and external areas along with only public spaces, lifts, public toilets, corridors, special category spaces and open Ro-Ro spaces (to which any passengers can be carried to).

Small "lobbies" or corridors used to separate an enclosed stairway from main laundries or galleys may have direct access to the stairway, subject to that they have a minimum deck area of 4.5 m², contain a fire hose station and a width of no 900 mm or less.

4.2.3.2.4 Details of means of escape

As a minimum, one of the means of escape required by Sections [4.2.3.2.1].(i) and [4.2.3.2.2] shall have a readily accessible enclosed stairway, which shall provide permanent fire shelter from the level of its origin to the suitable lifeboat and liferaft embarkation decks, or to the uppermost weather deck, if the embarkation deck does not go up to the main vertical zone being considered. In the latter case, direct access to the embarkation deck by way of external open stairways and passageways shall be provided and shall have emergency lighting as per the Regulation III/11.5 and slip-free surfaces underfoot. Boundaries facing external open stairways and passageways forming part of an escape route and boundaries in such a position that their failure during a fire would hamper escape to the embarkation deck shall have fire integrity, including insulation values, as per the tables 13.3.1 to 13.3.4, as appropriate.

Refer to the Guidelines for evacuation analysis for new and existing passenger ships (MSC.I/Circ.123 8).

- i Protection of access from the stairway enclosures to the lifeboat and liferaft embarkation areas shall be provided either directly or through safe internal routes which have fire integrity and insulation values for stairway enclosures as mentioned in tables 13.3.1 to 13.3.4, as appropriate.
- ii Stairways serving as only a space and a balcony in that space shall not be considered as part of one of the required means of escape.
- iii Each level in an atrium shall have two means of escape, one of which shall give direct access to an enclosed vertical means of escape and meet the requirements of Section [4.2.3.2.4].(i).
- iv The number, widths and continuity of escapes shall be as per the requirements of the Fire Safety Systems Code.

4.2.3.2.5 Marking of escape routes

- i Besides the emergency lighting required by SOLAS Regulations II-1/42 and III/11.5, the means of escape on the ship, including exits and stairways, shall be marked by photo-luminescent strip indicators or lighting placed at all points of the escape route, including angles and intersections and not above 300 mm from the deck. The marking must help passengers to identify the escape route and especially the escape exits. If electric illumination is used, it shall be connected to an emergency source of power in such a way that the failure of any single light or cut in a lighting strip will not make the marking ineffective. Plus, the escape route signs and fire equipment location markings shall be of photo luminescent material or marked by lighting as well. The Administration shall ascertain that all the lighting or photo luminescent equipment has been evaluated, tested and applied as per the guidelines of the Fire Safety Systems Code.
- ii The requirements of the Section [4.2.3.2.5].(i) shall also apply to the crew accommodation areas in case of passenger ships shipping more than 36 passengers.

4.2.3.2.6 Normally locked doors that form part of an escape route

- i The doors of cabin and stateroom shall not need keys to unlock them from inside the room. Also, along any designated escape route, the doors shall not require keys to unlock them when moving in the direction of escape.
- ii The latches fitted on the escape doors from public spaces shall normally be fitted with a means of quick release and their door-latching mechanism shall have an incorporated device that could release the latch upon the application of force in the direction of escape flow. Quick release mechanisms shall be properly designed and installed to the satisfaction of the Administration and, in particular:
 - a) Consist of bars or panels, the actuating portion of which extends across one half of the width of the door leaf, at least up to 760 mm and not beyond 1,120 mm above the deck;
 - b) Cause the latch to release when a force of not more than 67 N is applied; and
 - c) Not be equipped with any locking device, set screw or other arrangement that prevents the release of the latch when pressure is applied to the releasing device.

4.2.3.3 Means of escape in cargo ships

4.2.3.3.1 General

All the levels of accommodation shall be provided with at least two widely separated means of escape from each restricted space or group of spaces.

4.2.3.3.2 Escape from spaces below the lowest open deck

Below the lowest open deck, the main means of escape shall be a stairway only and the second option may be a trunk or a stairway.

4.2.3.3.3 Escape from spaces above the lowest open deck

Above the lowest open deck, again the main means of escape shall be stairways and other options are the doors to an open deck or a combination of both.

4.2.3.3.4 Dead-end corridors

In a cargo ship, dead-end corridors with length of more than 7 m shall not be accepted.

4.2.3.3.5 Width and continuity of escape routes

The number, width and continuity of escape routes shall be as per the regulations of the Fire Safety Systems Code.

4.2.3.3.6 Dispensation from two means of escape

Exceptionally, the Administration may exempt one of the means of escape, for crew spaces that are occasionally entered, but only if the required escape route is not dependent on the watertight doors

4.2.3.4 Emergency escape breathing devices

4.2.3.4.1 Emergency escape breathing devices shall conform to the Fire Safety Systems Code. Also, spare emergency escape breathing devices shall be kept on board.

4.2.3.4.2 All ships shall have at least two emergency escape breathing devices within accommodation spaces.

4.2.3.4.3 In all passenger ships, in each of the main vertical zones, at least two emergency escape breathing devices shall be carried.

4.2.3.4.4 In all passenger ships with more than 36 passengers onboard, two emergency escape breathing devices, in addition to those required in Section 3.4.3 above, shall be carried in each main vertical zone.

4.2.3.4.5 However, Sections [4.2.3.4.3] and [4.2.3.4.4] do not apply to stairway enclosures which constitute individual main vertical zones and to the main vertical zones in the fore or aft end of a ship which do not contain spaces of categories (6), (7), (8) or (12) as defined in Sect [4.3.2.2.3]

4.2.4 Means of escape from machinery spaces

4.2.4.1. Means of escape on passenger ships

Means of escape from each machinery space in passenger ships shall conform to the following provisions.

4.2.4.1.1 Escape from spaces below the bulkhead deck

For spaces below the bulkhead deck, two means of escape shall comprise of either:

- i Two sets of steel ladders, widely separated, leading to doors in the upper part of the space, similarly separated and from which access is provided to the most apt lifeboat and liferaft embarkation decks. One of these ladders shall be situated within a protected enclosure that meets the regulations given in Sect [4.3.2.2.3], as appropriate, from the lower part of the space it serves to a safe position outside the space. Automatically closing fire doors of the same fire integrity standards shall be fitted in the enclosure. Also, the ladder shall be fixed in such a way that heat is not transmitted to the enclosures through non-insulated fixing points. The protected enclosure shall have internal dimensions of minimum 800 mm x 800 mm, and shall have emergency lighting provisions; or
- ii One steel ladder going towards a door in the upper part of the space from where there is access to the embarkation deck and besides that, in the lower part of the space, in a site well separated from the ladder referred to, a steel door that operates from each side and which provides access to a safe escape route from the lower part of the space to the embarkation deck.

4.2.4.1.2 Escape from spaces above the bulkhead deck

Where the space is above the bulkhead deck, two means of escape shall be widely separated as much as possible and the doors emerging from such means of escape shall be in a place from where there is access to the most apt lifeboat and liferaft embarkation decks. Ladders in usage at such means of escape shall be of steel.

4.2.4.1.3 Dispensation from two means of escape

In a ship of less than 1,000 gross tonnage, the Administration may do without one of the means of escape, with due regards to the width and disposition of the upper part of the space. While for ship of 1,000 gross tonnage and above, the Administration may exempt one means of escape from any such space, including a normally unattended auxiliary machinery space, for as long as either a door or a steel ladder provides a safe escape route to the embarkation deck, keeping in consideration the nature and location of the space and whether persons are normally employed in that space. In the steering gear space, second means of escape shall be provided when the emergency steering position is located in that space, unless there is direct access to the open deck.

4.2.4.1.4 Escape from machinery control rooms

Two means of escape shall be provided from a machinery control room located within a machinery space, at least one of which will provide continuous fire shelter to a safe position outside the machinery space.

4.2.4.2. Means of escape on cargo ships

Means of escape from each machinery space in cargo ships shall conform to the following provisions.

