UNIVERSITÀ
DEGLI STUDI DI TRIESTE

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Progetto di impianti di propulsione navale

2.2 REGOLAMENTI DI CLASSE

Anno Accademico 2017/2018

Impianti di propulsione navale

Turbine a vapore - Parte C – Capitolo 1 – Sezione 4

Le prescrizioni di questa Sezione si applicano a :

- ❑ **tutte le turbine di propulsione,**

- ❑ **le turbine destinate a servizi ausiliari essenziali per la navigazione e la sicurezza, o per l'azionamento delle pompe carico nelle navi cisterna.**

Vengono elencate le prescrizioni in materia di :

- ❖ **Documentazione di progetto sottoposta ad approvazione**
- ❖ **Progetto e costruzione :**
  - ○ **Materiali**
  - ○ **Progetto e dettagli costruttivi :**
    - ▪ **Rotore e statore**
    - ▪ **Cuscinetti**
    - ▪ **Viratore**
    - ▪ **Potenza in marcia addietro (almeno 70% dei giri in MAV per 15 minuti)**

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- **Monitoraggio e controllo :**
  - **Regolatore di governo (necessario per turbine che azionano eliche a pale orientabili, giunti disaccoppiabili o dispositivi di trasmissione elettrici)**
  - **Dispositivo di protezione che intervenga quando la velocità supera di più del 15% la velocità di progetto ("overspeed")**
  - **Dispositivo di arresto per eccessivo spostamento assiale del rotore**
  - **Dispositivo di arresto per mancanza olio lubrificazione ai cuscinetti**
  - **Tavole con i requisiti minimi di monitoraggio e controllo**

- **Sistemazione e installazione :**
  - **Fondazioni**
  - **Giunzioni di superfici accoppiate**
  - **Installazione delle tubazioni (sollecitazioni ad alta temperatura)**

- **Test, ispezioni, certificati**

Impianti di propulsione navale

Turbine a vapore di propulsione - Monitoraggio e controllo

Table 3 : Main propulsion turbine

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Turbine			Auxiliary	
Identification of system parameter	Alarm	Indica-tion	Slow-down	Shut-down	Control	Stand by Start	Stop
• Main turbine speed		local					
	H			X			
					X		
• Main turbine axial displacement	X	local		X			
• Main turbine vibration	H	local					
Lubricating oil							
• Supply pressure		local					
	L			X (2)			
• Level of gravity tank	L (1)	local					
(1) Sensor to be located near the normal level (2) This is not to prevent astern operation for braking							

Data: 15/01/2007

Impianti di propulsione navale

Turbine a gas - Parte C – Capitolo 1 – Sezione 5

Le prescrizioni di questa Sezione si applicano a :

- ❑ **tutte le turbine di propulsione,**
- ❑ **le turbine destinate a servizi ausiliari essenziali per la navigazione e la sicurezza**

Vengono elencate le prescrizioni in materia di :

- ❖ **Documentazione di progetto sottoposta ad approvazione**
- ❖ **Progetto e costruzione :**
  - ○ **Materiali**
  - ○ **Progetto e dettagli costruttivi**
  - ○ **Costruzione saldata**
  - ○ **Monitoraggio e controllo :**
    - ▪ **Tavole con requisiti minimi di monitoraggio e controllo**
- ❖ **Sistemazione e installazione**
- ❖ **Test, ispezioni, certificati**

Data: 15/01/2007

Impianti di propulsione navale

Turbine a gas di propulsione e ausiliarie - Monitoraggio e controllo

Table 2 : Main propulsion and auxiliary turbines

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Turbine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
• Control system failure	X						
• Automatic starting failure	X						
Mechanical monitoring of gas turbine							
• Speed		local					
					X		
	H			X			
• Rotor axial displacement (Not applicable to roller bearing)		local					
	H			X			
• Vibration	H	local					
• Performed number of cycle of rotating part	H						
Gas generator monitoring							
• Flame and ignition failure	X			X			
• Fuel oil supply pressure	L	local					
• Fuel oil supply temperature	H	local					
• Cooling medium temperature	H	local					
• Exhaust gas temperature or gas temperature in specific locations of flow gas path. (Alarm before shut-down)		local					
	H			X			
• Pressure at compressor inlet (alarm before shut-down)		local					
	L			X			
Lubricating oil							
• Turbine supply pressure		local					
	L			X			
• Differential pressure across lubricating oil filter	H	local					
• Bearing or lubricating oil (discharge) temperature	H	local					

Turbosoffianti per sovralimentazione motori diesel

Parte C – Capitolo 1 – Sezione 14

Le prescrizioni di questa Sezione si applicano alle turbosoffianti di motori diesel di potenza superiore a 1000 kW delle seguenti categorie :

a) motori principali di propulsione

b) motori che azionano generatori elettrici ed altri ausiliari necessari per la sicurezza e la navigazione e pompe carico nelle navi cisterna

Impianti di propulsione navale

Riduttori di giri - Parte C – Capitolo 1 – Sezione 6

Le prescrizioni di questa Sezione si applicano a :

- ❑ **Riduttori di giri e/o invertitori per impianti propulsivi con potenza trasmessa di 220 kW e superiore**

- ❑ **Altri riduttori e moltiplicatori di giri con potenza trasmessa di 110 kW e superiore per macchinari ausiliari dedicati a servizi essenziali**

Vengono elencate le prescrizioni in materia di :

- ❖ **Documentazione di progetto sottoposta ad approvazione**
- ❖ **Calcolo della capacità di carico della dentatura :**
  - o **Simbologia**
  - o **Principi di calcolo :**
    - ▪ **Resistenza delle superfici dei denti alla pressione di contatto**
    - ▪ **Resistenza della radice dei denti a flessione / taglio**

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- **Fattori correttivi di calcolo :**
  - **Sovraccarichi esterni al riduttore / moltiplicatore**
  - **Ripartizione disuniforme dei carichi in caso di più percorsi**
  - **Sovraccarichi dinamici interni alla dentatura (vibrazioni)**
  - **Distribuzione non uniforme dei carichi sulla faccia del dente**
  - **Effetti degli errori del passo e del profilo sulla distribuzione del carico fra denti in presa**

- **Progetto e costruzione :**
  - **Materiali**
  - **Esecuzione dentatura**
  - **Ruote e pignoni**
  - **Alberi e cuscinetti**
  - **Cassa**
  - **Lubrificazione e controllo delle frizioni**
  - **Monitoraggio e controllo**

- **Installazione**
- **Test, ispezioni, certificati**

Impianti di propulsione navale

Linee d'alberi - Parte C – Capitolo 1 – Sezione 7

Le prescrizioni di questa Sezione si applicano ad alberi, giunti di accoppiamento, frizioni e altri componenti della linea d'alberi che trasmettono la potenza per la propulsione principale.

Vengono elencate le prescrizioni in materia di :

- **Documentazione di progetto sottoposta ad approvazione**
- **Progetto e costruzione**
  - **Materiali**
  - **Dimensionamenti alberi:**
    - **Diametro albero intermedio**
    - **Diametro albero portaelica**
  - **Camicie**
  - **Boccole astuccio poppiero, a seconda del tipo di lubrificazione (boccola con metallo bianco lubrificata ad olio, boccola in materiale sintetico lubrificata ad acqua di mare)**

Impianti di propulsione navale

- **Giunti di accoppiamento flangiati o a manicotto, giunti elastici, accoppiamenti a chiavetta**

- **Monitoraggio e controllo**

❖ **Sistemazione e installazione**

- **Allineamento**

The alignment of the propulsion machinery and shafting and the spacing and location of the bearings are to be such as to ensure that the loads are compatible with the material used and the limits prescribed by the Manufacturer.
The calculation is to take into account thermal, static and dynamic effects; the results are to include the reaction forces of bearings, bending moments, shear stresses and other parameters (such as gap and sag of each flanged coupling or jacking loads) and instructions for the alignment procedure.

❖ **Test, ispezioni, certificati**

2.2.2 Intermediate and thrust shafts *(1/7/2006)*

The minimum diameter of intermediate and thrust shafts is not to be less than the value d, in mm, given by the following formula:

$$d = F \cdot k \cdot \left[\frac{P}{n \cdot (1 - Q^4)} \cdot \frac{560}{R_m + 160} \right]^{1/3}$$

Q : • in the case of solid shafts: Q = 0

• in the case of hollow shafts: Q = ratio of the hole diameter to the outer shaft diameter in the section concerned.

where Q <= 0,4, Q = 0 is to be taken.

Hollow shafts whose longitudinal axis does not coincide with the longitudinal hole axis will be specially considered by the Society in each case.

F : • 95 for main propulsion systems powered by diesel engines fitted with slip type coupling,by turbines or by electric motors;

• 100 for main propulsion systems powered by diesel engines fitted with other type of couplings.

k : Factor whose value is given in Tab 2 depending upon the different design features of the shafts.

Impianti di propulsione navale

Table 2 : Values of factor k *(1/7/2006)*

For intermediate shafts with					For thrust shafts external to engines	
integral coupling flange and straight sections	shrink fit coupling	keyways, tapered or cylindrical connection	radial hole	longitudinal slot	on both sides of thrust collar	in way of axial bearing, where a roller bearing is used as a thrust bearing
1,00 (1)	1,00 (2)	1,10 (3) (4)	1,10 (5)	1,20 (6)	1,10 (1)	1,10

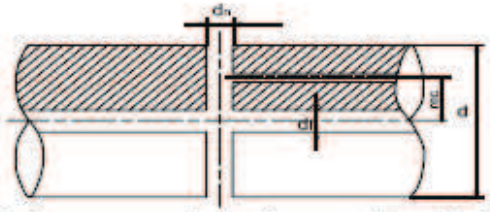
(1) Value applicable in the case of fillet radii in accordance with the provisions of [2.5.1].

(2) k refers to the plain shaft section only. Where shafts may experience vibratory stresses close to the permissible stresses for continuous operation, an increase in diameter to the shrink fit diameter is to be provided, e.g. a diameter increase of 1 to 2 % and a blending radius as described in [2.2.1].

(3) Keyways are, in general, not to be used in installations with a barred speed range.

(4) At a distance of not less than 0,2 d from the end of the keyway, the shaft diameter may be reduced to the diameter calculated using k = 1,0. Fillet radii in the transverse section of the bottom of the keyway are to be not less than 0,0125 d, d being the diameter as calculated above using k = 1,0.

(5) Value applicable in the case of diameter of radial bore d_h not exceeding 0,3 d, d being as defined in (4).
Cases foreseeing intersection between a radial and an eccentric (r_{ec}) axial bore (see figure below) are specially considered by the Society.



(6) Subject to limitations: slot length (l)/outside diameter < 0,8, inner diameter (d_i)/outside diameter < 0,8 and slot width (e)/outside diameter > 0,10. The end rounding of the slot is not to be less than e/2. An edge rounding is preferably to be avoided as this increases the stress concentration slightly. The k values are valid for 1, 2 and 3 slots, i.e. with slots at, respectively, 360, 180 and 120 degrees apart.

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2.2.2 Intermediate and thrust shafts *(1/7/2006)*

For shaft design features other than those given in the Table, the value of k will be specially considered by the Society in each case.

n : Speed of rotation of the shaft, in r.p.m., corresponding to power P

P : Maximum continuous power of the propulsion machinery for which the classification is requested, in kW.

Rm : Value of the minimum tensile strength of the shaft material, in N/mm2.
Whenever the use of a steel having Rm in excess of 800 N/mm2 is allowed in accordance with [2.1], the value of Rm to be introduced in the above formula is not to exceed the following:

• for carbon and carbon manganese steels, a minimum specified tensile strength not exceeding 760 N/mm2

• for alloy steels, a minimum specified tensile strength not exceeding 800 N/mm2.

2.2.3 Propeller shafts *(1/7/2006)*

For propeller shafts in general a minimum specified tensile strength Rm to be introduced in the following formula not exceeding 600 N/mm2 is to be taken for carbon, carbon manganese and alloy steel.

Where materials with greater specified or actual tensile strengths than the limitations given above are used, reduced shaft dimensions are not acceptable when derived from the formula in this item [2.2.3].

The minimum diameter of the propeller shaft is not to be less than the value dP, in mm, given by the following formula:

$$d_P = 100 \cdot k_P \cdot \left[\frac{P}{n \cdot (1 - Q^4)} \cdot \frac{560}{R_m + 160} \right]^{1/3}$$

where:

kp : Factor whose value, depending on the different constructional features of shafts, is given below.
The other symbols have the same meaning as in [2.2.2].
In cases of stainless steels and in other particular cases, at the discretion of the Society, the value of Rm to be introduced in the above formula will be specially considered.

2.2.3 Propeller shafts *(1/7/2006)*

In general, the diameter of the part of the propeller shaft located forward of the forward sterntube seal may be gradually reduced to the diameter of the intermediate shaft.

The values of factor kp to be introduced in the above formula are to be taken as follows:

kp = 1,26, for propeller shafts where:

• the propeller is keyed on to the shaft taper in compliance with the requirements of [2.5.5]

kp = 1,22, for propeller shafts where:

• the propeller is keyless fitted on to the shaft taper by a shrinkage method in compliance with Sec 8, [3.1.2], or the propeller boss is attached to an integral propeller shaft flange in compliance with [2.5.1]

• the sterntube of the propeller shaft is oil lubricated and provided with oil sealing glands approved by the Society or when the sterntube is water lubricated and the propeller shaft is fitted with a continuous liner.

The above values of kp apply to the portion of propeller shaft between the forward edge of the aftermost shaft bearing and the forward face of the propeller boss or the forward face of the integral propeller shaft flange for the connection to the propeller boss.

In no case is the length of this portion of propeller shaft to be less than 2,5 times the rule diameter dp obtained with the above formula.

2.2.3 Propeller shafts *(1/7/2006)*

The determination of factor kp for shaft design features other than those given above will be specially considered by the Society in each case.

For the length of the propeller shaft between the forward edge of the aftermost shaft bearing and the forward edge of the forward sterntube seal:

- kP = 1,15 is to be taken in any event.

Impianti di propulsione navale

Vibrazioni delle linee d'alberi
Parte C – Capitolo 1 – Sezione 9

Le prescrizioni di questa Sezione si applicano agli alberi delle seguenti installazioni :

- ❑ **Sistemi di propulsione in cui i motori primi sviluppano una potenza di 220 kW e superiore**

- ❑ **Altri sistemi in cui i motori a combustione interna sviluppano una potenza di 110 kW e superiore e muovono macchinari ausiliari dedicati a servizi essenziali**

Vengono elencate le prescrizioni in materia di :

- ❖ **Documentazione di progetto sottoposta ad approvazione**

Impianti di propulsione navale

❖ **Progetto dei sistemi in relazione alle vibrazioni :**

a) Special consideration shall be given to the design, construction and installation of propulsion machinery systems so that any mode of their vibrations shall not cause undue stresses in these systems in the normal operating ranges.

b) Calculations are to be carried out for all the configurations of the system likely to have any influence on the torsional, bending or axial vibrations.

c) Where torsional and axial vibrations may be coupled (e.g. due to helical gears), the effect of such vibrations is to be investigated.

❖ Vibrazioni torsionali

The torsional vibration torques (or stresses) calculated in the various components of the installation are additional to those resulting from the mean power transmitted by such components.

Torsional vibration calculations are to be carried out using a recognised method.

Torsional vibration calculations are to be carried out considering:

- normal firing of all cylinders, and
- misfiring of one cylinder.