4.2.4.2.1 Escape from machinery spaces of category A

Except as given in Section [4.2.4.2.2], two means of escape shall be provided from each machinery space of category A. Specifically, one of the following provisions shall be fulfilled:

- i Two sets of steel ladders, widely separated, going towards the doors in the upper part of the space, similarly separated and from where there is access to the open deck shall be there. One of these ladders shall be placed within a protected enclosure that satisfies regulations of Sect 2[2.3], and from the lower part of the space it leads to a safe position outside the space. Automatically-closing fire doors of the same fire integrity standards shall be fitted in the enclosure. The ladder shall be so fixed that heat is not transmitted into the enclosure through non-insulated fixing points. The enclosure shall have internal dimensions of minimum 800 mm x 800 mm, and shall have emergency lighting provisions; or
- ii One steel ladder leading to a door in the upper part of the space from where there is access to the open deck and, additionally, in the lower part of the space and in a position well separated from the ladder referred to, a steel door that can be operated from each side and which provides access to a safe escape route from the lower part of the space to the open deck.

4.2.4.2.2 Dispensation from two means of escape

In a ship of less than 1,000 gross tonnage, the Administration may exempt one of the means of escape required under Section [4.2.4.2.1], keeping in mind the dimension and disposition of the upper part of the space. In addition, the means of escape from machinery spaces of category A need not conform to the requirement for an enclosed fire shelter enlisted in Section [4.2.4.2.1].(i). In the steering gear space, a second means of escape shall be provided when the emergency steering position is there, unless there is direct access to the open deck.

4.2.4.2.3 Escape from machinery spaces other than those of category A

From machinery spaces other than those falling under category A, two escape routes shall be provided and a single escape route may be accepted for spaces that are entered only occasionally and where the maximum travel distance to the door is 5 m or less.

4.2.4.3. Emergency escape breathing devices

- 4.2.4.3.1 On all the ships, within the machinery spaces, emergency escape breathing devices shall be placed in such a place that they are ready to use, can be reached quickly and easily at any time, during a fire. The site of emergency escape breathing devices shall also take into account the layout of the machinery space and the number of persons employed in the spaces.
- 4.2.4.3.2 The number and location of emergency escape breathing devices shall be indicated in the fire control plan as per the requirements of Regulation 4.2.3.4
- 4.2.4.3.3 Emergency escape breathing devices shall conform to the Fire Safety Systems Code.

4.2.5 Means of escape on passenger ships from special category and open Ro-Ro spaces to which any passengers carried can have access

4.2.5.1. In special category and open ro-ro spaces to which any passengers can have access, the number and locations of the means of escape both below and above the bulkhead deck shall be to the satisfaction of the Administration and, in general, the safety of access to the embarkation deck shall be at least equivalent to that provided under Sections [4.2.3.2.1].(i), [4.2.3.2.2], [4.2.3.2.4].(i) and [4.2.3.2.4].(ii). Such spaces shall be provided with designated walkways to the means of escape with a breadth of minimum 600 mm. The parking arrangements for the vehicles shall maintain the walkways clear at all times.

4.2.5.2. At least, one of the escape routes from the machinery spaces where the crew is employed shall avoid direct access to any special category space.

4.2.6 Means of escape from Ro-Ro spaces

Minimum two means of escape shall be provided in Ro-Ro spaces where the crew are normally employed. The escape routes located at the fore and aft ends of the space shall provide a safe escape to the lifeboat and liferaft embarkation decks.

4.2.7 Additional requirements for Ro-Ro passenger ships

4.2.7.1. General

4.2.7.1.1 Escape routes shall be given from every normally occupied space on the ship to an assembly station. These escape routes shall be so arranged that they give most direct route possible to the assembly station, and shall be marked with symbols based on the guidelines developed by the Organization.

4.2.7.1.2 The escape route from cabins to stairway enclosures shall be as direct as possible, with a minimum number of changes in direction. It shall not be necessary to cross from one side of the ship to the other to reach an escape route. It shall not be necessary to climb more than two decks up or down in order to reach an assembly station or open deck from any passenger space.

4.2.7.1.3 External routes shall be provided from open decks, as referred to in Section 4.2.7.1.2, to the survival craft embarkation stations.

4.2.7.1.4 Where enclosed spaces adjoining an open deck, openings from the enclosed space to the open deck shall, where practicable, be capable of being used as an emergency exit.

4.2.7.1.5 Escape routes shall not be blocked by furniture and other obstructions other than tables and chairs which may be cleared later to provide open space. The cabinets and other heavy furnishings in public spaces and along escape routes shall be secured in place to prevent shifting, if the ship rolls or lists. Similarly, floor coverings shall also be secured in place. When the ship is under way, escape routes shall be kept clear of obstructions such as bedding, cleaning carts, luggage and boxes of goods.

4.2.7.2. Instruction for safe escape

4.2.7.2.1 Decks shall be sequentially numbered, starting with "1" at the tank top or lowest deck. The numbers shall be notably displayed at stair landings and lift lobbies. Decks may be named, but it is essential to number the deck number and display the deck number with its name.

4.2.7.2.2 Simple "mimic" plans displaying the "you are here" position and escape routes marked by arrows shall be notably displayed inside public spaces and on each cabin door. The plan shall clearly depict the directions of escape and shall have proper orientation with respect to its position on the ship.

4.2.7.3. Strength of handrails and corridors

4.2.7.3.1 Handrails or other handholds shall be provided in corridors along the entire escape route so that a firm handhold is available at every step of the way, where possible, to the assembly stations and embarkation stations. Such handrails shall be provided on both sides of longitudinal corridors more than 1.8 m in width and transverse corridors more than 1 m in width. The need to be able to cross lobbies, atriums and other large open spaces along escape routes shall be paid attention to. Handrails and other handholds shall be strong enough to withstand a distributed horizontal load of 750 N/m applied in the direction of the centre of the corridor or space, and a distributed vertical load of 750 N/m applied in the downward direction. The two loads need not be applied together.

4.2.7.3.2 The lowest 0.5 m of bulkheads and other partitions forming vertical divisions along escape routes shall be able to bear a load of 750 N/m so as to be used as walking surfaces from the side of the escape route with the ship at large angles of heel.

4.2.7.4. Evacuation analysis

An evacuation analysis shall be done early in the design process to evaluate the escape routes. This analysis shall be identify and eliminate congestion, as far as feasible, which may sometimes develop during abandonment as a result of normal movement of passengers and crew along escape routes, including the possibility that crew may need to move along these routes in a direction opposite to the movement of passengers. Additionally, the analysis shall be used to demonstrate that escape arrangements are adequately flexible to deal with the possibility that certain escape routes, embarkation stations, assembly stations or survival craft may not also be available as a result of a casualty.

4.3 OPERATIONAL READINESS AND MAINTENANCE

4.3.1 Purpose

The purpose of this regulation is to sustain and scrutinize the effectiveness of the fire safety measures provided in the ship. To meet this goal, the underlying functional requirements shall be met:

- The fire protection systems and fire-fighting systems and appliances shall be maintained in such a manner that they are ready for use; and
- Also, these fire protection and fire-fighting systems and appliances shall be tested and inspected from time to time.

4.3.2 General requirements

For the duration in which the ship is in service, the requirements of Section [4.3.1.] shall be conformed to. A ship is not in service when:

- It is declared that ship is not in service by the owner or his representative;
- It is in for repairs, lay-up (either at in port or at anchor) or in dry-dock; and
- In the case of passenger ships, when there are no passengers on board.

4.3.2.1 Operational readiness

4.3.2.1.1 The below mentioned fire protection systems shall be maintained in good working order so as to ascertain their required performance, in some fire emergency:

- i Means of escape systems and appliances;
- ii Structural fire protection, comprising of fire-resisting divisions and protection of openings and penetrations in these divisions; and
- iii Fire alarm systems and detection systems.

4.3.2.1.2 Fire-fighting systems and appliances shall be maintained in good working order and shall be made readily available for immediate use. For the sake of this, the portable extinguishers which have been expelled from service shall be recharged or replaced with an equivalent unit, almost immediately.

4.3.2.2 Maintenance, testing and inspections

4.3.2.2.1 Testing, maintenance and inspections shall be done on a regular basis, as directed by the guidelines developed by the Organization and in a manner that ensures the reliability of fire-fighting systems and appliances.

4.3.2.2.2 The maintenance plan shall always be available on the ship for inspection, whenever required by the Administration.

4.3.2.2.3 As a minimum, the maintenance plan shall comprise of the below mentioned fire protection systems and fire-fighting systems and appliances, where installed:

- i Fire pumps and hydrants, fire mains including nozzles, hoses and international shore connections;
- ii Fixed fire-extinguishing systems and other fire-extinguishing appliances;
- iii Fixed fire detection and fire alarm systems;
- iv Automatic sprinkler, fire detection and fire alarm systems;
- v General emergency alarm systems;
- vi Emergency shutdown of fuel supply;
- vii Ventilation systems, including smoke and fire dampers, fans and their controls;
- viii Fire doors, including their controls;
- ix Portable fire extinguishers, including spare charges;

- x Emergency escape breathing devices; and
- xi Fire-fighter's outfits.