For installations with controllable pitch propellers, two calculations are to be carried out:

- one for full pitch condition
- one for zero pitch condition.

Impianti di propulsione navale

Torsional vibration stresses in the various shafts are not to exceed the limits defined in [3.5]. Higher limits calculated by an alternative method may be considered, subject to special examination by the Society.

The limit for continuous running τ_1 may be exceeded only in the case of transient running in restricted speed ranges, which are defined in [3.5.5].
In no case are the torsional vibration stresses to exceed the limit for transient running τ_2.

Impianti di propulsione navale

Vibrazioni torsionali

Sollecitazioni alterne ammissibili sull' albero portaelica

Pt C - Ch 1 - Sec 9

d =	500	mm	Diametro dell' albero
Rm =	400	N/mm2	Carico di rottura del materiale (400<=Rm<=600)
CR =	31.11		Fattore dipendente dal carico di rottura del materiale
Ck =	0.55		Fattore dipendente dai particolari costruttivi dell' albero
Cd =	0.618		Fattore di dimensione dell'albero

λ = rapporto giri effettivi / giri nominali

τ = sollecitazione tangenziale ammissibile

λ	Cλ	τ 1 (N/mm2)	τ 2 (N/mm2)
0.10	2.98	31.5	72.3
0.20	2.92	30.9	70.8
0.30	2.82	29.8	68.4
0.40	2.68	28.4	65.0
0.50	2.50	26.5	60.6
0.60	2.28	24.1	55.3
0.70	2.02	21.4	49.0
0.80	1.72	18.2	41.7
0.90	1.38	14.6	33.5
1.00	1.38	14.6	33.5

- $\tau_1 = 0{,}55 \cdot C_R \cdot C_D \cdot C_\lambda$ for continuous running
- $\tau_2 = 2{,}3\ \tau_1$ for transient running.

τ : Torsional vibration stress, as defined in [3.3.1], in N/mm^2

τ_1 : Permissible stress due to torsional vibrations for continuous operation, in N/mm^2

τ_2 : Permissible stress due to torsional vibrations for transient running, in N/mm^2

R_m : Tensile strength of the shaft material, in N/mm^2

C_R : Material factor, equal to:

$$\frac{R + 160}{18}$$

d : Minimum diameter of the shaft, in mm

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- **Vibrazioni laterali del sistema propulsivo principale**

- **Vibrazioni assiali del sistema propulsivo principale**

Main propulsion systems are to be free from excessive lateral / axial vibrations throughout the working speed range.
Failing this, provision is to be made to limit the vibration amplitudes by modifying the dynamic system, or restricted speed ranges are to be imposed in the corresponding regions of speeds.

❖ **Verifiche in prova. Metodi di misura delle vibrazioni a bordo**

3.7 Torsional vibration measurements

3.7.1 General

a) The Society may require torsional vibration measurements to be carried out under its supervision in the following cases:

- where the calculations indicate the possibility of dangerous critical speeds in the operating speed range,
- where doubts arise as to the actual stress amplitudes or critical speed location, or
- where restricted speed ranges need to be verified.

b) Where measurements are required, a comprehensive report including the analysis of the results is to be submitted to the Society.

Impianti di propulsione navale

Eliche - Parte C – Capitolo 1 – Sezione 8

Le prescrizioni di questa Sezione si applicano ad eliche di qualsiasi grandezza e tipo intese per la propulsione

Vengono elencate le prescrizioni in materia di :

- **Generalità e definizioni (elica di pezzo, elica composta, elica a pale orientabili, mantello per elica, elica intubata, elica ad alto skew, grandezze geometriche dell'elica)**
  - **Documentazione di progetto sottoposta ad approvazione**
- **Progetto e costruzione :**
  - **Materiali**

    Common bronze, special types of bronze and cast steel used for the construction of propeller hubs and blades are to have a minimum tensile strength of 400 N/mm2.

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- **Sistemazione e installazione :**
  - **Calcolo del montaggio a forzamento dell'elica a pale fisse**
- **Test, ispezioni e certificazioni :**
  - **Ispezione dell'elica finita (test dei liquidi penetranti)**
  - **Prova idraulica del circuito idraulico di comando dell'elica a pale orientabili**
  - **Bilanciamento statico dell'elica**

Timone - Parte C – Capitolo 1 – Sezione 11

Prestazioni della timoneria (vedi anche SOLAS Chapter II-1 - Part C - Regulation 29)

3.3.1 Main steering gear

The main steering gear and rudder stock shall be:

a) of adequate strength and capable of steering the ship at maximum ahead service speed which shall be demonstrated,

b) capable of putting the rudder over from 35° on one side to 35° on the other side with the ship at its deepest seagoing draught and running ahead at maximum ahead service speed and, under the same conditions, from 35° on either side to 30° on the other side in not more than 28s.

Controllo della timoneria

3.4.1 Main and auxiliary steering gear control

Steering gear control shall be provided:

a) for the main steering gear, both on the navigation bridge and in the steering gear compartment,

b) where the main steering gear is arranged in accordance with [3.5.2], by two independent control systems, both operable from the navigation bridge and the steering gear compartment.

3.4.2 Control systems operable from the navigating bridge

Any main and auxiliary steering gear control system operable from the navigating bridge shall comply with the following:

- *if electrical, it shall be served by its own separate circuit supplied from a steering gear power circuit from a point within the steering gear compartment,*

3.5.2 Omission of the auxiliary steering gear

Where the main steering gear comprises two or more identical power units, auxiliary steering gear need not be fitted, provided that:

a)in a passenger ship, the main steering gear is capable of operating the rudder as required by paragraph [3.3.1] *while any one of the power units is out of operation,*

b)in a cargo ship, the main steering gear is capable of operating the rudder as required by paragraph [3.3.1] *while operating with all power units,*

c)the main steering gear is so arranged that after a single failure in its piping system or in one of the power units, the defect can be isolated so that steering capability can be maintained or speedily regained.

3.5.5 Hydraulic locking

Where the steering gear is so arranged that more than one system (either power or control) can be simultaneously operated, the risk of hydraulic locking caused by single failure is to be considered.

Prove mare della timoneria (Parte C – Capitolo 1 – Sezione 15)

3.11.2 Tests to be performed

Tests of the steering gear are to include at least:

a) functional test of the main and auxiliary steering gear with demonstration of the performances required by Sec 11, [3.4] and Sec 11, [4.4]
b) test of the steering gear power units, including transfer between steering gear power units
c) test of the isolation of one power actuating system, checking the time for regaining steering capability
d) test of the hydraulic fluid refilling system
e) test of the alternative power supply required by Sec 11, [2.3.2], item e)
f) test of the steering gear controls, including transfer of controls and local control
g) test of the means of communication between the navigation bridge, the engine room and the steering gear compartment
h) test of the alarms and indicators
i) where the steering gear design is required to take into account the risk of hydraulic locking, a test is to be performed to demonstrate the efficiency of the devices intended to detect this.

Impianti di propulsione navale

Thrusters - Parte C – Capitolo 1 – Sezione 12

Prescrizioni riguardanti :

- ❑ **thrusters trasversali per la manovra**
- ❑ **thrusters per propulsione, governo e posizionamento dinamico**

Definizioni :

1.2.1 Transverse thruster
A transverse thruster is an athwartship thruster developing a thrust in a transverse direction for manoeuvring purposes.

1.2.2 Azimuth thruster
An azimuth thruster is a thruster which has the capability to develop thrust in any direction through 360°.

Thrusters - Parte C – Capitolo 1 – Sezione 12

1.2.3 Water-jet

A water-jet is equipment constituted by a tubular casing (or duct) enclosing an impeller. The shape of the casing is such as to enable the impeller to produce a water-jet of such intensity as to give a positive thrust.

Water-jets may have means for deviating the jet of water in order to provide a steering function.

Viene fatta una distinzione fra thrusters per servizio continuo (propulsione) e thrusters per servizio intermittente (thrusters trasversali) in cui la potenza massima è sviluppata per non più di un'ora.

Per i thrusters propulsivi vale la prescrizione :

1.3.1 In general, at least two azimuth thrusters are to be fitted in ships where these are the sole means of propulsion.

Impianti di propulsione navale

Caldaie e recipienti in pressione - Parte C – Capitolo 1 – Sezione 3

Scopi del regolamento :

- **Caldaie e recipienti in pressione di costruzione adeguata al servizio, installati e protetti in modo da minimizzare i rischi per le persone;**

- **Continuità del servizio quando i componenti in oggetto siano parte essenziale del sistema di propulsione;**

- **Devono essere previsti mezzi per il mantenimento e il ripristino del servizio delle caldaie principali, anche quando i loro ausiliari essenziali diventano inoperativi (speciale attenzione per sistemi acqua alimento, nafta e aria combustione). Può essere accettata una riduzione di prestazioni del sistema propulsivo (vedi SOLAS)**

- **Prova a pressione dei componenti prima della loro immissione in servizio;**

- **Devono essere previsti mezzi atti ad evitare sovrappressioni pericolose**

Impianti di propulsione navale

Caldaie e recipienti in pressioni coperti dal regolamento :

- **Tutte le caldaie e i generatori di vapore, inclusi accessori;**

- **Recipienti in pressione di costruzione metallica e scambiatori di calore, inclusi accessori;**

- **Non sono coperte dal regolamento le caldaie con pressione p > 10 MPa (100 bar - da considerare caso per caso), recipienti in pressione per materiali radioattivi e piccoli recipienti in pressione contenuti in equipaggiamenti di tipo domestico.**

Definizioni :

- **Recipiente in pressione**

  Pressure vessel is a welded or seamless container used for the containment of fluids at a pressure above or below the ambient pressure and at any temperature. Fluid power cylinders in hydraulic or pneumatic plants are also considered pressure vessels.

Impianti di propulsione navale

- **Recipiente in pressione a fiamma :**

  Fired pressure vessel is a pressure vessel which is completely or partially exposed to fire from burners or combustion gases.

- **Caldaia :**

  a) Boiler is one or more fired pressure vessels and associated piping systems used for generating steam or hot water at a temperature above 120°C by means of heat resulting from combustion of fuel or from combustion gases.

  b) Any equipment directly connected to the boiler, such as economisers, superheaters, and safety valves, is considered as part of the boiler, if it is not separated from the steam generator by means of any isolating valve. Piping connected to the boiler is considered part of the boiler upstream of the isolating valve and part of the associated piping system downstream of the isolating valve.

Impianti di propulsione navale

- **Generatore di vapore :**

  Steam generator is a heat exchanger and associated piping used for generating steam. In general, in these Rules, the requirements for boilers are also applicable for steam generators, unless otherwise indicated.

- **Scambiatore di calore :**

  Heat exchanger is a pressure vessel used to heat or cool a fluid with another fluid. In general heat exchangers are composed of a number of adjacent chambers, the two fluids flowing separately in adjacent chambers. One or more chambers may consist of bundles of tubes.

- **Surriscaldatori, economizzatori, risurriscaldatori, desurriscaldatori : sono scambiatori di calore associati ad una caldaia**

- **Inceneritore : dispositivo di bordo atto a bruciare rifiuti solidi di composizione simile ai rifiuti domestici e rifiuti liquidi derivanti dalle operazioni di bordo (residui oleosi, morchie, ecc.)**

❑Pressione di progetto (design pressure) :

The design pressure is the pressure used by the manufacturer to determine the scantlings of the vessel.
This pressure cannot be taken less than the maximum working pressure and is to be limited by the set pressure of the safety valve, as prescribed by the applicable Rules.

❑Temperatura di progetto (design temperature) :

a)Design temperature is the actual metal temperature of the applicable part under the expected operating conditions, as modified in Tab 1. This temperature is to be stated by the manufacturer and is to take account of the effect of any temperature fluctuations which may occur during the service.

b)The design temperature is to be not less than the temperatures stated in Tab 1, unless specially agreed between the manufacturer and the Society on a case by case basis.
For boilers the design temperature is to be not less than 250 °C.

Impianti di propulsione navale

Table 1 : Minimum design temperature

TYPE OF VESSEL	MINIMUM DESIGN TEMPERATURE
Pressure parts of pressure vessels and boilers not heated by hot gases or adequately protected by insulation	Maximum temperature of the internal fluid
Pressure vessel heated by hot gases	25°C in excess of the temperature of the internal fluid
Water tubes of boilers mainly subjected to convection heat	25°C in excess of the temperature of the saturated steam
Water tubes of boilers mainly subjected to radiant heat	50°C in excess of the temperature of the saturated steam
Superheater tubes of boilers mainly subjected to convection heat	35°C in excess of the temperature of the saturated steam
Superheater tubes of boilers mainly subjected to radiant heat	50°C in excess of the temperature of the saturated steam
Economiser tubes	35°C in excess of the temperature of the internal fluid
For combustion chambers of the type used in wet-back boilers	50°C in excess of the temperature of the internal fluid
For furnaces, fire-boxes, rear tube plates of dry-back boilers and other pressure parts subjected to similar rate of heat transfer	90°C in excess of the temperature of the internal fluid

Classi delle caldaie e dei recipienti in pressione :

Boilers and pressure vessels are classed as indicated in Tab 2 in consideration of their service, characteristics and scantlings. The symbols used in the table have the following meanings:

p : Design pressure, in MPa
T : Design temperature, in °C
D : Inside diameter of the vessel, in mm
t_A : Actual thickness of the vessel, in mm

Impianti di propulsione navale

Table 2 : Pressure vessels classification

Equipment	class 1	class 2	class 3
Boilers	$p > 0{,}35$ MPa	$p \leq 0{,}35$ MPa	-
Steam heated generators or steam generators heated by another fluid	$p > 1{,}15$ MPa, or $p.D > 1500$	All steam generators which are not class 1	-
Pressure vessels and heat exchangers	$p > 4$ MPa, or $t_A > 40$ mm, or $T > 350$°C	$1{,}75 < p \leq 4$ MPa, or $15 < t_A \leq 40$ mm, or $150 < T \leq 350$°C, or $p.t_A > 15$	All pressure vessels and heat exchangers which are not class 1 or 2
Pressure vessels for toxic substances	All	-	-
Pressure vessels for corrosive substances	$p > 4$ MPa, or $t_A > 40$ mm, or $T > 350$°C	All pressure vessels which are not class 1	-
Note 1: Whenever the class is defined by more than one characteristic, the equipment is to be considered belonging to the highest class of its characteristics, independently of the values of the other characteristics.			

Accessi :
Boilers are to be provided with openings in sufficient number and size to permit internal examination, cleaning and maintenance operations.

Boiler burners
Burners are to be arranged so that they cannot be withdrawn unless the fuel supply to the burners is cut off.

Feed check valves
Each fired boiler supplying steam to essential services is to be fitted with at least two feed check valves connected to two separate feed lines. For unfired steam generators a single feed check valve may be allowed

Water sample
Every boiler shall be provided with means to supervise and control the quality of the feed water. Suitable arrangements shall be provided to preclude, as far as practicable, the entry of oil or other contaminants which may adversely affect the boiler.

Impianti di propulsione navale

Safety valve arrangement

Every steam boiler and every steam generator with a total heating surface of 50 m^2 and above is to be provided with not less than two spring loaded safety valves of adequate capacity.

Safety valve setting

Safety valves are to be set under steam in the presence of the Surveyor to a pressure not higher than 1,03 times the design pressure.