4.3.2.2.4 The maintenance program may also be computer-based.

4.3.3 Additional requirements for passenger ships

In addition to the fire protection systems and appliances enlisted in Section [4.3.2.2.3], ships with more than 36 passengers onboard shall develop a maintenance plan for low-location lighting and public address systems.

4.3.4 Additional requirements for tankers

Alongside the fire protection systems and appliances enlisted in Section [4.3.2.2.3], tankers shall have a maintenance plan for:

- a) Inert gas systems;
- b) Fire safety arrangements in cargo pump-rooms;
- c) Deck foam systems; and
- d) Flammable gas detectors.

4.4 OPERATIONS

4.4.1 Purpose

The purpose of this guideline is to furnish information and directions for proper ship and cargo handling operations with respect to fire safety. For this purpose, the functional requirements given below shall be met:

4.4.1.1. Fire safety operational booklets shall be readily available on board; and

4.4.1.2. The flammable vapour releases arising from cargo tank venting shall be restricted.

4.4.2 Fire safety operational booklets

4.4.2.1. The requisite fire safety operational booklet shall comprise of the essential information and directions for the safe operation of the ship and cargo handling operations with respect to fire safety. The booklet shall also include information of the responsibility of the crew for general fire safety of the ship both during loading and discharging of cargo and while it is under way. Essential fire safety precautions for handling general cargoes shall be described. For ships carrying hazardous goods and flammable bulk cargoes, the fire safety operational booklet shall also give reference to the pertinent fire-fighting and emergency cargo handling instructions encompassed in the Code of Safe Practice for Solid Bulk Cargoes, the International Bulk Chemical Code, the International Gas Carrier Code and the International Maritime Dangerous Goods Code, as appropriate.

- 4.4.2.2. The fire safety operational booklet shall be available in every crew mess room, recreation room and crew cabin.
 - 4.4.2.3. The fire safety operational booklet shall be written in the working language of the ship.
 - 4.4.2.4. The fire safety operational booklet may be pooled with the training manuals required in SOLAS Regulation 15.2.3.
- 4.4.3 Additional requirements for tankers

4.4.3.1. General

The fire safety operational booklet referred to in Section [4.4.2] shall include requisites for preventing fire spread to the cargo area due to ignition of flammable vapours and along with procedures of cargo tank gas-purging and/or gas-freeing, taking into account the requisites in Section [4.4.3.2].

4.4.3.2. Procedures for cargo tank purging and/or gas-freeing

4.4.3.2.1 When the ship is provided with an inert gas system, the cargo tanks shall first be purged in as per the requisites of Regulation 15.3.8.6, until the concentration of hydrocarbon vapours in the cargo tank has come down to less than 2% by volume. Thereafter, gas-freeing may take place at the cargo tank deck level.

4.4.3.2.2 When the ship is not equipped with an inert gas system, the operation shall be done in such a manner that the flammable vapour is initially discharged through:

- i The vent outlets as specified in SOLAS Regulation 4.5.3.4;
- ii Outlets at, minimum 2 m above the cargo tank deck level with a vertical efflux velocity of 30 m/s, maintained constantly during the gas-freeing operation; or
- iii Outlets at, minimum 2 m above the cargo tank deck level with a vertical efflux velocity of 20 m/s and which are protected by suitable devices to prevent the passage of flame.

The above mentioned outlets shall be positioned not less than 10 m, measured horizontally, from the closest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery, which may include chain locker openings, anchor windlass and equipment which may be an ignition hazard.

4.4.3.2.3 When the flammable vapour concentration at the outlet has been reduced to 30% of the lower flammable limit, gas-freeing may be continued at cargo tank deck level.

**SECTION 5 ALTERNATIVE DESIGN ARRANGEMENTS AND
SPECIAL REQUIREMENTS**

Contents

5.1 Alternative Design And Arrangements 689

5.2 Helicopter Facilities 690

5.3 Carriage Of Dangerous Goods 694

5.4 Protection Of Vehicle, Special Category And Ro-Ro Spaces 699

5.1 ALTERNATIVE DESIGN AND ARRANGEMENTS**5.1.1 Purpose**

The purpose of this rule is to give a methodology for alternative design and provisions for fire safety.

5.1.2 General

5.1.2.1 Fire safety design and arrangements may diverge from the prescriptive requirements laid in other parts, provided that they meet the goal of fire safety as well as the functional requirements.

5.1.2.2 When fire safety design or arrangements diverge from the prescriptive requirements of this chapter, evaluation, engineering analysis and sanction of the alternative design and arrangements shall be gathered as per this rule.

5.1.3 Engineering Analysis

The engineering analysis shall be made ready and submitted to the INTLREG, and shall comprise of, as a minimum, the underlying elements:

5.1.3.1 Determination of the concerned ship type and space(s);

5.1.3.2 Identification of prescriptive requirement(s) with which the ship or the space(s) will not fall in line with;

5.1.3.3 Identification of the fire and explosion hazards of the ship or the space(s) concerned, together with:

- a) Identification of the potential ignition sources;
- b) Identification of the fire growth potential of each space concerned;
- c) Identification of the smoke and toxic runoff generation potential of each space concerned;
- d) Identification of the potential for the spread of smoke, fire or of toxic runoffs from the space (s) concerned to other spaces;

5.1.3.4 Determination of the requisite fire safety performance criteria for the ships or the space(s) concerned, addressed specifically by the prescriptive requirement(s):

- a) Performance criteria shall be based on the fire safety objectives and on the functional requisites of this chapter;
- b) Performance criteria shall provide a degree of safety not less than that attained by using the prescriptive requirements; and
- c) Performance criteria shall be measurable and quantifiable.

5.1.3.5 Comprehensive description of the alternative design and arrangements, also comprising a list of the assumptions used in the design and any intended operational constriction or conditions; and

5.1.3.6 Technical justification demonstrating that the alternative design and arrangements meet the requisite fire safety performance criteria.

Refer to the Guidelines on alternative design and arrangements for fire safety (MSC/Circ.1002).

5.1.4 Evaluation of the alternative design and arrangements

5.1.4.1. The engineering analysis required in Section [5.1.3] shall be evaluated and approved by the INTLREG, taking into consideration the guidelines developed by the IMO.

5.1.4.2. A copy of the documentation, as approved by the INTLREG, signifying that the alternative design and arrangements fulfilling this regulation shall be done on board the ship.

5.1.5 Exchange of information

The Administration shall speak to the IMO to know about the applicable information concerning alternative design and arrangements approved by them for circulation to all Contracting Governments.

5.1.6 Re-evaluation due to change of conditions

If the assumptions and operational limitations that were set in the alternative design and arrangements are altered, the engineering analysis shall be conducted under the altered condition and shall be approved by INTLREG.

5.2 HELICOPTER FACILITIES

5.2.1 Purpose

The purpose of this rule is to furnish additional measures to meet the fire safety objectives of this chapter for ships fitted with special facilities for helicopters. For this purpose, the underlying functional requisites shall be met:

5.2.1.1. Helideck structure shall be such that it safeguard the ship from the fire hazards associated with helicopter operations;

5.2.1.2. Fire-fighting appliances shall also be adequate to safeguard the ship from the fire hazards associated with helicopter operations;

5.2.1.3. Re-fuelling, hangar facilities and operations shall take the required measures to safeguard the ship from the fire hazards associated with helicopter operations; and

5.2.1.4. Operation manuals and training shall be available.

5.2.2 Application

5.2.2.1 In addition to fulfilling the requirements of other chapters, as appropriate, ships equipped with helidecks shall conform to the requirements of this regulation.

5.2.2.2 Where helicopters land or conduct winching operations on an occasional or emergency basis on ships without helidecks, fire-fighting equipment fitted as per the requirements in other chapters may be used. This equipment shall be made readily available in close proximity to the landing or winching areas during helicopter operations.

- 5.2.2.3 Notwithstanding the requirements of Section [5.2.2] above, Ro-Ro passenger ships without helidecks shall fulfill the SOLAS regulation 111/28.