Local control and monitoring
Means to effectively operate, control and monitor the operation of oil fired boilers and their associated auxiliaries are to be provided locally. The functional condition of the fuel, feed water and steam systems and the boiler operational status are to be indicated by pressure gauges, temperature indicators, flow-meter, lights or other similar devices.

Emergency shut-off
Means are to be provided to shut down boiler forced draft or induced draft fans and fuel oil service pumps from outside the space where they are located, in the event that a fire in that space makes their local shut-off impossible.

Automatic shut-off of oil fired propulsion and auxiliary boilers
Each burner is to be fitted with a flame scanner designed to automatically shut off the fuel supply to the burner in the event of flame failure. In the case of failure of the flame scanner, the fuel to the burner is to be shut off automatically.

Hydrostatic tests

Testing pressure

Upon completion, pressure parts of boilers and pressure vessels are to be subjected to a hydraulic test under a pressure pt defined below as a function of the design pressure p:

- pt = 1,5 p where p <= 4 MPa
- pt = 1,4 p + 0,4 where 4 MPa < p <= 25 MPa
- pt = p + 10,4 where p > 25 MPa

Impianti di propulsione navale

Sistemi di tubazioni - Parte C – Capitolo 1 – Sezione 10

Le prescrizioni di questa Sezione si applicano in generale a tutti i sistemi di tubazioni con riguardo a :

- **progetto e costruzione**
- **saldatura dei tubi in acciaio**
- **piegatura dei tubi**
- **sistemazione e installazione**
- **certificati, ispezioni e test**

Definizioni :

Tubazioni e sistemi di tubazioni

a) Piping includes pipes and their connections, flexible hoses and expansion joints, valves and their actuating systems, other accessories (filters, level gauges, etc.) and pump casings.

b) Piping systems include piping and all the interfacing equipment such as tanks, pressure vessels, heat exchangers, pumps and centrifugal purifiers, but do not include boilers, turbines, internal combustion engines and reduction gears.

Data: 15/01/2007

Impianti di propulsione navale

Definizioni :

Pressione di progetto

- The design pressure of a piping system is the pressure considered by the manufacturer to determine the scantling of the system components. It is not to be taken less than the maximum working pressure expected in this system or the highest setting pressure of any safety valve or relief device, whichever is the greater.

- The design pressure of a boiler feed system is not to be less than 1,25 times the design pressure of the boiler or the maximum pressure expected in the feed piping, whichever is the greater.

- The design pressure of steam piping located upstream of pressure reducing valves (high pressure side) is not to be less than the setting pressure of the boiler or superheater safety valves.

Impianti di propulsione navale

Definizioni :

Pressione di progetto

- The design pressure of a piping system located on the low pressure side of a pressure reducing valve where no safety valve is provided is not to be less than the maximum pressure on the high pressure side of the pressure reducing valve.

- The design pressure of a piping system located on the delivery side of a pump or a compressor is not to be less than the setting pressure of the safety valve for displacement pumps or the maximum pressure resulting from the operating (head-capacity) curve for centrifugal pumps, whichever is the greater.

Temperatura di progetto

- The design temperature of a piping system is the maximum temperature of the medium inside the system.

Impianti di propulsione navale

Definizioni :

Classe della tubazione

Piping systems are subdivided into three classes, denoted as class I, class II and class III, for the purpose of acceptance of materials, selection of joints, heat treatment, welding, pressure testing and the certification of fittings.

Vedi tabella 3 alla pagina seguente

Materiale della tubazione :

I materiali metallici devono essere impiegati secondo quanto indicato nella tabella 4

Impianti di propulsione navale

Table 3 : Class of piping systems *(1/7/2002)*

Media conveyed by the piping system	CLASS I	CLASS II	CLASS III
Fuel oil (1)	p > 1,6 or T > 150	other (2)	p ≤ 0,7 and T ≤ 60
Thermal oil	p > 1,6 or T > 300	other (2)	p ≤ 0,7 and T ≤ 150
Flammable Hydraulic oil (5)	p>1,6 or T>150	other (2)	p ≤ 0,7 and T≤60
Lubricating oil	p> 1,6 or T > 150	other (2)	p ≤ 0,7 and T ≤ 60
Other flammable media: • heated above flashpoint, or • having flashpoint <60°C and liquefied gas	without special safeguards (3)	with special safeguards (3)	
Oxyacetylene	irrespective of p		
Toxic media	irrespective of p, T		
Corrosive media	without special safeguards (3)	with special safeguards (3)	
Steam	p > 1,6 or T > 300	other (2)	p ≤ 0,7 and T ≤ 170
Air, gases, water, non-flammable hydraulic oil (4)	p > 4 or T > 300	other (2)	p ≤ 1,6 and T ≤ 200
Open-ended pipes (drains, overflows, vents, exhaust gas lines, boiler escape pipes)			irrespective of T

(1) Valves under static pressure on fuel oil tanks belong to class II.
(2) Pressure and temperature conditions other than those required for class I and class III.
(3) Safeguards for reducing the possibility of leakage and limiting its consequences, e.g. pipes led in positions where leakage of internal fluids will not cause a potential hazard or damage to surrounding areas which may include the use of pipe ducts, shielding, screening, etc.
(4) Valves and fittings fitted on the ship side and collision bulkhead belong to class II.
(5) Steering gear piping belongs to class I irrespective of p and T

Note 1: p : Design pressure, as defined in [1.3.2], in MPa.
Note 2: T : Design temperature, as defined in [1.3.3], in °C.

Data: 15/01/2007

Impianti di propulsione navale

Table 4 : Conditions of use of metallic materials in piping systems *(1/7/2003)*

Material	Allowable classes	Maximum design temperature (°C) (1)	Particular conditions of use
Carbon and carbon-manganese steels	III, II, I	400 (2)	Class I and II pipes are to be seamless drawn pipes (3)
Copper and aluminium brass	III, II, I	200	• Not to be used in fuel oil systems, except for class III pipes of a diameter not exceeding 25 mm not passing through fuel oil tanks • Not to be used for boiler blow-down valves and pieces for connection to the shell plating (4)
Copper-nickel	III, II, I	300	
Special high temperature resistant bronze	III, II, I	260	
Stainless steel	III, II, I	300	Austenitic stainless steel is not recommended for sea water systems
Spheroidal graphite cast iron	III, II	350	• Spheroidal cast iron of the ferritic type according to the material rules of the Society may be accepted for bilge, ballast and cargo oil piping • The use of this material for pipes, valves and fittings for other services, in principle Classes II and III, will be subject to special consideration • Spheroidal cast iron pipes and valves fitted on ship's side should have specified properties to the Society's satisfaction, according to the intention of Regulation 22 of the 1966 Convention on Load Lines • Minimum elongation is not to be less than 12% on a gauge length of $5{,}65.S^{0.5}$, where S is the actual cross-sectional area of the test piece • Not to be used for boiler blow-down valves and pieces for connection to the shell plating

Impianti di propulsione navale

Grey cast iron	III II (5)	220	Grey cast iron is not to be used for the following systems: • boiler blow-down systems and other piping systems subject to shocks, high stresses and vibrations • bilge lines in tanks • parts of scuppers and sanitary discharge systems located next to the hull below the freeboard deck or for passengers ships below the bulkhead deck • ship side valves and fittings • valves fitted on the collision bulkhead • valves fitted to fuel oil and lubricating oil tanks under static pressure head • class II fuel oil systems • thermal oil systems
Aluminium and aluminium alloys	III, II (6)	200	Aluminium and aluminium alloys are not to be used on the following systems: • flammable oil systems • sounding and air pipes of fuel oil tanks • fire-extinguishing systems • bilge system in boiler or machinery spaces or in spaces containing fuel oil tanks or pumping units • scuppers and overboard discharges except for pipes led to the bottoms or to the shell above the freeboard deck or fitted at their upper end with closing means operated from a position above the freeboard deck • boiler blow-down valves and pieces for connection to the shell plating.

Impianti di propulsione navale

(1) Maximum design temperature is not to exceed that assigned to the class of piping.

(2) Higher temperatures may be accepted if metallurgical behaviour and time dependent strength (ultimate tensile strength after 100000 hours) are in accordance with national or international standards or specifications and if such values are guaranteed by the steel manufacturer.

(3) Pipes fabricated by a welding procedure approved by the Society may also be used.

(4) Pipes made of copper and copper alloys are to be seamless.

(5) Use of grey cast iron is not allowed when the design pressure exceeds 1,3 MPa.

(6) Accessories of aluminium or aluminium alloys intended for flammable oil systems may be accepted subject to the satisfactory result of an endurance flame test to be carried out according to the "Rules for the type approval of flexible hoses and expansion joints" issued by the Society.

Note 1: On board oil tankers and chemical tankers aluminised 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.

6 - Impianti sentina

6.2 Principle

6.2.1 General

An efficient bilge pumping system shall be provided, capable of pumping from and draining any watertight compartment other than a space permanently appropriated for the carriage of fresh water, water ballast, fuel oil or liquid cargo and for which other efficient means of pumping are to be provided, under all practical conditions. Efficient means shall be provided for draining water from insulated holds.

Bilge pumping system is not intended at coping with water ingress resulting from structural or main sea water piping damage.

6.2.2 Availability of the bilge system

The bilge system is to be able to work while the other essential installations of the ship, especially the fire-fighting installations, are in service.

6.2.3 Bilge and ballast systems

The arrangement of the bilge and ballast pumping system shall be such as to prevent the possibility of water passing from the sea and from water ballast spaces into the cargo and machinery spaces, or from one compartment to another.

Provisions shall be made to prevent any deep tank having bilge and ballast connections being inadvertently flooded from the sea when containing cargo, or being discharged through a bilge pump when containing water ballast.

6.3 Design of bilge systems

6.3.1 General

a)The bilge pumping system is to consist of pumps connected to a bilge main line so arranged as to allow the draining of all spaces mentioned in [6.2.1] through bilge branches, distribution boxes and bilge suctions, except for some small spaces where individual suctions by means of hand pumps may be accepted as stated in [6.6.3] and [6.6.4].

6.3.2 Number and distribution of bilge suctions

a)Draining of watertight spaces is to be possible, when the ship is on an even keel and either is upright or has a list of up to 5°, by means of at least:

- two suctions in machinery spaces, including one branch bilge suction and one direct suction and, in addition, for spaces containing propulsion machinery, one emergency bilge suction

- one suction in other spaces.

6.5 Draining of machinery spaces

6.5.1 General

Where all the propulsion machinery, boilers and main auxiliaries are located in a single watertight space, the bilge suctions are to be distributed and arranged in accordance with the provisions of [6.5.5].

6.5.2 Branch bilge suction

The branch bilge suction is to be connected to the bilge main.

6.5.3 Direct suction

The direct suction is to be led direct to an independent power bilge pump and so arranged that it can be used independently of the main bilge line.
The use of ejectors for pumping through the direct suction will be given special consideration.

6.5.4 Emergency bilge suction

a)The emergency bilge suction is to be led directly from the drainage level of the machinery space to a main circulating (or cooling) pump and fitted with a non-return valve.

b)In ships where, in the opinion of the Society, the main circulating (or cooling) pump is not suitable for this purpose, the emergency bilge suction is to be led from the largest available independent power driven pump to the drainage level of the machinery space. Such a pump is not to be a bilge pump. Its capacity when the emergency suction is operating is to be at least equal to the required capacity of each bilge pump as determined in [6.7.4].

c)The emergency bilge suction is to be located at the lowest possible level in the machinery spaces.

6.7.1 Number and arrangement of pumps

a) For cargo ships, at least two power pumps connected to the main bilge system are to be provided, one of which may be driven by the propulsion machinery.

b) Bilge pumps driven by the propulsion machinery are not allowed on ships exceeding 1000 gross tonnage.

c) Each pump may be replaced by a group of pumps connected to the bilge main, provided their total capacity meets the requirements specified in [6.7.4].

d) Alternative arrangements, such as the use of a hand pump in lieu of a power pump, will be given special consideration by the Society.

6.7.3 Use of bilge pumps for other duties *(1/1/2007)*

Bilge pumps may be used for other duties, such as fire, general service, sanitary service or ballast provided that:

- such duties are of intermittent nature
- any failure of the piping systems connected to the bilge pumps does not render the bilge system inoperable
- pumps are immediately available for bilge duty when necessary.

6.7.4 Capacity of the pumps

a) Each power bilge pump is to be capable of pumping water through the required main bilge pipe at a speed of not less than 2 m/s.

b) The capacity of each pump or group of pumps is not to be less than:

$$Q = 0{,}00565\, d^2$$

where:

Q : Minimum capacity of each pump or group of pumps, in m3/h

d : Internal diameter, in mm, of the bilge main as defined in [6.8.1].

6.8 Size of bilge pipes

6.8.1 Bilge main line *(1/1/2001)*

a)The diameter of the bilge main is to be calculated according to the following formula:

$$d = 25 + 1{,}68\sqrt{L\,(B + D)}$$

where :

d : The internal diameter of the bilge main, in mm

L : Length of the ship is the length measured between perpendiculars taken at the extremities of the deepest subdivision load line, in m.

B : Breadth of the ship is the extreme width from outside of frame to outside of frame at or below the deepest subdivision load line, in m.

D : Moulded depth of the ship to the bulkhead deck, in m, provided that, in a ship having an enclosed cargo space on the bulkhead deck which is internally drained in accordance with the requirements of [8.5.3] and which extends for the full length of the ship,

D: is measured to the next deck above the bulkhead deck. Where the enclosed cargo spaces cover a lesser length, D is to be taken as the moulded depth to the bulkhead deck plus lh/L where l and h are the aggregate length and height, respectively, of the enclosed cargo spaces, in m.

6.8.3 Branch bilge suction pipes *(1/7/2004)*

a) The internal diameter, in mm, of pipes situated between distribution boxes and suctions in holds and machinery spaces is not to be less than the diameter given by the following formula (a smaller actual diameter may be accepted, as specified in [6.8.1], b):

$$d = 25 + 2{,}16\sqrt{L_1\,(B + D)}$$

where:

B and D : as defined in [6.8.1]

L1 : Length of the compartment, in m. d1 is not to be less than 50 mm and need not exceed 100 mm.

b) For ships other than passenger ships, which have side ballast tanks forming a double hull, the diameter of suction pipes in holds may be determined by introducing as B the actual breadth of the holds.

Impianti di propulsione navale

10 - Impianti di raffreddamento

- **Ridondanza dei componenti principali per garantire continuità del servizio**

- **Sia l'impianto di raffreddamento ad acqua mare che quello ad acqua dolce devono essere dotati di due pompe di circolazione, una in servizio, l'altra in stand-by, quest'ultima con capacità pari a quella della pompa in servizio.**

- **Devono essere previste almeno due prese mare (destra e sinistra), ciascuna sufficiente per l'intero servizio.**

10.2.2 Availability of the cooling system

The cooling system is to be so designed that, in the event of one essential component being inoperative, the cooling of propulsion machinery is maintained. Partial reduction of the propulsion capability may be accepted, however, when it is demonstrated that the safe operation of the ship is not impaired.

Impianti di propulsione navale

10.3.1 General

a) Sea water cooling of the propulsion engines, auxiliary engines and other essential equipment is to be capable of being supplied by two different means.
b) Where required, standby pumps are not to be connected to the sea inlet serving the other sea water pumps, unless permitted under [10.7.1], item b).