5.2.3 Structure

- 5.2.3.1 Construction of Steel and other equivalent material
In general, the helidecks shall be made of steel or other equivalent materials. In case the helideck forms the deck head of a deckhouse or superstructure, it shall be insulated to "A-60" class standard.

- 5.2.3.2 Construction of aluminium or other low melting point metals

In case the platform is cantilevered over one side of the ship, after each fire on the ship or on the platform, a structural analysis shall be done to determine its aptness for further use; and

If the platform is situated above the deckhouse or similar structure of the ship, the underlying conditions shall be satisfied:

- i. The deckhouse top and bulkheads under the platform shall have no openings;
- ii. Windows under the platform shall have steel shutters; and
- iii. After each fire on the platform or in close proximity, a structural analysis shall be conducted to determine its aptness for further use.

5.2.4 Means of escape

A helideck shall have both a main and an emergency means of escape and access for fire fighting and rescue personnel. These shall be situated as far apart from each other as possible and preferably on opposite sides of the helideck.

5.2.5 Fire fighting appliances

In close vicinity to the helideck, the underlying fire-fighting appliances shall be given and stored near the means of access to that helideck:

- 5.2.5.1 Minimum two dry powder extinguishers with total capacity of not under 45 kg;
- 5.2.5.2 Carbon dioxide extinguishers of a total capacity of not under 18 kg or equivalent;
- 5.2.5.3 A suitable foam application system comprising of monitors or foam-making branch pipes capable of delivering foam to all parts of the helideck in all weather conditions in which helicopters can operate. The system shall be capable of giving a discharge rate as required in table 13.5.9 for possibly five minutes;

Table 13.5.9

Category	Helicopter overall length	Discharge rate foam solution (l/min)
H1	up to but not including 15 m	250
H2	from 15 m up to but not including 24 m	500
H3	from 24 m up to but not including 35 m	800

- 5.2.5.4 The main agent shall be fit for use with salt water and conform to performance standards not inferior to those acceptable to INTLREG;
- 5.2.5.5 Minimum two nozzles of an approved dual-purpose type (jet/spray) and hoses adequate to reach any part of the helideck;
- 5.2.5.6 Besides the requirements of Sect.[3.4.13] two sets of fire-fighter's outfits; and
- 5.2.5.7 Minimum the following equipment shall be stored in a manner that provides for immediate use and protection from the elements:
 - i. Pliers, side-cutting;
 - ii. Adjustable wrench;
 - iii. Blanket, fire-resistant;
 - iv. Lift line 5 mm diameter and 15 m in length;
 - v. Cutters, bolt, 60 cm;
 - vi. Ladder;
 - vii. Hook, grab or salving;
 - viii. Hacksaw, heavy duty complete with six (6) spare blades;
 - ix. Set of assorted screwdrivers; and
 - x. Harness knife complete with sheath.

5.2.6 Drainage facilities

Drainage facilities located in the way of helidecks shall be made of steel and lead directly overboard without depending of any other system. They should be designed in such a way that the drainage does not fall onto any part of the ship.

5.2.7 Helicopter re-fuelling and hangar facilities

Where the ship has helicopter re-fueling and hangar facilities, the underlying requirements shall be conformed to:

- 5.2.7.1 A designated area shall be given for the storage of fuel tanks which shall be:
 - a) As remote, as much as feasible, from accommodation spaces, escape routes and embarkation stations; and
 - b) Cut off from areas having a source of vapour ignition;
- 5.2.7.2 The fuel storage area shall be have arrangements whereby fuel spillage may be gathered and drained to a protected location;
- 5.2.7.3 Tanks and allied equipment shall be safeguarded against physical injure and from a fire in an adjacent area;
 - 5.2.7.3.1 Handrails or other handholds shall be given all along the escape route so that a firm handhold is available at every step of the way, where possible, till the assembly and embarkation stations. Such handrails shall be there on both sides of longitudinal corridors and measure more than 1.8 m in width and transverse corridors shall measure 1 m in width. The need to be able to cross lobbies, atriums and other large open spaces along escape routes shall be paid attention to. Handrails and other handholds shall be tough enough to withstand a distributed horizontal load of 750 N/m applied in the direction of the centre of the corridor or space, and a

distributed vertical load of 750 N/m applied in the downward direction. The two loads need not be simultaneously applied.

5.2.7.3.2 The lowest 0.5 m of bulkheads and other partitions forming vertical divisions along escape routes shall be able to bear a load of 750 N/m so as to be used as walking surfaces from the side of the escape route with the ship at large angles of heel.

5.2.7.4 Where portable fuel storage tanks are used, exceptional attention shall be given to:

- Design of the tank for its intended purpose;
- Mounting and securing provisions;
- Electric bonding; and
- Checking procedures;

5.2.7.5 Storage tank fuel pumps shall be rendered with means which allow shutdown from a safe remote location in the event of a fire. Where a gravity fueling system is installed, equivalent closing arrangements shall be provided to cut off the fuel source;

5.2.7.6 The fuel pumping unit shall be attached to one tank at a time. The piping between the tank and the pumping unit shall be of steel or equivalent material, as short as possible, and safeguarded against damage;

5.2.7.7 Electrical fuel pumping units and associated control equipment shall be of a suitable manner for the location and potential hazards;

5.2.7.8 Fuel pumping units shall fit in a device which will put a stop to over-pressurization of the delivery or filling hose;

5.2.7.9 Equipment used in refueling operations shall be electrically bonded;

5.2.7.10 "NO SMOKING" signs shall be displayed at required locations;

5.2.7.11 Hangar, refueling and maintenance facilities shall be treated as category A machinery spaces with respect to fixed fire-extinguishing, structural fire protection and detection system requirements;

5.2.7.12 Enclosed hangar facilities or enclosed spaces containing refueling installations shall be provided with mechanical ventilation, as required by SOLAS regulation 20.3 for closed ro-ro spaces of cargo ships. Ventilation fans shall be of non-sparking type; and

5.2.7.13 Electric equipment and wiring in enclosed hangars and spaces comprising of refuelling installations shall conform to SOLAS regulations 20.3.2, 20.3.3 and 20.3.4.

5.2.8 Operations manual and fire-fighting arrangements

5.2.8.1 Each helicopter facility shall have onboard an operations manual, comprising of a description and a checklist of safety procedures, preventive measures and equipment requisites. This manual may be part of the ship's emergency response procedures.

5.2.8.2 The procedures and precautions to be followed during refuelling operations shall be as per the recognized safe practices and shall be contained in the operations manual.

- 5.2.8.3 Fire-fighting personnel, consisting of minimum two persons trained for rescue and fire-fighting duties, and fire-fighting equipment shall be readily available all the time when helicopter operations are anticipated.
- 5.2.8.4 Fire-fighting personnel shall be physically present during re-fuelling operations though they may not be involved with re-fuelling activities.
- 5.2.8.5 On-board refresher training shall be conducted and additional supplies of fire-fighting media shall be given for training and testing of the equipment.

5.3 CARRIAGE OF DANGEROUS GOODS

5.3.1 Purpose

The purpose of this rule is to lay out some additional safety measures that address the fire safety objectives of this chapter for ships transporting dangerous goods. For this purpose, the underlying functional requirements shall be met:

- 5.3.1.1 Fire protection systems shall be there that helps in safeguarding the ship from the additional fire hazards associated with transportation of dangerous goods;
- 5.3.1.2 Dangerous goods shall be sufficiently estranged from ignition sources; and
- 5.3.1.3 Suitable personnel protective equipment shall be provided for the hazards associated with the transportation of dangerous goods.

5.3.2 General requirements

- 5.3.2.1 Besides conformation to the requirements of other chapters and SOLAS regulations 18 and 20, as appropriate, ship types and cargo spaces, referred to in Section 3.3.2.2 proposed for the transportation of dangerous goods shall also fulfill the requirements of this regulation, as appropriate, except when transmitting dangerous goods in limited quantities* unless such requirements have already met the requirements elsewhere in this chapter. The types of ships and modes of transportation of dangerous goods are referred to in Section [5.3.2.2] and in table 19.1. Cargo ships weighing below 500 gross tonnage shall fulfill this regulation, but INTLREG may decrease the requirements and such reduced requirements shall be recorded in the document of compliance referred to in Section 4.
- 5.3.2.2 The ship types and cargo spaces given below shall govern the application of tables 19.1 & 19.2 in SOLAS regulation 19:
 - 5.3.2.2.1 Ships and cargo spaces not specifically designed for the transportation of freight containers, but proposed for the carrying dangerous goods in packaged form, including goods in freight containers and portable tanks;
 - 5.3.2.2.2 Purpose-built container ships and cargo spaces proposed for the transportation of dangerous goods in freight containers and portable tanks;
 - 5.3.2.2.3 Ro-Ro ships and Ro-Ro spaces proposed for the transportation of dangerous goods;

- 5.3.2.2.4 Ships and cargo spaces proposed for the transportation of solid dangerous goods in bulk; and
- 5.3.2.2.5 Ships and cargo spaces proposed for transportation of dangerous goods other than liquids and gases in bulk in ship borne barges.

5.3.3 Special requirements

Unless specified, the following requisites shall govern the application of tables 19.1, 19.2 and 19.3 of SOLAS to "on-deck" and "under-deck" stowage of dangerous goods where the numbers of the following Sections are indicated in the first column of the tables.

5.3.3.1 Water supplies

- 5.3.3.1.1 Arrangements shall be made to ascertain instant availability of water supply from the fire main at the required pressure either by permanent pressurization or by suitably placed remote arrangements for the fire pumps.
- 5.3.3.1.2 The quantity of water shall be adequate to supply water to four nozzles of size and at pressures, capable of reaching any part of the cargo space when empty. This amount of water may be applied by equivalent means to the satisfaction of the INTLREG.
- 5.3.3.1.3 Means shall be given for effective cooling of the designated under-deck cargo space by at least 5/min per square metre of the horizontal area of cargo spaces, either by a fixed arrangement of spraying nozzles or by flooding the cargo space with water. Hoses may be used for this job in small cargo spaces and areas of larger cargo spaces at the discretion of the INTLREG. However, the drainage and pumping arrangements shall be such as to avert the build-up of free surfaces. The drainage system shall be sized to remove no less than 125% of the combined capacity of both the water spraying system pumps and the required number of fire hose nozzles. The drainage system valves shall be operable from outside the protected space at a position in the close proximity of the extinguishing system controls. Bilge wells shall be of adequate holding capacity and shall 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 unfavorable effect upon stability of the added weight and free surface of water shall be taken into account to the extent deemed necessary by INTLREG in its approval of the stability information.
- 5.3.3.1.4 Provision to flood a designated under-deck cargo space with suitable specified media may be replaced for the requisites in Section [5.3.1.3]
- 5.3.3.1.5 The total requisite capacity of the water supply shall satisfy Sections [5.3.3.1.2] and [5.3.3.1.3], if applicable, simultaneously calculated for the largest designated cargo space. The capacity requirements of Section [5.3.3.1.2] shall be met by the total capacity of the main fire pump(s), excluding the capacity of the emergency fire pump, if fitted. If a drencher system is used to satisfy Section [5.3.3.1.3], the drencher pump shall also be taken into consideration in total capacity calculation.

5.3.3.2 Sources of ignition

Electrical equipment and wiring shall not be fitted in enclosed cargo spaces or vehicle spaces, unless it is vital for operational purposes in the opinion of the INTLREG. However, if electrical equipment is fitted in such spaces, it shall be of certified safe type" for use in the dangerous environments to which it may be exposed unless it is possible to completely segregate the electrical system (e.g. by removal of links in the system, other than fuses). Cable penetrations of the decks and bulkheads shall be sealed against the passage of gas or vapour through runs of cables and cables within the cargo spaces to shelter them against damage from impact. Any other equipment which may form a source of ignition of flammable vapour shall also not be allowed.

5.3.3.3 Detection system

Ro-Ro spaces shall be fitted with a fixed fire detection and fire alarm system conforming to the requirements of the Fire Safety Systems Code. All other types of cargo spaces shall be fitted with either fixed fire detection and fire alarm system or a sample extraction smoke detection system fulfilling the requirements of the Fire Safety Systems Code. If a sample extraction smoke detection system is fitted, of the Fire Safety Systems Code so as to avoid the outflow of toxic fumes into inhabited areas.

5.3.3.4 Ventilation

5.3.3.4.1. Adequate power ventilation shall be there in enclosed cargo spaces. The arrangement shall be such that it provides some six air changes per hour in the cargo space, based on an empty cargo space, and for elimination of vapours from the upper or lower parts of the cargo space, as appropriate.

5.3.3.4.2. The fans shall be such that the possibility of ignition of flammable gas/air mixtures is totally avoided. Suitable wire mesh guards shall be fitted over inlet and outlet ventilation openings.

5.3.3.4.3. Natural ventilation shall be there in enclosed cargo spaces proposed for the transmittance of solid dangerous goods in bulk, where there is no provision for mechanical ventilation.

5.3.3.5 Bilge pumping

5.3.3.5.1. Where it is intended to transport flammable or toxic liquids in enclosed cargo spaces, the bilge pumping system shall be designed to shield against accidental pumping of such liquids through machinery space piping or pumps. Where huge quantities of such liquids are transmitted, consideration shall be given to the provision of additional means of draining to those cargo spaces.

- 5.3.3.5.2. If the bilge drainage system is additional to the system served by pumps in the machinery space, the capacity of the system shall not be under 10 m/h per cargo space served. If the additional system is common, the capacity need not surpass 25 m /h. The additional bilge system need not be arranged with redundancy.
- 5.3.3.5.3. Whenever flammable or toxic liquids are transmitted, the bilge line into the machinery space shall be cut off either by fitting a blank flange or by a closed lockable valve.
- 5.3.3.5.4. Enclosed spaces outside machinery spaces containing bilge pumps serving cargo spaces intended for transmittance of flammable or toxic liquids shall be fitted with distinct mechanical ventilation giving minimum six air changes per hour. If the space has access from some other enclosed space, the door shall be self-closing.
- 5.3.3.5.5. If bilge drainage of cargo spaces is arranged by gravity drainage, the drainage shall be either led directly overboard or to a closed drain tank placed outside the machinery spaces. The tank shall be given a vent pipe to a safe location on the open deck. Drainage from a cargo space into bilge wells in a lower space is only allowed if that space satisfies the same requisites as the cargo space above.

5.3.3.6 Personnel protection

- 5.3.3.6.1. Four sets of full protective clothing that is resistant to chemical attack shall be given, in addition to, the fire-fighter's outfits required by Sect [3.4.13]. The protective clothing shall cover the whole body, so that no part of the body is unsafe or unshielded.
- 5.3.3.6.2. Minimum two self-contained breathing apparatuses are required, in addition to the SOLAS regulation 10.10. Two spare charges suitable for use with the breathing apparatus shall be provided for each required apparatus. Passenger ships carrying 36 passengers or more and cargo ships those are equipped with suitably located means for fully recharging the air cylinders free from contamination need to transmit only one extra charge for each apparatus.

5.3.3.7 Portable fire extinguishers

Portable fire extinguishers with a total capacity of 12 kg of dry powder or equivalent shall be provided for the cargo spaces. These extinguishers shall be there in addition to any portable fire extinguishers required elsewhere in this chapter.

5.3.3.8 Insulation of machinery space boundaries

Bulkheads forming boundaries between cargo spaces and machinery spaces of category A shall be insulated to "A-60" class standard, unless the dangerous goods are stowed at least 3 m horizontally away from such bulkheads. Other boundaries between such spaces shall be insulated to "A-6 0" class standard.

5.3.3.9 Water-spray system

Each open Ro-Ro space having a deck above it and each space deemed to be a closed Ro-Ro space because of being incapable of getting sealed shall be fitted with an approved fixed pressure water-spraying system for manual operation which shall shield all parts of deck and vehicle platform in the space, though INTLREG may allow the use of some other fixed fire-extinguishing system that has proved to be no less effective by full-scale test.

However, the pumping and drainage arrangements shall be such that they prevent the build-up of free surfaces. The drainage system shall be sized to remove no less than 125% of the combined capacity of both the water-spraying system pumps and the required number of fire hose nozzles. The drainage system valves shall be operable from outside the protected space at a position in the vicinity of the extinguishing system controls. Bilge wells shall be of adequate holding capacity and so arranged at the side shell of the ship that their mutual distance is not more than 40 m in each watertight compartment. If this is not feasible, the unfavorable effect upon stability of the additional weight and free surface of water shall be taken into account to the extent deemed necessary by INTLREG in its approval of the stability information.