10.3 Design of sea water cooling systems
10.3.2 Centralised cooling systems *(1/7/2002)*

a) In the case of centralised cooling systems, i.e. systems serving a group of propulsion engines and/or auxiliary engines, reduction gears, compressors and other essential equipment, the following sea water pumps are to be arranged:

- one main cooling water pump, which may be driven by the engines, of a capacity sufficient to provide cooling water to all the equipment served

- one independently driven standby pump of at least the same capacity

10.3.3 Individual cooling of propulsion engines *(1/7/2002)*

a) Individual cooling systems of propulsion engines are to include at least:
- one main cooling water pump, which can be driven by the engine
- one independently driven standby pump

10.4 Design of fresh water cooling systems.
10.4.2 Cooling systems

a) Fresh water cooling systems of essential equipment are to include at least:
- one main cooling water pump, which can be driven by the equipment
- one independently driven standby pump.

10.7 Arrangement of cooling systems
10.7.1 Sea inlets

a) At least two sea inlets complying with [2.8] are to be provided for the cooling system, one for each means of cooling required in [10.3.1].

b) The two sea inlets may be connected by a cross-over supplying both main cooling pump and standby cooling pump.

Impianti di propulsione navale

11 - Impianti olio combustibile

- **Devono alimentare i motori e le caldaie con olio combustibile avente adeguate caratteristiche di purezza, viscosità e pressione**

- **Vanno progettati per prevenire pericoli di traboccamenti, perdite, contatti della nafta con possibili fonti di accensione, surriscaldamenti e solidificazioni della nafta**

- **La nafta deve avere un flash point > 60 °C(43 °Cper i motori dei gruppi di emergenza)**

11.4 - Impianti riempimento e travaso olio combustibile

- Provisions are to be made to allow the transfer of fuel oil from any storage, settling or service tank to another tank.

- ..... , the fuel oil transfer piping system is to be completely separate from the other piping systems of the ship.

Vanno previste due pompe di travaso, una in stand-by

Impianti di propulsione navale

11.5 - Sistemazione delle casse combustibile : valgono le norme previste dalla SOLAS (vedi Ch II-2 Part B – Regulation 4 – 2.2.3), quindi le casse devono :

- **essere strutturali**
- **essere situate, ove possibile, fuori da locali macchine di cat. A**
- **nel caso fossero situate in locali di cat. A, almeno una delle loro facce deve essere contigua ai confini del locale. Le casse non devono avere fondi esposti verso il locale (devono quindi avere il fondo a contatto con il cielo doppio fondo dello scafo)**
- **devono rispettare i requisiti della Parte B , Capitolo 2 (intercapedini con altre casse) :**

  - **2 Cofferdams**

    2.1 Cofferdam arrangement

    2.1.1 Cofferdams are to be provided between compartments intended for liquid hydrocarbons (fuel oil, lubricating oil) and those intended for fresh water (drinking water, water for propelling machinery and boilers) as well as tanks intended for the carriage of liquid foam for fire extinguishing.

11.6 – Progetto delle casse

Le casse devono essere dotate :

- **di chiusura a distanza delle aspirazioni**
- **di sfogo d'aria, tubo di rigurgito, sonde e livelli**
- **se destinate all'imbaco di nafta pesante, di un sistema di riscaldamento atto a mantenere il combustibile fluido e atto ad essere pompato**

11.7 – Progetto del sistema di riscaldamento combustibile

In generale il combustibile può essere riscaldato fino a una temperatura di 10°C inferiore al flash point. Se la temperatura eccede tale limite (casse decantazione e servizio), vanno prese speciali precauzioni :

- the length of the vent pipes from such tanks and/or a cooling device is sufficient for cooling the vapours to at least 10°C below the flashpoint of the fuel oil and a temperature sensor is fitted in the vent pipe and adjusted to give an alarm if the temperature should exceeds a limit set at 10°C below the flashpoint of the fuel, or the outlet of the vent pipes is located 3 m away from a source of ignition
- the vent pipes are fitted with suitable flame screens
- there are no openings from the vapour space of the fuel tanks into machinery spaces (bolted manholes are acceptable)
- enclosed spaces are not located directly over such fuel tanks, except for well ventilated cofferdams
- electrical equipment is not fitted in the vapour space of the tanks, unless it is certified to be intrinsically safe.

Impianti di propulsione navale

11.8 – Progetto del sistema di trattamento combustibile

- **La nafta pesante usata per i motori diesel deve essere depurata e filtrata secondo le prescrizioni del costruttore del motore**

- **Le casse decantazione e servizio vanno munite di drenaggi per l'evacuazione dell'acqua e delle impurità che si accumulano sul fondo cassa**

- **Se il combustibile deve essere depurato, vanno installati almeno due depuratori, ciascuno dei quali sufficiente per depurare la quantità di nafta necessaria al normale funzionamento del motore.**

11.9 – Progetto del sistema di alimentazione combustibile

Devono essere previste due casse di servizio per ogni tipo di combustibile usato a bordo. Se il motore principale e i motori ausiliari funzionano tutti a nafta pesante, si possono installare due casse servizio, una per nafta pesante, l'altra per marine diesel oil.

11.9.2 Fuel oil service tanks *(1/1/2001)*

a) Two fuel oil service tanks for each type of fuel used on board necessary for propulsion and vital systems, or equivalent arrangements, are to be provided on each new ship, with a capacity of at least 8 h at maximum continuous rating of the propulsion plant and normal operating load at sea of the generator plant.

b) Where main engines, auxiliary engines and boilers are operated with heavy fuel oil, the following equivalent arrangements may be accepted for fuel oil service tanks:

- one heavy fuel oil service tank with a capacity of at least 8 h at maximum continuous rating of the propulsion plant and normal operating load at sea of the generator plant and of the auxiliary boiler
- one marine diesel oil service tank with a capacity of at least 8 h at maximum continuous rating of the propulsion plant and normal operating load at sea of the generator plant and of the auxiliary boiler.

Impianti di propulsione navale

c) Where main engine and auxiliary boilers are operated with heavy fuel oil and auxiliary engines are operated with marine diesel oil, the following equivalent arrangements may be accepted for fuel oil service tanks:

- one heavy fuel oil service tank with a capacity of at least 8 h at maximum continuous rating of the propulsion plant and normal operating load at sea of the auxiliary boiler

- two marine diesel oil service tanks, each with a capacity of at least the higher of:

- 8 h at normal operating load at sea of the auxiliary engines
- 4 h at maximum continuous rating of the propulsion plant and normal operating load at sea of the generator plant and of the auxiliary boiler.

11.9 – Progetto del sistema di alimentazione combustibile

- **Alimentazione combustibile alle caldaie principali e alle caldaie destinate a fornire vapore a servizi essenziali :**

  the fuel oil supply system is to include at least two units, each one comprising:
  - a suction filter
  - an independent pump
  - a heater in the case of heavy fuel oil
  - a discharge filter.

- **Alimentazione combustibile ai motori a combustione interna :**

  - **due filtri in parallelo sulla mandata alle pompe iniezione**
  - **quando si rende necessaria una pompa d'alimento "booster", deve essere prevista una seconda pompa in stand-by**
  - **quando il combustibile richiede di essere preriscaldato prima dell'invio al motore, vanno installati :**

    - **un dispositivo di controllo e misura della viscosità**
    - **due riscaldatori nafta, uno stand-by**

Impianti di propulsione navale

11.10 – Monitoraggio e controllo

Allarmi e controlli secondo la tabella allegata :

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indica-tion	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil overflow tank level	H (1)						
Air pipe water trap level on fuel oil tanks	H (2)						
Fuel oil temperature after heaters	H (4)	local		X (5)			
Sludge tank level		local					
Fuel oil settling tank and service tank temperature	H (3)	local					
Fuel oil level in daily service tank	L+H (1)	local					
Fuel oil daily service tank temperature	H (3)	local					

(1) Or sightglasses on the overflow pipe
(2) Or alternative arrangement as per [9.1.7] item c)
(3) Applicable where heating arrangements are provided
(4) Or low flow alarm in addition to temperature control when heated by steam or other media
(5) Cut off of electrical power supply when electrically heated

11.10 – Monitoraggio e controllo

Inoltre :

- **controllo automatico della temperatura per riscaldatori a vapore, elettrici o di altro tipo**

- **interruzione dell'alimentazione elettrica a bruciatori, pompe nafta e depuratori sia dall'interno del locale che da posizione esterna in caso di incedio**

12 - Impianti olio lubrificante

Prescrizioni simili a quelle degli impianti olio combustibile: ridondanza, filtrazione, prevenzione rischi incendio. In aggiunta richiesto un adeguato raffreddamento dell'olio.

12.2.1 General

a) Lubricating oil systems are to be so designed as to ensure reliable lubrication of the engines, turbines and other equipment, including electric motors, intended for propulsion:

- over the whole speed range, including starting, stopping and, where applicable, manoeuvring
- for all the inclinations angles stated in Sec 1

b) Lubricating oil systems are to be so designed as to ensure sufficient heat transfer and appropriate filtration of the oil.

c) Lubricating oil systems are to be so designed as to prevent oil from entering into contact with sources of ignition.

12 - Impianti olio lubrificante

12.2.2 Availability

a) Lubricating oil systems are to be so designed that, in the event that any one pump is inoperative, the lubrication of the engines and other equipment is maintained. Partial reduction of the propulsion capability may be accepted, however, when it is demonstrated that the safe operation of the ship is not impaired.

b) An emergency lubricating system, such as a gravity system, is to be provided to ensure sufficient lubrication of equipment which may be damaged due to a failure of the pump supply.

12.4.1 Lubrication of propulsion engines *(1/7/2005)*

a) Main engines are to be provided with at least two power lubricating pumps, of such a capacity as to maintain normal lubrication with any one pump out of action.

14 - Impianti olio idraulico

14.1 Application

14.1.1 Hydraulic installations intended for essential services *(1/7/2005)*

Unless otherwise specified, this Article applies to all hydraulic power installations intended for essential services, including:

- actuating systems of thrusters
- actuating systems of steering gear
- actuating systems of lifting appliances
- manoeuvring systems of hatch covers
- manoeuvring systems of stern, bow and side doors and bow visors
- manoeuvring systems of mobile ramps, movable platforms, elevators and telescopic wheelhouses
- starting systems of diesel engines and gas turbines
- remote control of valves.

Impianti di propulsione navale

Per gli impianti idraulici che servono servizi essenziali, sono previsti requisiti di ridondanza (possibilità di funzionamento anche con un componente essenziale fuori servizio, due unità di potenza).

Inoltre le unità idrauliche di potenza devono essere sistemate al di fuori dei locali motori principali e caldaie.
In caso ciò non fosse possibile, le unità devono essere schermate per evitare l'accensione di accidentali spruzzi d'olio su superfici calde.

15 - Impianti vapore

15.2.2 Availability

a) Where a single boiler is installed, the steam system may supply only non-essential services.

b) Where more than one boiler is installed, the steam pipingsystem is to be so designed that, in the event that any one boiler is out of action, the steam supply to essential services can be maintained.

15.3 Design of steam lines
15.3.1 General

a) Every steam pipe and every connected fitting through which steam may pass is to be designed, constructed and installed such as to withstand the maximum working stresses to which it may be subjected.

b) When the design temperature of the steam piping system exceeds 400°C, calculations of thermal stresses are to be submitted to the Society as specified in [2.3].

15.3.3 Provision for dumping

In order to avoid overpressure in steam lines due to excessive steam production, in particular in systems where the steam production cannot be adjusted, provisions are to be made to allow the excess steam to be discharged to the condenser by means of an appropriate dump valve.

Impianti di propulsione navale

16 – Impianti acqua alimento e condensato
Ricordiamo quanto prescritto nelle generalità (1.3.2 – b) :

> The design pressure of a boiler feed system is not to be less than 1,25 times the design pressure of the boiler or the maximum pressure expected in the feed piping, whichever is the greater.

Inoltre :
16.2.1 General
Boiler feed water and condensate systems are to be so designed that:

- reserve feed water is available in sufficient quantity to compensate for losses
- feed water is free from contamination by oils or chlorides
- feed water for propulsion systems is suitably de-aerated.

E' prescritta la ridondanza sia dell'alimento che dell'estrazione (almeno due pompe, di cui una in stand-by).

Impianti di propulsione navale

17 - Impianti aria compressa

Le prescrizioni si applicano a impianti per servizi essenziali quali :
- **impianti aria avviamento**
- **impianti aria per strumentazione e controlli**

L'aria distribuita agli utenti degli impianti deve essere priva di umidità e olio e non deve trovarsi a temperatura eccessiva

17.2.2 Availability

a) Compressed air systems are to be so designed that, in the event of failure of one air compressor or one air receiver intended for starting, control purposes or other essential services, the air supply to such services can be maintained.

b) The compressed air system for starting main engines and auxiliary engines for essential services is to be so arranged that it is possible to ensure the initial charge of air receiver(s) without the aid of a power source outside the ship.

17.3.1 Initial charge of starting air receivers

a) Where, for the purpose of [17.2.2], an emergency air compressor is fitted, its driving engine is to be capable of being started by hand-operated devices. Independent electrical starting batteries may also be accepted.

Requisiti per l'impianto aria di avviamento.

Il numero di avviamenti che l'impianto deve essere in grado di sostenere senza ricarica dei serbatoi è specificato nella Pt C, Ch 1, Sec 2 relativa ai motori diesel :

3.1.1 Mechanical air starting

a) Air starting the main and auxiliary engines is to be arranged such that the necessary air for the first charge can be produced on board the ship without external aid.

b) The total capacity of air receivers is to be sufficient to provide, without replenishment, not less than 12 consecutive starts alternating between ahead and astern of each main engine of the reversible type, and not less than 6 consecutive starts of each main non-reversible type engine connected to a controllable pitch propeller or other device enabling the start without opposite torque. The number of starts refers to the engine in cold and ready-to-start condition (all the driven equipment that cannot be disconnected is to be taken into account).

Impianti di propulsione navale

Requisiti per l'impianto aria di avviamento.

Capacità e tempi di ricarica dei serbatoi sono prescritti nella Pt C, Ch 1, Sec 10 paragrafo 17 :

17.3.2 Number and capacity of air compressors *(1/7/2004)*

a) Where main and auxiliary engines are arranged for starting by compressed air, two or more air compressors are to be fitted with a total capacity sufficient to supply within one hour, the receivers being at atmospheric pressure, the quantity of air needed to satisfy the provisions of Sec 2, [3.1.1]. This capacity is to be approximately equally divided between the number of compressors fitted, excluding the emergency compressor fitted in pursuance of [17.3.1].

b) At least one of the compressors is to be independent of the engines for which starting air is supplied and is to have a capacity of not less than 50% of the total required in a).

17.3.3 Number and capacity of air receivers

a) Where main engines are arranged for starting by compressed air, at least two air receivers are to be fitted of approximately equal capacity and capable of being used independently.

b) The total capacity of air receivers is to be sufficient to provide without replenishment the number of starts required in Sec 2, [3.1.1]. It is also to take into account the air delivery to other consumers, such as control systems, whistle, etc., which are connected to the air receivers.

18 – Impianti scarichi gas

18.2.2 Limitation of exhaust line surface temperature

a) Exhaust gas pipes and silencers are to be either water cooled or efficiently insulated where:
   - their surface temperature may exceed 220°C, or
   - they pass through spaces of the ship where a temperature rise may be dangerous.

b) The insulation of exhaust systems is to comply with the provisions of Sec 1, [3.7.1].

18.2.3 Limitation of pressure losses

Exhaust gas systems are to be so designed that pressure losses in the exhaust lines do not exceed the maximum values permitted by the engine or boiler manufacturers.

18.2.4 Intercommunication of engine exhaust gas lines or boiler smoke ducts

a) Exhaust gas from different engines is not to be led to a common exhaust main, exhaust gas boiler or economiser, unless each exhaust pipe is provided with a suitable isolating device.

18.4 Arrangement of exhaust piping systems

18.4.1 Provision for thermal expansion

a) Exhaust pipes and smoke ducts are to be so designed that any expansion or contraction does not cause abnormal stresses in the piping system, and in particular in the connection with engine turboblowers.

Impianti di propulsione navale

Sistemi di tubazioni

Pressione di progetto è la pressione assunta dal costruttore per determinare il dimensionamento dei componenti del sistema di tubazioni.
Non deve essere inferiore alla massima pressione di lavoro dell'impianto o della pressione di taratura più alta delle valvole di sicurezza presenti nell'impianto.

Temperatura di progetto è la massima temperatura del fluido all'interno del sistema di tubazioni.

I Registri di Classifica assegnano ad ogni sistema di tubazioni (tubi ed accessori relativi) una Classe in base ai seguenti parametri :

- **tipo di fluido convogliato,**
- **pressione di progetto,**
- **temperatura di progetto.**

Una volta definita la Classe della tubazione, tutti i suoi componenti devono rispettare i requisiti da essa imposti.
Qualora uno solamente dei parametri che definisce la Classe fosse maggiore del limite stabilito, la tubazione verrà assegnata alla Classe superiore.

Data: 15/01/2007

Sistemi di tubazioni

Esempio:

- **vapore a 170 °C e 7 bar ⇨ classe III**
- **vapore a 170 e 8 bar ⇨ classe II**

Tutte le tubazioni per tutti i tipi di fluido che eccedono i limiti della classe II appartengono alla classe I.

In base alla Classe, vengono definiti i materiali da impiegare, i tipi d'accoppiamento da adottare, i procedimenti di saldatura, i trattamenti termici, i test, i collaudi e le pressioni di prova.

Impianti di propulsione navale

Table 3 : Class of piping systems *(1/7/2002)*

Media conveyed by the piping system	CLASS I	CLASS II	CLASS III
Fuel oil **(1)**	p > 1,6 or T > 150	other **(2)**	p ≤ 0,7 and T ≤ 60
Thermal oil	p > 1,6 or T > 300	other **(2)**	p ≤ 0,7 and T ≤ 150
Flammable Hydraulic oil **(5)**	p>1,6 or T>150	other **(2)**	p ≤ 0,7 and T≤60
Lubricating oil	p> 1,6 or T > 150	other **(2)**	p ≤ 0,7 and T ≤ 60
Other flammable media: • heated above flashpoint, or • having flashpoint <60°C and liquefied gas	without special safeguards **(3)**	with special safeguards **(3)**	
Oxyacetylene	irrespective of p		
Toxic media	irrespective of p, T		
Corrosive media	without special safeguards **(3)**	with special safeguards **(3)**	
Steam	p > 1,6 or T > 300	other **(2)**	p ≤ 0,7 and T ≤ 170
Air, gases, water, non-flammable hydraulic oil **(4)**	p > 4 or T > 300	other **(2)**	p ≤ 1,6 and T ≤ 200
Open-ended pipes (drains, overflows, vents, exhaust gas lines, boiler escape pipes)			irrespective of T

(1) Valves under static pressure on fuel oil tanks belong to class II.

(2) Pressure and temperature conditions other than those required for class I and class III.

(3) Safeguards for reducing the possibility of leakage and limiting its consequences, e.g. pipes led in positions where leakage of internal fluids will not cause a potential hazard or damage to surrounding areas which may include the use of pipe ducts, shielding, screening, etc.

(4) Valves and fittings fitted on the ship side and collision bulkhead belong to class II.

(5) Steering gear piping belongs to class I irrespective of p and T

Note 1: p : Design pressure, as defined in [1.3.2], in MPa.

Note 2: T : Design temperature, as defined in [1.3.3], in °C.

Data: 15/01/2007

Sistemi di tubazioni

Diametro Nominale

Il diametro nominale (DN) è l'indicazione per individuare la dimensione teorica di un tubo senza indicarne lo spessore, ad esempio per tubo DN 65 le reali dimensioni del tubo possono essere:

DN	65			
Diametro esterno	76,1			
Spessore	3,6	4,5	5,4	7,1

Lo spessore del tubo sarà scelto in base al servizio ed alla Classe attribuita al servizio al quale il tubo appartiene.

Impianti di propulsione navale

Pressione Nominale (Nominal Pressure)

La pressione nominale PN è un'indicazione convenzionale usata per individuare gli elementi accoppiabili di una tubazione aventi uguale livello qualitativo e costruttivo. Tutti i componenti della stessa tubazione (valvole, flange, filtri, guarnizioni, ...) devono essere pertanto caratterizzati dallo stesso valore di PN.

La serie delle pressioni nominali adottata per le tubazioni delle costruzioni navali è la seguente:

- **PN 6, PN 10, PN 16, PN 40 con indicazione metrica del DN**
- **ANSI 300, ANSI 600, ANSI 900 con indicazione del DN in pollici**

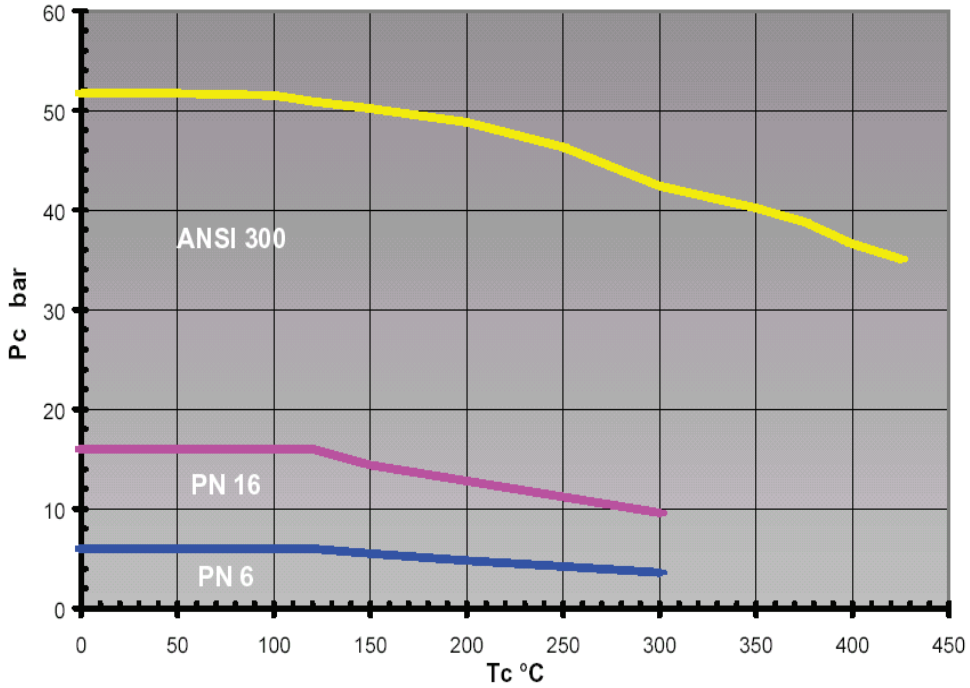
I dati per la scelta della PN sono solamente la pressione di progetto e la temperatura di progetto.

I diagrammi allegati riportano i criteri per la determinazione del PN di tubazioni in acciaio al carbonio :

Impianti di propulsione navale

Tubazioni in acciaio al carbonio Serie PN 6, PN 16 e ANSI 300

Temperatura °C	Serie PN 6	Serie PN 16	Serie ANSI 300
-10 ÷ 50	6	16	51,7
100	6	16	51,5
120	6	16	50,9
150	5,5	14,4	50,2
200	4,8	12,8	48,8
250	4,2	11,2	46,3
300	3,6	9,6	42,4
350	--	--	40,2
375	--	--	38,8
400	--	--	36,6
425	--	--	35,1
Secondo	ISO 7005-1		ANSI B16.5

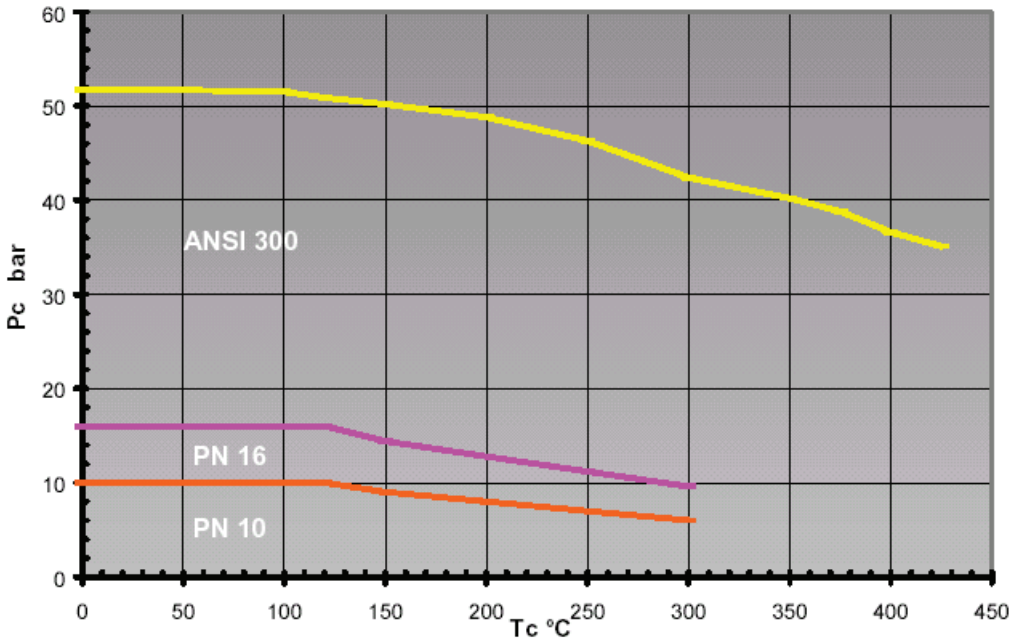


Data: 15/01/2007

Impianti di propulsione navale

Temperatura °C	Serie PN 10	Serie PN 16	Serie ANSI 300
-10 ÷ 50	10	16	51,7
100	10	16	51,5
120	10	16	50,9
150	9	14,4	50,2
200	8	12,8	48,8
250	7	11,2	46,3
300	6	9,6	42,4
350	--	--	40,2
375	--	--	38,8
400	--	--	36,6
425	--	--	35,1
Secondo	ISO 7005-1		ANSI B16.5

Tubazioni in acciaio al carbonio Serie PN 10, PN 16 e ANSI 300



Data: 15/01/2007

Pressione Nominale (Nominal Pressure)

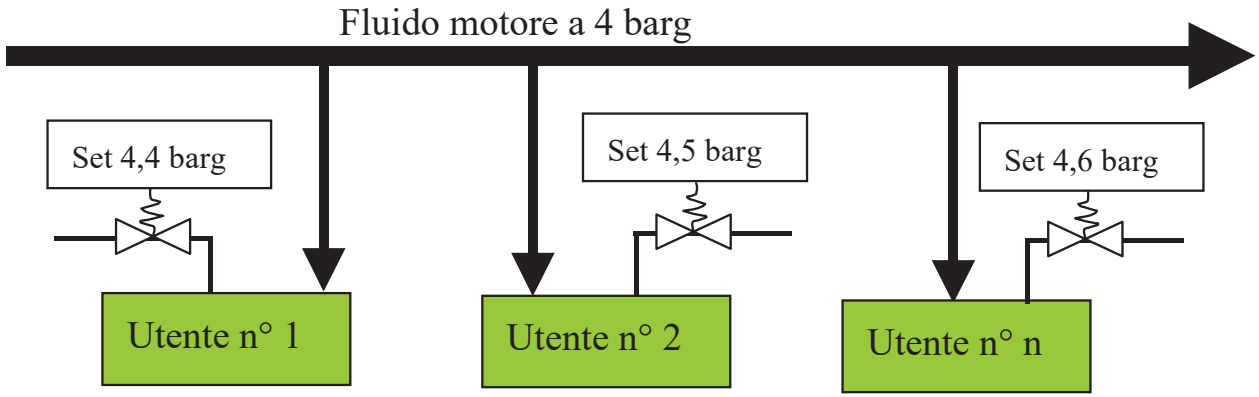
Ad ogni PN corrisponde una pressione massima ammissibile :

- **PN6 – pressione ammissibile fino a 6 kg/cm^2**
- **PN10 – pressione ammissibile fino a 10 kg/cm^2**
- **PN16 – pressione ammissibile fino a 16 kg/cm^2**
- **PN40 – pressione ammissibile fino a 40 kg/cm^2**

Pressione di esercizio (Working Pressure)

E' la pressione di lavoro dell' impianto. Viene identificata nella pressione di scatto della valvola di sicurezza con la taratura più alta.

Da quanto sopra e da quanto indicato nel diagramma, la pressione di esercizio sarà di 4.6 barg.



NOTA

E' improprio parlare di tubi PN6, PN16, ecc. : si dovrebbe parlare di sistema di tubazioni (insieme di tubi ed accessori vari) PN6, PN16.

Di per sè il tubo non ha un PN o una Classe ben definita.
Lo stesso tubo con lo stesso spessore può indifferentemente appartenere a qualsiasi Classe.

Impianti di propulsione navale

Ad esempio, un tubo DN65 (76.1 x 3.60 mm) ha un campo di applicazione teorico come indicato nella tabella :

ø est, tubo mm	spess. mm	peso kg/ml	sez. passeg. cmq	TUBI ACCIAIO AL CARBONIO - SELEZIONE N 004.05 - MAX. PRESS. AMMISSIBILI (kg/cmq)																						
				≤ 120°C								> 120 ÷ 200°C					> 200 ÷ 250°C					> 250 ÷ 300°C			>300 ÷ 350°C			>350÷400
				OLIO LUBRIFICANTE IMP. FRIGORIFERO	ACQUA DOLCE (TUBI ZINCATI)	ACQUA ALIMENTO CIRCUITO CHIUSO	ACQUA DOLCE (TUBI NERI)	ARIA COMPRESSA NAFTA COMBUSTIB.	ACQUA ALIMENTO CIRCUITO APERTO	SENTINA E ACQUA MARE (TUBI ZINCATI)	CARICO PETROLIFERO	ACQUA ALIMENTO CIRCUITO CHIUSO	VAPORE SATURO	NAFTA COMBUSTIB.	ACQUA ALIMENTO CIRCUITO APERTO ESTRAZ. CALDAIE	SERPENTINE RISCALDAMENTO CISTERNE CARICO	VAPORE SURRISCALDATO E DESURRISCALDATO	ACQUA ALIMENTO CIRCUITO CHIUSO	VAPORE SATURO	ACQUA ALIMENTO CIRCUITO APERTO ESTRAZ. CALDAIE	SERPENTINE RISCALDAMENTO CISTERNE CARICO	VAPORE SURRISCALDATO E DESURRISCALDATO	VAPORE SATURO	ESTRAZIONE CALDAIE	VAPORE SURRISCALDATO E DESURRISCALDATO	VAPORE SATURO	ESTRAZIONE CALDAIE	VAPORE SURRISCALDATO E DESURRISCALDATO
76.1	3.60	6.7	37.5	101	97	94	83	75	57	57	40	76	67	61	46	32	74	69	61	42	29	62	51	35	55	45	31	48
	5.40	9.41	33.5	165	162	158	146	139	120	120	102	128	118	112	97	82	121	116	108	88	74	102	90	74	89	79		79
	8.00	13.40	28.4	257	253	249	237	229	209	209	190	201	192	185	169		189	183	174	154		159	146	129	140	129		124

In base al materiale, allo spessore ed al tipo di servizio, il tubo appartiene di volta in volta alla classe assegnata alla tubazione.
Dalla lettura della tabella si riscontra che lo spessore minimo teorico del tubo riesce a coprire tutte le Cassi per tutti i servizi arrivando fino a PN 40 (31 barg – 350°C).
Anche se dalla tabella di cui sopra (costruita in base a formule indicate dagli Enti di Classifica) si ha l' assicurazione che il tubo scelto soddisfa tutti i requisiti richiesti dalla Classe a cui sarà legato, bisognerà sempre tener conto che i tubi in commercio hanno delle tolleranze di fabbricazione sullo spessore del ± 17%.