5.3.3.10 Separation of Ro-Ro spaces

5.3.3.10.1. In ships having ro-ro spaces, a parting shall be provided between a closed ro-ro space and an adjacent open ro-ro space. The parting shall be such that it minimizes the passage of perilous vapours and liquids between such spaces. Alternatively, such parting need not be provided if the ro-ro space is considered to be a closed cargo space along its entire length and fully conforms to the relevant special requirements of this chapter.

5.3.3.10.2. In ships having ro-ro spaces, a separation shall be provided between a closed ro-ro space and the adjacent weather deck. The separation shall be such as to minimize the passage of dangerous vapours and liquids between such spaces. Alternatively, a parting need not be given if the arrangements of the closed ro-ro spaces are in line with those required for the dangerous goods transmitted on adjacent weather decks.

5.3.4 Document of compliance

INTLREG shall provide the ship with an apt document as evidence of conformation to construction and equipment with the requisites of this regulation. Certification for dangerous goods, except solid dangerous goods in bulk, is not needed for those cargoes that are specified in class 6.2 and 7, as defined in SOLAS regulation VII/2, and dangerous goods in restricted quantities.

5.4 PROTECTION OF VEHICLE, SPECIAL CATEGORY AND RO-RO SPACES**5.4.1 Purpose**

The purpose of this rule is to provide additional safety measures in order to address the fire safety objectives of this chapter for ships fitted with vehicle, special category and Ro-Ro spaces. For this purpose, the following functional requirements shall be met:

5.4.1.1. Fire protection systems shall be provided to adequately safeguard the ship from the fire hazards allied with vehicle, special category and Ro-Ro spaces;

5.4.1.2. Ignition sources shall be placed distinct from vehicle, special category and Ro-Ro spaces; and

5.4.1.3. Vehicle, special category and Ro-Ro spaces shall be satisfactorily ventilated.

5.4.2 General requirements**5.4.2.1. Application**

In addition to conforming to the requirements of regulations in other chapters, as appropriate, vehicle, special category and ro-ro spaces shall fulfill the requirements of this regulation.

5.4.2.2. Basic principles for passenger ships

5.4.2.2.1. The fundamental principles underlying the provisions of this regulation is that the main vertical zoning required by SOLAS regulation 9.2 may not be practicable in vehicle spaces of passenger ships and, therefore, equivalent protection must be obtained in such spaces on the basis of a horizontal zone concept and by the provision of an efficient fixed fire-extinguishing system. Based on this concept, a horizontal zone for the purpose of this regulation may include special category spaces on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m.

5.4.2.2.2. The basic principle underlying the provisions of Section [5.4.2.2.1] is also applicable to Ro-Ro spaces.

5.4.2.2.3. The requirements of ventilation systems, openings in "A" class divisions and penetrations in "A" class divisions for maintaining the integrity of vertical zones in this chapter shall be applied equally to decks and bulkheads forming the boundaries dividing horizontal zones from each other and from the rest of the ship.

5.4.3 Precaution against ignition of flammable vapours in closed vehicle spaces, closed Ro-Ro spaces and special category spaces**5.4.3.1. Ventilations systems**

5.4.3.2. Capacity of ventilation systems

There shall be an effective power ventilation system that is capable of giving at least the following air changes:

Passenger ships:	
Special category spaces	10 air charges per hour
Closed Ro-Ro and vehicles spaces other than special category spaces for ships carrying more than 36 passengers	10 air charges per hour
Closed Ro-Ro and vehicle spaces other than special category spaces for ships carrying not more than 36 passengers	6 air changes per hour
Cargo ships:	6 air changes per hour

INTLREG may assess and increased number of air changes when vehicles are being loaded and unloaded.

5.4.3.3. Performance of ventilation systems

- i. In passenger ships, the power ventilation system required in Section [5.4.3.2] shall be kept parted from other ventilation systems and shall be in operation at all times when vehicles are in such spaces. Ventilation ducts serving such cargo spaces capable of being effectively sealed shall be separated for each such space. The system shall be capable of being controlled from a position outside such spaces.
- ii. In cargo ships, ventilation fans shall normally be run constantly whenever vehicles are on board. Where this is not feasible, they shall be operated for a sometime daily as weather allows and in any case for a reasonable period prior to discharge, after which period the ro-ro or vehicle space shall be proved gas-free. One or more portable combustible gas detecting instruments shall be taken for this purpose. The system shall entirely be separate from other ventilating systems. Ventilation ducts serving ro-ro or vehicle spaces shall be able to effectively seal each cargo space and being controlled from a position outside such spaces.
- iii. The ventilation system shall be such that it puts a stop on air stratification and the creation of air pockets.

5.4.3.4. Indication of ventilation systems

Means shall be provided on the navigation bridge to indicate any loss of the required ventilating capacity.

5.4.3.5. Closing appliances and ducts

Arrangements shall be provided to allow a quick shutdown and effective closure of the ventilation system from outside of the space in case of fire, taking into consideration the weather and sea conditions.

Ventilation ducts, including dampers, within a common horizontal zone shall be made of steel. In passenger ships, ventilation ducts that pass through other horizontal zones or machinery spaces shall be "A-60" class steel ducts constructed as per the SOLAS regulations 9.7.2.1.1 and 9.7.2.1.2.

5.4.3.6. Permanent openings

Permanent openings in the side plating, the ends or deck head of the space shall be so situated that a fire in the cargo space does not endanger stowage areas and embarkation stations for survival craft and accommodation spaces, service spaces and control stations in superstructures and deckhouses above the cargo spaces.

5.4.3.7. Electrical equipment and wiring

5.4.3.7.1. Except as provided in Section [5.4.3.7.2], electrical equipment and wiring shall be of a type suitable for use in an explosive petrol and air mixture.

5.4.3.7.2. In case of other than special category spaces below the bulkhead deck, notwithstanding the provisions in Section [5.4.3.7.1], above a height of 450 mm from the deck and from each platform for vehicles, if fitted, except platforms with openings of sufficient size allowing penetration of petrol gases downwards, electrical equipment of a type so enclosed and protected as to prevent the escape of sparks shall be allowed as an alternative, on condition that the ventilation system is so designed and operated as to provide constant ventilation of the cargo spaces at the rate of minimum ten air changes per hour, whenever vehicles are on board.

5.4.3.8. Electrical equipment and wiring in exhaust ventilation ducts

Electrical equipment and wiring, if installed in an exhaust ventilation duct, shall be of a type approved for use in explosive petrol and air mixtures and the outlet from any exhaust duct shall be sited in a safe position, having regard to other possible sources of ignition.

5.4.3.9. Other ignition sources

Other equipment which may comprise of a source of ignition of flammable vapours shall not be allowed.

5.4.3.10. Scuppers and discharges

Scuppers shall not be led to machinery or other spaces where sources of ignition may be present.

5.4.4 Detection and Alarm

5.4.4.1. Fixed fire detection and fire alarm systems

Except as provided in Section [5.4.3.1], there shall be provided a fixed fire detection and fire alarm system fulfilling the requirements of the Fire Safety Systems Code. The fixed fire detection system shall be capable of quickly detecting the onset of fire. The type of detectors and their spacing and location shall be to the satisfaction of the INTLREG, taking into consideration the effects of ventilation and other relevant factors. After installation, the system shall be tested under conditions of normal ventilation and shall give an overall response time to the satisfaction of the INTLREG.

5.4.4.2. Sample extraction smoke detection systems

Except open Ro-Ro spaces, open vehicle spaces and special category spaces, a sample extraction smoke detection system conforming to the requirements of the Fire Safety Systems Code may be used as an alternative for the fixed fire detection and fire alarm system

5.4.4.3. Special category spaces

- a) A competent fire patrol system shall be maintained in special category spaces and if it is maintained by an incessant fire watch all the time during the voyage, a fixed fire detection and fire alarm system is not needed.
- b) Manually operated call points shall be so spaced that no part of the space is over 20 m from a manually operated call point, and one shall be placed close to each exit from such spaces.

5.4.5 Structural fire protection

Albeit the provisions of regulation 9.2.2, in passenger ships with more than 36 passengers onboard, the boundary bulkheads and decks of special category spaces and Ro-Ro spaces shall be insulated to "A-60" class standard. However, where a category (5), (9) or (10) space, as defined in SOLAS regulation 9.2.2.3, is on one side of the division, the standard may be changed to "A-0". Where fuel oil tanks are below a special category space or a Ro-Ro space, the integrity of the deck between such spaces may be reduced to "A-0" standard.