Impianti di propulsione navale

Esempio di scelta di un tubo :

1. **scelta del materiale del tubo in funzione del fluido, del servizio, di particolari esigenze tecnico-economiche del progetto, ecc.;**

2. **determinazione del diametro interno in base alla portata di progetto e alla velocità massima ammissibile del fluido da convogliare;**

3. **assegnazione della Classe in base al tipo di fluido, alla pressione e alla temperatura di progetto (vedi tab. 3);**

4. **calcolo della sollecitazione massima ammissibile K in base al materiale del tubo e alla temperatura di progetto (vedi tab. 9 per acciaio al C e C – Mn).**
   Il calcolo di K può essere fatto anche direttamente con le formule dei Registri;

5. **calcolo dello spessore in base a K e alla pressione di progetto. In ogni caso lo spessore deve essere maggiore di un valore minimo ammissibile specificato da tabelle dei Registri.**

6. **scelta del DN in base al diametro interno e allo spessore.**

Table 9 : Permissible stresses for carbon and carbon-manganese steel pipes

Specified minimum tensile strength (N/mm²)	Design temperature (°C)												
	≤50	100	150	200	250	300	350	400	410	420	430	440	450
320	107	105	99	92	78	62	57	55	55	54	54	54	49
360	120	117	110	103	91	76	69	68	68	68	64	56	49
410	136	131	124	117	106	93	86	84	79	71	64	56	49
460	151	146	139	132	122	111	101	99	98	85	73	62	53
490	160	156	148	141	131	121	111	109	98	85	73	62	53

Impianti di propulsione navale

Calcolo dello spessore del tubo :

- **t** spessore regolamentare (mm)
- **t_o** spessore base (mm)
- **b** riduzione spessore per piegatura (mm)
- **ρ** raggio di curvatura dell'asse del tubo (mm)
- **c** margine per corrosione, dato da tabelle in funzione del materiale e del servizio (mm)
- **a** tolleranza percentuale negativa per tener conto delle imprecisioni di costruzione del tubo (12.5 per tubi acciaio laminati a caldo; 10 per tubi rame e leghe rame, tubi acciaio trafilati a freddo e tubi acciaio saldati)
- **p** pressione di progetto (MPa)
- **D** diametro esterno (mm)
- **K** sollecitazione ammissibile (N/mm^2)
- **e** fattore di efficienza della saldatura (pari a 1 per tubi senza saldatura)

$$t = \frac{t_o + b + c}{1 - \frac{a}{100}} \qquad t_o = \frac{pD}{2Ke + p} \qquad b = \frac{Dt_o}{2.5\rho}$$

Tipi di accoppiamenti

A flangia

- **La flangia è una piastra anulare munita di fori che, accoppiata ad un'altra flangia tramite bulloni, unisce due tubi o condotte contigue. Per garantire la tenuta dell' accoppiamento si interpone tra le flange strette dai bulloni una guarnizione costruita in un materiale più tenero delle flange (anche metallo). Questo tipo di accoppiamento è il più usato negli impianti di bordo per la praticità di installazione e smontaggio dei suoi componenti. E' usato per tutti gli impianti di ogni classe di tubazione anche se, in presenza di forti pressioni unite ad alta temperatura, gli accoppiamenti saldati sono preferibili. La parte debole di questo accoppiamento è la guarnizione che, per installazione errata o difetti di costruzione, può lasciar trafilare degli spruzzi che, oltre a provocare un malfunzionamento dell' impianto, possono essere causa di infortuni al personale e danneggiare macchinari situati nei pressi dell' accoppiamento.**



Impianti di propulsione navale

A manicotto

- **Il manicotto viene usato al posto dell' accoppiamento flangiato quando si vogliono evitare i possibili spruzzi derivati da rotture nelle guarnizioni. Anche in questo caso però, poichè la saldatura interna non può essere ripresa su tutte e due le estremità dei tubi accoppiati, il flusso del fluido nell' interspazio tra manicotto e tubo può, con l' andare del tempo, erodere sia il tubo che il manicotto e provocare gli stessi inconvenienti dell' accoppiamento flangiato. I manicotti si possono usare per tutti i sistemi di III classe e fino al DN 50 compreso per i tubi di II classe.**

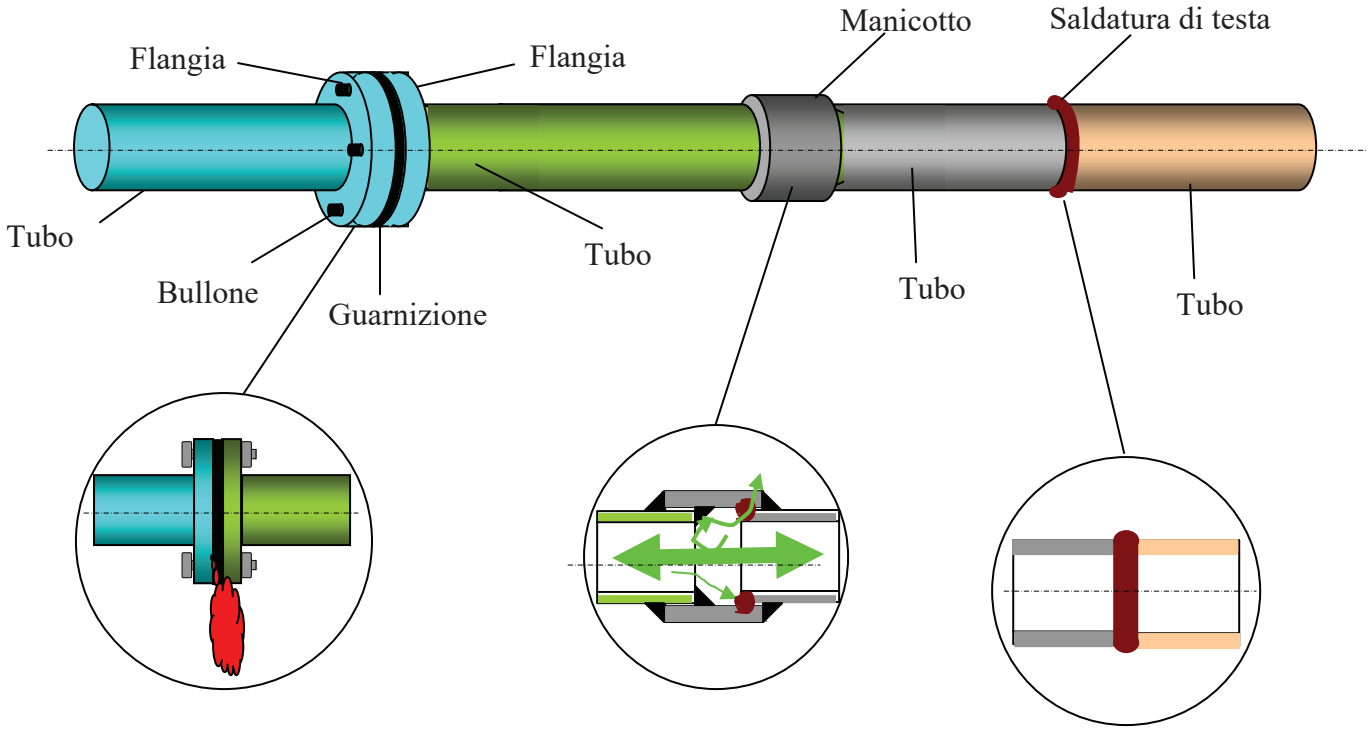
Saldato

- **La saldatura di testa è il sistema più sicuro di accoppiamento che, se eseguito a regola d' arte, fa si che i due tronchi di tubo risultino un tronco solo. Non è di pratica installazione in quanto, per eseguire modifiche e smontare accessori o parti dell' impianto, si devono necessariamente tagliare i tubi. Può essere usato per tutte le classi di tubazioni anche se si preferisce usarlo solamente per la Classe I o laddove fluidi infiammabili ad alta pressione e temperatura devono essere convogliati sopra macchinari caldi, quadri elettrici e transiti del personale.**

Impianti di propulsione navale

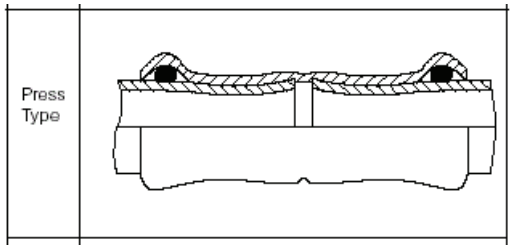
Tipi di accoppiamenti :

- **flangiati**
- **a manicotto**
- **saldati**



Impianti di propulsione navale

Giunzione meccanica a pressione (Pressfitting)



Prodotti / Pressfitting

Applicazioni | Specifiche tecniche | Installazione | Programma di fornitura

Descrizione del sistema

Il sistema CHIBRO pressfitting consente di realizzare in modo affidabile e conveniente le tubazioni di molti tipi di impianti, nel campo civile, industriale e navale, nella gamma di diametri da 15 a 108 mm.

Il sistema CHIBRO pressfitting è costituito dai seguenti componenti:

- **Raccordi**
  curve, tee, riduzioni, etc. in acciaio inossidabile austenitico Cr-Ni-Mo n° 1.4404 secondo UNI EN 10088 (AISI 316 L).
- **Tubi**
  tubi elettrouniti in acciaio inossidabile austenitico Cr-Ni-Mo n° 1.4404 secondo UNI EN 10088 (AISI 316 L).
- **Pinza elettroidraulica**
  per la giunzione dei componenti mediante compressione dei raccordi sul tubo.

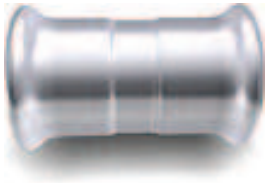
Il programma di fornitura è completato da vari accessori accoppiabili ai tubi con la stessa tecnologia del sistema CHIBRO pressfitting.

Principali vantaggi del Sistema CHIBRO pressfitting

- semplicità e rapidità di montaggio
- affidabilità anche in severe condizioni di esercizio
- eliminazione delle fasi di lavorazione dei tubi in officina normalmente eseguite con i sistemi tradizionali
- resistenza alla corrosione
- riduzione del peso movimentato ed installato
- nessun rischio di incendio durante l'installazione

Impianti di propulsione navale

Giunzione meccanica a pressione (Pressfitting)



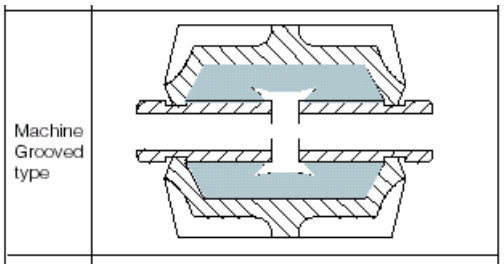
RACCORDI CHIBRO PRESSFITTING

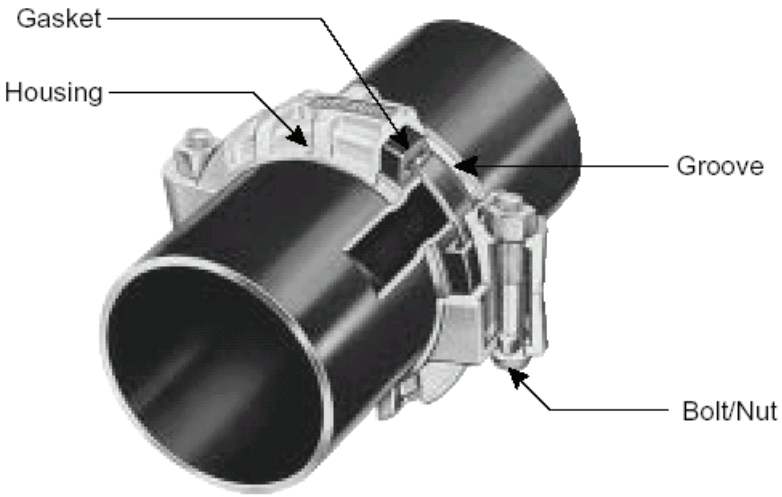
Gli elementi di base del Sistema sono gli speciali raccordi CHIBRO pressfitting in acciaio inossidabile AISI 316 L che, disponibili in varie tipologie e dimensioni (vedi programma di fornitura) consentono di realizzare gli impianti utilizzando solo raccordi e tubi in verghe. I raccordi hanno ad ogni estremità una camera toroidale nella quale è inserito un o-ring in gomma sintetica che, una volta deformato dall'azione di pressatura della pinza, realizza la tenuta ermetica in accoppiamento con il tubo. La tenuta meccanica è invece garantita dalla deformazione congiunta del raccordo e del tubo in esso innestato. L'o-ring di tenuta è realizzato in EPDM, elastomero particolarmente resistente all'invecchiamento, all'ozono, al calore ed agli agenti chimici con particolare riferimento agli additivi normalmente impiegati nell'acqua potabile e nei circuiti di raffreddamento. Per impianti che prevedano il trasporto di olii combustibili e lubrificanti è previsto un o-ring in NBR, materiale elastomerico con questi compatibile. Usando gli appositi raccordi misti è possibile collegare le tubazioni realizzate con il Sistema CHIBRO pressfitting anche ad elementi flangiati o filettati di tipo standard.

TUBI CHIBRO PRESSFITTING

Il secondo elemento del Sistema è costituito dai tubi CHIBRO pressfitting in acciaio inossidabile AISI 316 L che sono forniti in verghe di lunghezza fissa di 6 m.

Giunzione meccanica “Machine grooved” (Victaulic)



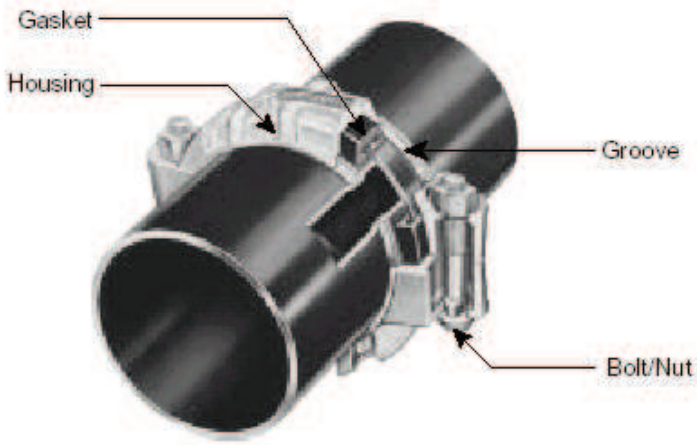


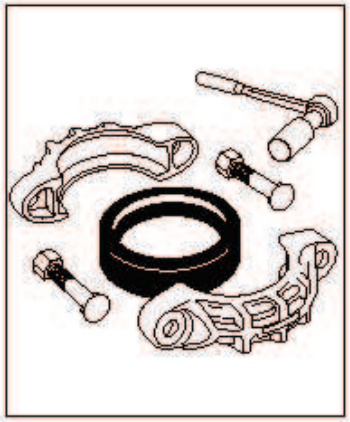
PRODUCT DESCRIPTION

The Victaulic grooved piping system is the most versatile, economical and reliable piping system available. It is up to three times faster to install than welding, easier and more reliable than threading or flanging, resulting in lowest total installed cost.

The system is designed for roll grooved or cut grooved standard pipe or roll grooved light wall pipe. Pipe end preparation is fast and easy either in the shop or on the job site with a variety of Victaulic grooving tools available.

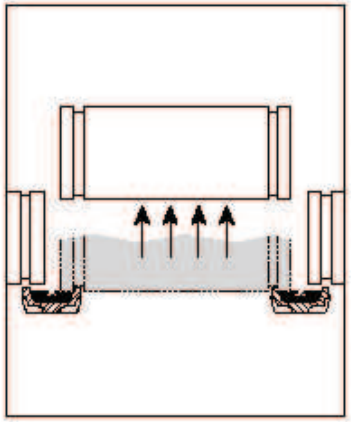
In addition to speed and ease of assembly, the Victaulic system offers varied mechanical benefits to the designer, installer and owner. With the introduction of Zero-Flex® and FireLock® rigid couplings, the option of flexibility or rigidity adds to the design versatility. Flexible and rigid couplings can be incorporated as needed in any system to take full advantage of the characteristics of each.





Installed cost savings from 10% to 30%

• Minimal equipment investment • Fast assembly in tight places • Clean system. . . no pipe dope or welding slag to contaminate pipes • Costs are more predictable. . . estimates more accurate



Each joint is a union

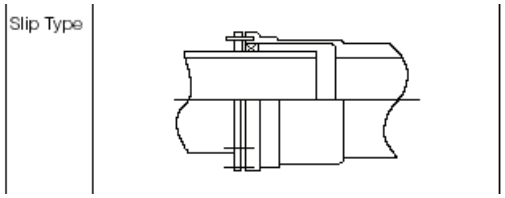
• Removal of two couplings permits removal of pipe section for cleaning or servicing • Easy future add-on, change or renovation of pipe to distribute internal wear from abrasives or slurries

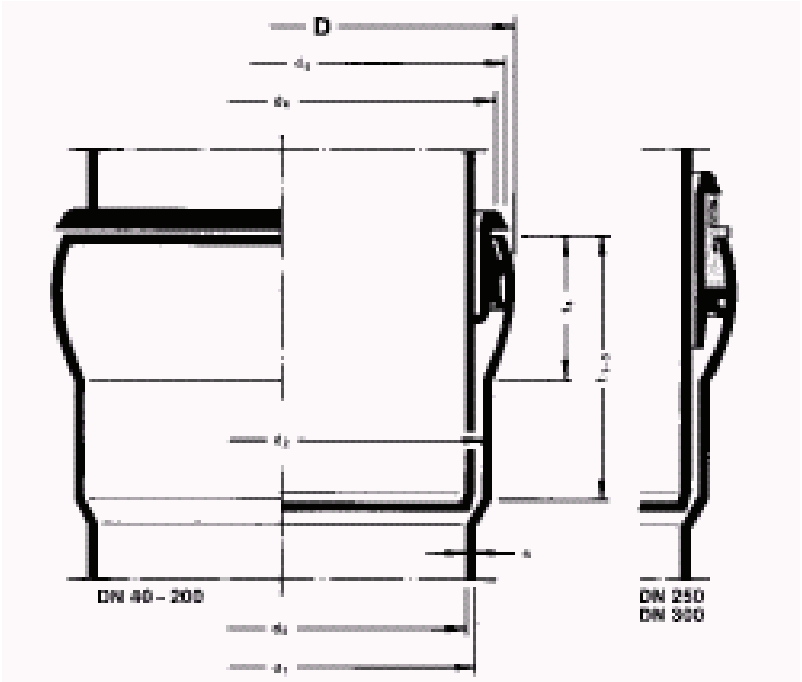
• **WARNING: Depressurize and drain the piping system before attempting to install, remove, or adjust any Victaulic piping products.**

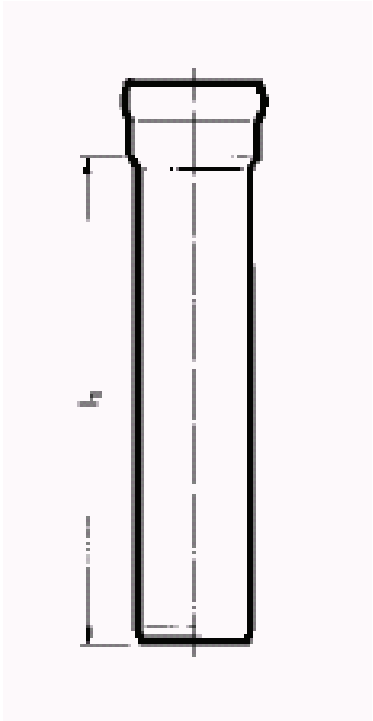
Data: 15/01/2007

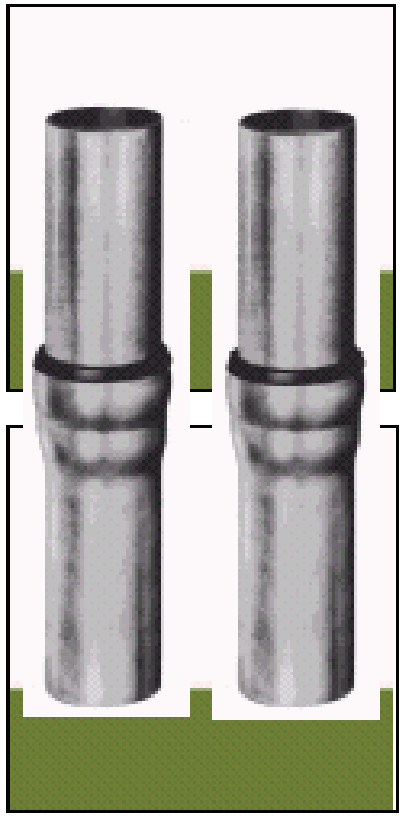
Impianti di propulsione navale

Giunzione meccanica tipo LORO









Data: 15/01/2007

Impianti di propulsione navale

Giunzioni a bicchiere (STECKDRAIN)

Tubazioni e raccordi in acciaio inossidabile
per impianti di scarico a gravità e sottovuoto

Prodotti/Steckdrain

| Specifiche tecniche | Installazione | Programma di fornitura

Descrizione del sistema

Nell'industria, negli ospedali, nelle costruzioni navali, nelle grandi cucine per comunità, le acque reflue sono cariche di svariate sostanze, non di rado corrosive.
In determinate condizioni di concentrazione e di temperature queste sostanze possono danneggiare meccanicamente, chimicamente o per elettrolisi i materiali con cui vengono a contatto.

Se questo genere di acque deve venire evacuato per mezzo di tubazioni, queste tubazioni devono essere in materiali adatti a resistere ragionevolmente a tali agenti corrosivi.

Per soddisfare queste esigenze la STECKDRAIN ha realizzato un programma di tubazioni di scarico in acciaio inossidabile AISI 304, AISI 316 e, per altre esigenze, in materiali diversi.

Programma STECKDRAIN in acciaio inossidabile

I componenti del programma STECKDRAIN, elementi e raccordi, sono ricavati da tubo elettrounito in acciaio inossidabile austenitico.

- Qualità del materiale AISI 304 UNI X 5 Cr Ni 18 10
  oppure
- Qualità del materiale AISI 316 UNI X6 Cr Ni Mo Ti 17 12

Per impieghi particolari si possono avere in altri materiali.

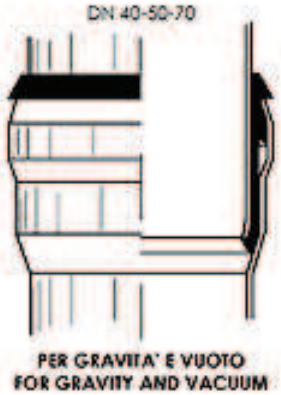
Data: 15/01/2007

Impianti di propulsione navale

Giunzioni a bicchiere (STECKDRAIN)

IL BICCHIERE

Il bicchiere del programma STECKDRAIN è costituito da due spazi anulari entro i quali viene alloggiata la guarnizione ed il tubo che viene infilato.
La particolare conformazione del bicchiere assicura rigidità e stabilità alla giunzione e garantisce l'ermeticità del giunto nel tempo, a dispetto delle tensioni assiali e trasversali che possono agire dall'esterno e dal peso della rete di tubazione.
Il giunto a bicchiere STECKDRAIN è omologato ufficialmente, la produzione delle parti componenti è continuamente sorvegliata e soggetta a periodici controlli esterni.



Data: 15/01/2007

Impianti di propulsione navale

Giunzioni a bicchiere (STECKDRAIN)

Prodotti/Steckdrain

Descrizione | Specifiche tecniche | Installazione | Programma di fornitura

Applicazioni

ANELLI DI TENUTA

L'anello di tenuta è una guarnizione di forma esterna particolare che si alloggia nella sede del bicchiere avente forma corrispondente. Esso viene posizionato in modo tale da agganciarsi al bordo del bicchiere e ricoprirne il bordo esterno. Quando si introduce nel bicchiere l'estremità dell'altro tubo, l'anello viene compresso fra la parete interna del bicchiere e la parete esterna del tubo producendo una perfetta ermeticità.
Il collarino che si aggrappa sopra al bordo del bicchiere ha la duplice funzione di trattenere in posizione l'anello elastico mentre si introduce il tubo e di dimostrare ad assemblaggio avvenuto che gli anelli di tenuta sono in posizione regolare.
All'aumentare della pressione all'interno del tubo, aumenta anche la pressione dell'anello contro le pareti, per cui la tenuta è sempre perfetta.
La guarnizione di serie è in gomma EPDM.

Si possono fornire gli anelli di tenuta nei seguenti materiali:

EPDM = APTK
CR = Neoprene

In casi estremi è possibile fornire gli anelli in FKM (Viton) e Si (Silicone).

SECTION 2 DIESEL ENGINES

1 General

1.1 Application

1.1.1 *(1/7/2005)*

Diesel engines listed below are to be designed, constructed, installed, tested and certified in accordance with the requirements of this Section, under the supervision and to the satisfaction of the Society's Surveyors:

a) main propulsion engines

b) engines driving electrical generators and other auxiliaries essential for safety and navigation and cargo pumps in tankers, when they develop a power of 110 kW and over.

All other engines are to be designed and constructed according to sound marine practice, with the equipment required in [2.3.4], [2.5.2], [2.7.2] [2.7.3], [2.7.5] and [2.7.8] and delivered with the relevant works' certificate (see Pt D, Ch 1, Sec 1, [4.2.3]).

Engines intended for propulsion of lifeboats and compression ignition engines intended for propulsion of rescue boats are to comply with the relevant Rule requirements.

Additional requirements for control and safety systems for dual fuel engines are given in App 2.

In addition to the requirements of this Section, those given in Sec 1 apply.

1.2 Documentation to be submitted

1.2.1 *(1/7/2005)*

For each type of engine that is required to be approved according to a) and b) of [1.1.1], the Manufacturer is to submit to the Society the documents listed in Tab 1.

Plans listed under items [2] and [3] in Tab 1 are also to contain details of the lubricating oil sump in order to demonstrate compliance with Sec 1, [2.4].

Where considered necessary, the Society may request the submission of further documents, including details of evidence of existing type approval or proposals for a type testing program in accordance with [4.2] and [4.3].

Where changes are made to an engine type for which the documents listed in Tab 1 have already been examined or approved, the engine Manufacturer is to resubmit to the Society for consideration and approval only those documents concerning the engine parts which have undergone substantial changes.

If the engines are manufactured by a licensee, the licensee is to submit, for each engine type, a list of all the drawings specified in Tab 1, indicating for each drawing the relevant number and revision status from both licensor and licensee.

Where the licensee proposes design modifications to components, the associated documents are to be submitted by the licensee to the Society for approval or for information purposes. In the case of significant modifications, the licensee is to provide the Society with a statement confirming the licensor's acceptance of the changes. In all cases, the licensee is to provide the Surveyor entrusted to carry out the testing, with a complete set of the documents specified in Tab 1.

1.3 Definitions

1.3.1 Engine type

In general, the type of an engine is defined by the following characteristics:

- the cylinder diameter
- the piston stroke
- the method of injection (direct or indirect injection)
- the kind of fuel (liquid, gaseous or dual-fuel)
- the working cycle (4-stroke, 2-stroke)
- the gas exchange (naturally aspirated or supercharged)
- the maximum continuous power per cylinder at the corresponding speed and/or brake mean effective pressure corresponding to the above-mentioned maximum continuous power
- the method of pressure charging (pulsating system or constant pressure system)
- the charging air cooling system (with or without intercooler, number of stages, etc.)
- cylinder arrangement (in-line or V-type).

1.3.2 Engine power

The maximum continuous power is the maximum power at ambient reference conditions [1.3.3] which the engine is capable of delivering continuously, at nominal maximum speed, in the period of time between two consecutive overhauls.

Power, speed and the period of time between two consecutive overhauls are to be stated by the Manufacturer and agreed by the Society.

The rated power is the maximum power at ambient reference conditions [1.3.3] which the engine is capable of delivering as set after works trials (fuel stop power) at the maximum speed allowed by the governor.

The rated power for engines driving electric generators is the nominal power, taken at the net of overload, at ambient reference conditions [1.3.3], which the engine is capable of delivering as set after the works trials [4.5].

Table 1 : Documentation to be submitted *(1/7/2005)*

No.	I/A/A* **(1)**	Document	Document details
1	I	Engine particulars as per the Society form "Particulars of diesel engines" or equivalent form	-
2	I	Engine transverse cross-section	Max inclination angles, oil surface lines, oil suction strum position
3	I	Engine longitudinal section	Max inclination angles, oil surface lines, oil suction strum position
4	I / A*	Bedplate and crankcase, cast or welded. For welded bedplates or crankcases, welding details and instructions	The weld procedure specification is to include design of welded joints, electrodes used, welding sequence, pre- and post-heat treatment, non-destructive examinations
5	I	Thrust bearing assembly **(2)**	-
6	I / A*	Thrust bearing bedplate, cast or welded. For welded bedplates or cranks, welding details and instructions **(2)**	The weld procedure specification is to include design of welded joints, electrodes used, welding sequence, pre- and post-heat treatment, non-destructive examinations
7	I / A*	Frame/framebox, cast or welded with welding details and instructions **(3)**	The weld procedure specification is to include design of welded joints, electrodes used, welding sequence, pre- and post-heat treatment, non-destructive examinations
8	I	Tie rod	-
9	I	Cylinder head, assembly	-
10	I	Cylinder liner	-
11	A	Crankshaft, details, for each cylinder number	-
12	A	Crankshaft, assembly, for each cylinder number	-
13	A	Thrust shaft or intermediate shaft (if integral with engine)	-
14	A	Shaft coupling bolts	-
15	I	Counterweights (if not integral with crankshaft), with associated fastening bolts	Bolt fastening instructions
16	I	Connecting rod	-
17	I	Connecting rod, assembly	Bolt fastening instructions
18	I	Crosshead, assembly **(4)**	-
19	I	Piston rod, assembly **(4)**	-
20	I	Piston, assembly	-
21	I	Camshaft drive, assembly	-

(1) A = to be submitted for approval, in four copies
A* = to be submitted for approval of materials and weld procedure specifications, in four copies
I = to be submitted for information, in duplicate.
Where two indications I / A are given, the first refers to cast design and the second to welded design.