5.4.6 Fire extinction

5.4.6.1. Fixed fire-extinguishing systems

5.4.6.1.1. Vehicle spaces and ro-ro spaces which are not special category spaces and are capable of being sealed from a location outside of the cargo spaces shall be fitted with a fixed gas fire-extinguishing system which shall conform to the provisions of the Fire Safety Systems Code, except:

- i If a carbon dioxide fire-extinguishing system is fitted, the quantity of gas available shall be ample to give a minimum volume of free gas equal to 45% of the gross volume of the largest such cargo space which is capable of being sealed, and the arrangements

shall be such as to ensure that at least two thirds of the gas required for the relevant space shall be introduced within 10 min;

- ii Any other fixed inert gas fire-extinguishing system or fixed high-expansion foam fire-extinguishing system may be fitted, provided the INTLREG content that an equivalent protection is attained; and
- iii As an alternative, a fire-extinguishing system meeting the requisites of Section [5.4.6.1.2] may be fitted.

5.4.6.1.2. Ro-Ro vehicle spaces and special category spaces not capable of being scaled shall be fitted with an approved fixed pressure water-spraying system for manual operation which shall safeguard all parts of any deck and vehicle platform in such spaces. Such water-spray systems shall have:

- i A pressure gauge on the valve manifold;
- ii Clear marking on each manifold valve indicating the spaces served;
- iii Instructions for maintenance and operation placed in the valve room; and
- iv Sufficient number of drainage valves.

5.4.6.1.3. INTLREG may allow the use of any other fixed fire-extinguishing system" that has been shown, by a full-scale test in conditions simulating a flowing petrol fire in a vehicle space or a Ro-Ro space, to be not less effective in controlling fires expected to occur in such a space.

5.4.6.1.4. When fixed pressure water-spraying fire-extinguishing systems are provided, in view of the serious loss of stability which could arise due to large quantities of water accumulating on the deck or decks during the operation of the water-spraying system, the following arrangements shall be provided:

- i In passenger ships:
 - a In the spaces above the bulkhead deck, scuppers shall be fitted so as to ascertain that such water is quickly discharged directly overboard;
 - b In Ro-Ro passenger ships, discharge valves for scuppers, fitted with positive means of closing operable from a position above the bulkhead deck as per the requirements of the international convention on load lines in force, shall be kept open while the ships are at sea;
 - c Any operation of valves referred to in Section [5.4.6.1.4].(i).(b) shall be recorded in the log-book;
- ii In the spaces below the bulkhead deck, INTLREG may require pumping and drainage facilities to be provided additional to the requirements of SOLAS regulation II-1/35-1. In such case, the drainage system shall be sized to remove no less than 125% of the joint capacity of both the water-spraying system pumps and the required number of fire hose nozzles.

The drainage system valves shall be operable from outside the protected space at a position in the vicinity of the extinguishing

system controls. Bilge wells shall be of adequate holding capacity and shall 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;

- iii In cargo ships, the drainage and pumping arrangements shall be such as to avert the build-up of free surfaces. In such case, the drainage system shall be sized to remove no less than 12.5% of the joint capacity of both the water-spraying system pumps and the required number of fire hose nozzles. The drainage system valves shall be operable from outside the sheltered space at a position in the vicinity of the extinguishing system controls. Bilge wells shall be of adequate holding capacity and shall 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 adverse effect upon stability of the added weight and free surface of water shall be taken into consideration to the extent deemed necessary by INTLREG in its approval of the stability information. Such information shall be included in the stability information supplied to the master as required by SOLAS regulation II-1/5-1.

5.4.6.2. Portable fire extinguishers

5.4.6.2.1. Portable fire extinguishers shall be there at each deck level in each hold or compartment where vehicles are carried, spaced not beyond 20 m on both sides of the space. To such a cargo space, minimum one portable fire extinguisher shall be located at each access.

5.4.6.2.2. In addition to the provision of Section [5.4.6.2.1], the underlying fire-extinguishing appliances shall be given in vehicle, ro-ro and special category spaces proposed for the carriage of motor vehicles with fuel in their tanks for their own propulsion:

- i Minimum three water-fog applicators; and
- ii One portable foam applicator unit fulfilling the provisions of the fire safety systems code, provided that minimum two such units are available in the ship for use in such spaces.

I. ANNEX 1– INTERNAL COMBUSTION ENGINE APPROVAL APPLICATION FORM AND DATA SHEET

Class Application number (if applicable):

General Data	
Engine Designer: Contact Person: Address:	Engine Manufacturer(s), Licensee(s) and/or Manufacturing Sites* Name Country
Document Purpose (Select options for either 1 (a) or 1(b))	
1(a). Type Approval Application	
Service Requested ☐ New Type Approval ☐ Renew Type Approval ☐ Amend Type Approval ☐ Design Evaluation ☐ Update TA Supplement ☐ Other	Required activities† ☐ DA, TT, COP ☐ COP, if design change then amended or new certificate process to be followed ☐ DA &COP, Further TT if previously approved engine has been substantively modified (as required by UR M71) ☐ DA, TT, applicable where designer does not have production facilities, Type Approval to be granted to specific production facility once associated COP has been completed ☐ Update to Supplement, only for minor changes not affecting the <i>Type Approval Certificate</i> ☐ e.g. National/Statutory Administration requirements i.e. MSC.81(70) for emergency engines
ForTA amendments or Supplement updates, details of what is to be changed:	
For 'Other', Details of the requirements to be considered:	
I (b) Addendum for Individual Engine FAT and Certification	
Individual engine requiring FAT and Certification, only where the performance data for the engine being certified differs from the details provided ☐ On the original Type Approval Application. Only section 3b requires completion. Where changes to other sections are necessary, new Type Approval Application may be required	
Reference number of Internal Combustion Engine Approval Application Form previously submitted and reference number of the Type Approval Certificate.	(Copy of original application form to be attached to this document)

2. Existing documentation			
Previous Class Type Approval Certificate No. or related Design Approval No. (if applicable)			
Formerly issued documentation for engine (E.g. previous type test reports, in-service experience justification reports, etc.)	Issuing Body:	Document Type:	Document No.:
Existing Certification (E.g. Manufacturer's quality certification ISO 9001 etc.)	Issuing Body:	Document Type:	Document No.:
3. Design (mark all that apply)			
3 a. Engine Particulars:			
Engine Type Manufactured Since [†] :		Number of delivered marine engines [†] :	
Application	☐ Direct drive Propulsion ☐ Single Engine ☐ Multi-engine installation	☐ Auxiliary ☐ Aux. Services Electric Propulsion	☐ Emergency

Engine Manufacturer's Application Identification Number

Mechanical Design	2-stroke ☐	4-stroke ☐	In-line ☐	Vee(V-angle ☐ °)	Other ☐
	☐ Cross-head	☐ Trunk-piston	☐ Reversible	☐ Non-Reversible	
	Cylinder bore (mm)		Length of piston stroke (mm)		
Supercharging	☐ Without Supercharging	☐ With Supercharging ☐ With Charge air cooling ☐ Constant pressure charging system		☐ With charge air cooling ☐ Pulsating pressure charging system	
Valve operation	☐ Cam control		☐ Electronic control		

Fuel Injection	☐ Direct injection	☐ Indirect injection	☐ Cam controlled injection	☐ Electronically controlled injection
Fuel Types§ (Classification according to ISO 8216)	☐ Marine residual fuel cSt (Max. kinematic viscosity at 50°C) ☐ Marine distillate fuel DMA, DMB, DMC ☐ Marine distillate fuel DMX ☐ Low flashpoint liquid fuel (specify fuel type) ☐ Gas (specify gas type) ☐ Other (specify) ☐ Dual Fuel (specify combinations of fuels to be used)			
3 b. Performance Data (Related to: Barometric pressure 1,000 mbar; Air temperature 45°C; Relative humidity 60%; Seawater temperature 32°C)				
Model reference No. (if applicable)				
Max. continuous rating kW/cyl				
Rated speed 1/min				
Mean indicated pressure MPa				
Mean effective pressure MPa				
Max. firing pressure MPa				
Charge air pressure MPa				
Compression ratio -				
Mean piston speed m/s				
3 c. Crankshaft				
Design	☐ Solid Built	☐ Semi-built	☐ Built	
Method of Manufacture	☐ Cast	☐ Forged ☐ Slab forged	☐ Approved die forged	☐ Continuous grain flow process
State approved forge/works name:				

Is the crankshaft hardened by an approved process which includes the fillet radii of crankpins and journals? ☐ Yes ☐ No					
If yes, state process:					
Crankshaft material specification:					
U.T.S. (N/mm ²)			Yield strength (N/mm ²)		
Hardness value (Brinell /Vickers)			Elongation (%)		
Dimensional Data					
If shrunk on webs, state shrinkage allowance (mm)			Yield strength of crank web material (N/mm ²)		
Centre of gravity of connecting rod from large end centre (mm)			Radius of gyration of connecting rod (mm)		
Mass of each crank web (kg)			Centre of gravity of web from journal axis (mm)		
Mass of each counterweight (kg)			Centre of gravity of each counterweight from journal axis (mm)		
Axial length of main bearing (mm)			Main bearing working clearance (mm)		
Mass of flywheel at driving end (kg)			Mass of flywheel at opposite end (kg)		
Nominal alternating torsional stress in crankpin (N/mm ²)			Nominal alternating torsional stress in crank journal (N/mm ²)		
Length between centers (Total length)(mm)					
3d.			Firing		order
State numbering system of cylinders from left to right as per above diagrams (as applicable)					
Number of cylinders		Clockwise firing order		Counter-clockwise firing order	
4. Engine Ancillary Systems					
4 a. Turbochargers		☐ Fitted		☐ Not Fitted	
Turbocharger oil supply by:		☐ Engine lube. oil system		☐ TC internal lube. oil system	
No. of cylinders	No. of aux blowers	No. of charge air coolers	No. of Turbo-chargers	TC manufacturer & type	TC type approval certificate No.

4 b. Speed governor				
Engine application (Main/Aux/Emergency)	Manufacturer / type	Mode of operation	Type approval cert. No. (if electric / electronic governor)	
4c. Over speed protection				
Independent over speed protection available ☐ Yes ☐ No				
Manufacturer / type, if electronic: Type approval certificate No.				
4 d. Electronic systems				
Engine control and management system <i>Note: use Remarks section to identify when a different engine control system will be used for Type Test</i>				
Hardware: Manufacturer & Model: / Software: Name & Version		Type approval certificate No. Software conformity certificate No.		
Additional electronic system 1: Manufacturer & type: /		System function: Type approval certificate No.		
Additional electronic system 2: Manufacturer & type: /		System function: Type approval certificate No.		
Additional electronic system 3: Manufacturer & type: /		System function: Type approval certificate No.		
4e. Starting System				
Type:				
4 f. Safety devices / functions				
A flame arrestor or a bursting disk is installed in the starting air system		Before each starting valve ☐ Yes ☐ No In the starting air manifold ☐ Yes ☐ No		
Crankcase relief valves available		☐ Yes ☐ No		
Manufacturer / type				
Type approval certificate No.				
No. of Cylinders	Total Crank-case gross volume including attachments (m3)	Type & size (mm) of relief valve	Relief area per relief valve (mm2)	No. of relief valves
Method used for detection of potentially explosive crankcase condition				
Oil mist detector: Manufacturer / type				
Type approval certificate No				
☐ Alternative method	☐ Crankcase pressure monitoring	☐ Bearing temperature monitoring		
☐ Oil splash temperature monitoring	☐ Recirculation arrangements	☐ other		
Cylinder overpressure warning device available ☐ Yes ☐ No				
Type:		Opening pressure (bar):		

4 g. Attached ancillary equipment <i>(Mark all that apply)</i>					
Engine driven pumps:					
☐ Main lubricating oil pump	☐ Sea cooling water pump	☐ LT-fresh cooling water pump	☐ HT-fresh cooling water pump		
☐ Fuel oil booster pump	☐ Hydraulic oil pump	☐ Other ()			
Engine attached motor driven pumps					
Lubricating oil pump		Cooling fresh water pump		Fuel oil booster pump	
Hydraulic oil pump		Other ()			
Engine attached cooler or heater					
☐ Lubricating oil cooler	☐ Lubricating oil cooler	☐ Fuel oil valve cooler			
☐ Hydraulic oil cooler	☐ Cooling fresh water cooler				
Engine attached filter:					
Lubricating oil filter	☐ Single	☐ Duplex	☐ Automatic		
Fuel oil filter	☐ Single	☐ Duplex	☐ Automatic		
5. Inclination limits					
<i>(Engine operation is safeguarded under the following limits)</i>		Athwart ships		Fore-and-aft	
		Static	Dynamic	Static	Dynamic
Main & Auxiliary machinery		15.0 °	22.5 °	5.0 °	7.5 °
Emergency machinery		22.5 °	22.5 °	10.0 °	10.0 °
Emergency machinery on ships for the carriage of liquefied gas and liquid chemicals		30.0 °	30.0 °		
6. Main engine emergency operation					
At failure of one auxiliary blower, engine can be started and operated at partial load			☐ Yes	☐ No	
At failure of one turbocharger, engine operation can be continued			☐ Yes	☐ No	
7. References: Additional Information Attached to Application					
Document Name/Number		Summary of information contained in document			
8 Additional Remarks:					

* All parties that affect the final complete engine (e.g. manufacture, modify, adjust) are to be listed. All sites where such work is carried out may be required to complete COP assessment.

† DA = Design Appraisal, TT = Type Test, COP = Assessment of Conformity of Production. Refer 1-1/A3, 4-2-1/A1 and 4-2-1/13.7.

‡ Only in case of TA Extension.

§ Refer 'Definitions' at the end of this application form for more information

Completed By:

Signature:

Company:

Job Title:

Stamp

Date

Complete Engine includes the control system and all ancillary systems and equipment referred to in the Rules that are used for safe operation of the engine and for which there are rule requirements, this includes systems allowing the use of different fuel types. The exact list of components/items that will need to be tested in together with the bare engine will depend on the specific design of the engine, its control system and the fuel(s) used but may include, but are not limited to, the following:

- i) Turbocharger(s)
- ii) Crankcase explosion relief devices
- iii) Oil mist detection and alarm devices
- iv) Piping
- v) Electronic monitoring and control system(s) – software and hardware
- vi) Fuel management system (where dual fuel arrangements are fitted)
- vii) Engine driven pumps
- viii) Engine mounted filters

Fuel Types: All fuels that the engine is designed to operate with are to be identified on the application form as this may have impact on the requirements that are applicable for Design Appraisal and the scope of the tests required for Type Testing. Where the engine is to operate in a Dual Fuel mode, the combinations of fuel types are to be detailed. E.g. Natural Gas + DMA, Natural Gas + Marine Residual Fuel, the specific details of each fuel are to be provided as indicated in the relevant rows of the Fuel pes part of section 3a of this form.

ANNEX 1- 2– Tabular Listing of Licensor’s and Licensee’s Drawing and Data

Licensee: _____

Licensor: _____

Licensee Engine No. _____

Engine type: _____

No	Component s or System	Licensor			Licensee		Has Design been modified by Licensee?		If Yes, indicate following information	
		Dwg. No. & Title	Rev. No	Date of Class Approv al or Review	Dwg. No.	Rev. No.	Yes	No	Identification of Alternative approved by Licensor	Date of Class Approval or Review of Licensee Drawing
1										
2										
3										
4										
5										
6										
7										
8										

I attest the above information to be correct and accurate

Person in Charge

(Licensee)

:

Name;

Signature:

Date:

Engine Licensee Proposed Alternative to Licensors Design			
Licensee information			
Licensee:		Ref No.:	
Description:		Info No.:	
Engine type:		Main Section:	
Engine No.:		Plant Id.:	
Design Spec: General Specific Nos:			
Licensee design:	State relevant part or drawing numbers. Insert drawing clips or pictures. Add any relevant information		Licensee Proposed Alternative
		For example: • Differences in geometry • Differences in the functionality • Material • Hardness • Surface condition • Alternative standard • Licensee production information introduced on the drawing • Weldings or castings	
Reason ☐ Licensee's production ☐ Sub-supplier's ☐ production Cost down ☐ Tools	Interchangeability with licensors design Yes ☐ No ☐	Non-conformity Report Research, Assessment, Evaluation ☐ CR ☐ AE	Certified by licensor: Initials: Date:
Licensor comments			
LoAE: ☐ Accepted as alternative execution (Licensor undertakes responsibility) ☐ No objection Not acceptable (Licensee undertakes responsibility)		NCR: ☐ Approved ☐ Conditionally approved ☐ Rejected	Certified by licensor: Initials: Date:
Licensor ref.:		Date:	
Licensee ref.:		Date:	