(2) To be submitted only if the thrust bearing is not integral with the engine and not integrated in the engine bedplate.

(3) Only for one cylinder.

(4) To be submitted only if sufficient details are not shown on the engine transverse and longitudinal cross-sections.

(5) Dimensions and materials of pipes, capacity and head of pumps and compressors and any additional functional information are to be included. The layout of the entire system is also required, if this is part of the goods to be supplied by the engine Manufacturer.

(6) Required only for engines with cylinder bore of 200 mm and above or crankcase gross volume of 0,6 m^3 and above.

(7) Operation and service manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance. Where the operation and service manuals identify special tools and gauges for maintenance purposes, refer to Sec 10, [2.4.5].

(8) For comparison with Society requirements for material, NDT and pressure testing as applicable.

No.	I/A/A* **(1)**	Document	Document details
22	A **(8)**	Material specifications of main parts of engine, with detailed information on: non-destructive tests, and pressure tests	Information on non-destructive tests is required for items 4, 7, 8, 9, 10, 11, 14, 17, 20, including acceptable defects and repair procedures. Information on pressure tests is required for items 4, 7, 9, 10, 20 and for injection pumps and exhaust manifold
23	A	Arrangement of foundation (for main engines only)	-
24	A	Schematic layout or other equivalent documents for starting air system on the engine **(5)**	-
25	A	Schematic layout or other equivalent documents for fuel oil system on the engine **(5)**	-
26	A	Schematic layout or other equivalent documents for lubricating oil system on the engine **(5)**	-
27	A	Schematic layout or other equivalent documents for cooling water system on the engine **(5)**	-
28	A	Schematic diagram of engine control and safety system on the engine **(5)** (see also [2.7])	List, specification and layout of sensors, automatic controls and other control and safety devices
29	I	Failure Mode and Effect Analysis (FMEA) of the electronic control system	The failure mode and effects analysis (FMEA) to demonstrate that failure of an electronic control system will not result in the loss of essential services for the operation of the engine and that operation of the engine will not be lost or degraded beyond an acceptable performance criterion of the engine, where engines incorporate electronic control in systems as per 24 to 28.
30	I	Shielding and insulation of exhaust pipes, assembly	-
31	A	Shielding of high pressure fuel pipes, assembly (see also [2.5.2])	Recovery and leak detection devices
32	A	Crankcase explosion relief valves **(6)** (see also [2.3.4])	Volume of crankcase and other spaces (camshaft drive, scavenge, etc.)
33	I	Operation and service manuals **(7)**	-
34	A	Schematic layout or other equivalent documents of hydraulic system (for valve lift) on the engine	-
35	A	Type test program and type test report	-
36	A	High pressure parts for fuel oil injection system	Specification of pressure, pipe dimensions and materials

(1) A = to be submitted for approval, in four copies
A* = to be submitted for approval of materials and weld procedure specifications, in four copies
I = to be submitted for information, in duplicate.
Where two indications I / A are given, the first refers to cast design and the second to welded design.

(2) To be submitted only if the thrust bearing is not integral with the engine and not integrated in the engine bedplate.

(3) Only for one cylinder.

(4) To be submitted only if sufficient details are not shown on the engine transverse and longitudinal cross-sections.

(5) Dimensions and materials of pipes, capacity and head of pumps and compressors and any additional functional information are to be included. The layout of the entire system is also required, if this is part of the goods to be supplied by the engine Manufacturer.

(6) Required only for engines with cylinder bore of 200 mm and above or crankcase gross volume of 0,6 m^3 and above.

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(8) For comparison with Society requirements for material, NDT and pressure testing as applicable.

1.3.3 Ambient reference conditions

The power of engines as per [1.1.1] (a), (b) and (c) is to be referred to the following conditions:

- barometric pressure = 0,1 MPa
- relative humidity = 60%
- ambient air temperature = 45°C
- sea water temperature (and temperature at inlet of sea water cooled charge air cooler) = 32°C.

In the case of ships assigned with a navigation notation other than unrestricted navigation, different temperatures may be accepted by the Society.

The engine Manufacturer is not expected to provide the above ambient conditions at a test bed. The rating is to be adjusted according to a recognised standard accepted by the Society.

1.3.4 Same type of engines

Two diesel engines are considered to be of the same type when they do not substantially differ in design and construction characteristics, such as those listed in the engine type definition as per [1.3.1], it being taken for granted that the documentation concerning the essential engine components listed in [1.2] and associated materials employed has been submitted, examined and, where necessary, approved by the Society.

2 Design and construction

2.1 Materials and welding

2.1.1 Crankshaft materials

In general, crankshafts are to be of forged steel having a tensile strength not less than 400 N/mm^2 and not greater than 1000 N/mm^2.

The use of forged steels of higher tensile strength is subject to special consideration by the Society in each case.

The Society, at its discretion and subject to special conditions (such as restrictions in ship navigation), may accept crankshafts made of cast carbon steel, cast alloyed steel or spheroidal or nodular graphite cast iron of appropriate quality and manufactured by a suitable procedure having a tensile strength as follows:

a) between 400 N/mm^2 and 560 N/mm^2 for cast carbon steel

b) between 400 N/mm^2 and 700 N/mm^2 for cast alloyed steel.

The acceptable values of tensile strength for spheroidal or nodular graphite cast iron will be considered by the Society on a case by case basis.

2.1.2 Welded frames and foundations

Steels used in the fabrication of welded frames and bedplates are to comply with the requirements of Part D.

Welding is to be in accordance with the requirements of Sec 1, [2.2].

2.2 Crankshaft

2.2.1 Check of the scantling

The check of crankshaft strength is to be carried out in accordance with App 1.

2.3 Crankcase

2.3.1 Strength *(1/1/2006)*

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 in [2.3.4]. Crankcase doors are to be fastened sufficiently securely for them not be readily displaced by a crankcase explosion.

2.3.2 Ventilation and drainage *(1/1/2006)*

Ventilation of the crankcase, or any arrangement which could produce a flow of external air within the crankcase, is in principle not permitted except for dual fuel engines, where crankcase ventilation is to be provided in accordance with App 2, [2.1.2]

Where provided, crankcase ventilation pipes are to be as small as practicable to minimise the inrush of air after a crankcase explosion.

If forced extraction of the oil mist atmosphere gases from the crankcase is provided (for mist smoke detection purposes, for instance), the vacuum in the crankcase is not to exceed 2,5 x 10^{-4} N/mm^2.

To avoid interconnection between crankcases and the possible spread of fire following an explosion, crankcase ventilation pipes and oil drain pipes for each engine are to be independent of any other engine.

Lubricating oil drain pipes from the engine sump to the drain tank are to be submerged at their outlet ends.

2.3.3 Warning notice

A warning notice is to be fitted either on the control stand or, preferably, on a crankcase door on each side of the engine.

This warning notice is to specify that, whenever overheating is suspected within the crankcase, the crankcase doors or sight holes are not to be opened before a reasonable time has elapsed, sufficient to permit adequate cooling after stopping the engine.

2.3.4 Relief valves *(1/1/2007)*

a) Diesel engines of a cylinder diameter of 200 mm and above or a crankcase gross volume of 0,6 m^3 and above are to be provided with crankcase explosion relief valves according to the requirements of this item [2.3.4].

   The total volume of the stationary parts within the crankcase may be discounted in estimating the crankcase gross volume (rotating and reciprocating components are to be included in the gross volume).

b) Relief valves are to be provided with lightweight spring-loaded valve discs or other quick-acting and self-closing devices to relieve a crankcase of pressure in the event of

an internal explosion and to prevent the inrush of air thereafter.

The valve discs in relief valves are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

Relief valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0,02 N/mm^2.

The free area of each crankcase explosion relief valve is not to be less than 45 cm^2. The aggregate free area of the valves fitted on an engine is not to be less than 115 cm^2 per cubic metre of the crankcase gross volume.

Relief valves are to be provided with a flame arrester that permits flow for crankcase pressure relief and prevents passage of flame following a crankcase explosion.

Relief valves are to be type approved. Type testing is to be carried out in a configuration that represents the installation arrangements that will be used on an engine in accordance with App 5.

Where relief valves are provided with arrangements for shielding emissions from the valve following an explosion, the valve is to be type tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valve.

c) Relief valves are to be provided with a copy of the Manufacturer's installation and maintenance manual that is pertinent to the size and type of valve being supplied for installation on a particular engine.

The manual is to contain the following information:

1) Description of valve with details of function and design limits
2) Copy of type test certification
3) Installation instructions
4) Maintenance in service instructions to include testing and renewal of any sealing arrangements
5) Actions required after a crankcase explosion.

A copy of the installation and maintenance manual required above is to be provided on board ship.

Plans showing details and arrangements of crankcase explosion relief valves are to be submitted for approval in accordance withTab 1.

Valves are to be provided with suitable markings that include the following information:

- Name and address of Manufacturer
- Designation and size
- Month/Year of manufacture
- Approved installation orientation.

d) Engines of a cylinder diameter of 200 mm and above, but not exceeding 250 mm, are to have at least one valve near each end; however, for engines with more than 8 crankthrows, an additional valve is to be fitted near the middle of the engine.

Engines of a cylinder diameter of 250 mm and above, but not exceeding 300 mm, are to have at least one valve in way of each alternate crankthrow, with a minimum of two valves.

Engines of a cylinder diameter exceeding 300 mm are to have at least one valve in way of each main crankthrow.

e) 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 m^3 or above.

Scavenge spaces in open connection to the cylinders are to be fitted with explosion relief valves.

2.3.5 Oil mist detection/monitoring arrangements *(1/1/2007)*

Where crankcase oil mist detection/monitoring arrangements are to be fitted to engines, they are to be type approved and tested in accordance with App 6 and are to comply with the requirements indicated hereafter.

The oil mist detection/monitoring 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:

- Schematic layout of engine oil mist detection/monitoring and alarm system showing location of engine crankcase sample points and piping arrangements together with pipe dimensions to detector/monitor
- Evidence of study to justify the selected location of sample points and sample extraction rate (if applicable) in consideration of the crankcase arrangements and geometry and the predicted crankcase atmosphere where oil mist can accumulate
- The Manufacturer's maintenance and test manual
- Information relating to type or in-service testing of the engine carried out with engine protection system test arrangements having approved types of oil mist monitoring equipment.

A copy of the oil mist detection/monitoring equipment maintenance and test manual required above is to be provided on board ship.

Oil mist monitoring and alarm information is to be capable of being read from a safe location away from the engine.

Where there are multi-engine installations, each engine is to be provided with oil mist detection/monitoring and a dedicated alarm.

Oil mist detection/monitoring and alarm systems are to be capable of being tested on the test bed and on board under engine at standstill and engine running at normal operating conditions in accordance with test procedures that are acceptable to the Society.

Alarms and shutdowns for the oil mist detection/monitoring system are to be in accordance with Pt F, Ch 3, Sec 1, Tab 2, Pt F, Ch 3, Sec 1, Tab 3 and Pt F, Ch 3, Sec 1, Tab 27 and the system arrangements are to comply with Ch 3, Sec 2, [6] and Ch 3, Sec 2, [7].

The oil mist detection/monitoring arrangements are to provide an alarm indication in the event of a foreseeable functional failure in the equipment and installation arrangements.

The oil mist detection/monitoring 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.

Where oil mist detection/monitoring equipment includes the use of programmable electronic systems, the arrangements are to be in accordance with Chapter 3.

Plans showing details and arrangements of oil mist detection/monitoring and alarm arrangements are to be submitted for approval in accordance with Tab 1.

The equipment together with detectors/monitors is to be tested when installed on the test bed and on board ship to demonstrate that the detection/monitoring and alarm system functionally operates. The testing arrangements are to be to the satisfaction of the Society.

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

Where alternative methods are provided for the prevention of the build-up of potentially explosive oil mist conditions within the crankcase, details are to be submitted for consideration. The following information is to be included in the details to be submitted for consideration:

- 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, e.g. bearing temperature monitoring, oil splash temperature, crankcase pressure monitoring, recirculation arrangements
- 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 minimise a potential crankcase explosion, details of the arrangements are to be submitted to the Society for consideration.

2.4 Scavenge manifolds

2.4.1 Fire extinguishing

For two-stroke crosshead type engines, scavenge spaces in open connection (without valves) to the cylinders are to be connected to a fixed fire-extinguishing system, which is to be entirely independent of the fire-extinguishing system of the machinery space.

2.4.2 Blowers

Where a single two-stroke propulsion engine is equipped with an independently driven blower, alternative means to drive the blower or an auxiliary blower are to be provided ready for use.

2.4.3 Relief valves

Scavenge spaces in open connection to the cylinders are to be fitted with explosion relief valves in accordance with [2.3.4].

2.5 Systems

2.5.1 General

In addition to the requirements of the present sub-article, those given in Sec 10 are to be satisfied.

Flexible hoses in the fuel and lubricating oil system are to be limited to the minimum and are to be type approved.

Unless otherwise stated in Sec 10, propulsion engines are to be equipped with external connections for standby pumps for:

- fuel oil supply
- lubricating oil and cooling water circulation.

2.5.2 Fuel oil system

Relief valves discharging back to the suction of the pumps or other equivalent means are to be fitted on the delivery side of the pumps.

In fuel oil systems for propulsion machinery, filters are to be fitted and arranged so that an uninterrupted supply of filtered fuel oil is ensured during cleaning operations of the filter equipment, except when otherwise stated in Sec 10.

a) *All external high pressure fuel delivery lines between the high pressure fuel pumps and fuel injectors are to be protected with a shielded piping system capable of containing fuel from a high pressure line failure.*

A shielded pipe incorporates an outer pipe into which the high pressure fuel pipe is placed forming a permanent assembly.

The shielded piping system is to include a means for collection of leakages and arrangements are to be provided for an alarm to be given in the event of a fuel line failure.

If flexible hoses are used for shielding purposes, these are to be approved by the Society.

When in fuel oil return piping the pulsation of pressure with peak to peak values exceeds 2 MPa, shielding of this piping is also required as above.

b) For ships classed for restricted navigation, the requirements under a) may be relaxed at the Society's discretion.

2.5.3 Lubricating oil system

Efficient filters are to be fitted in the lubricating oil system when the oil is circulated under pressure.

In such lubricating oil systems for propulsion machinery, filters are to be arranged so that an uninterrupted supply of filtered lubricating oil is ensured during cleaning operations of the filter equipment, except when otherwise stated in Sec 10.

Relief valves discharging back to the suction of the pumps or other equivalent means are to be fitted on the delivery side of the pumps.

The relief valves may be omitted provided that the filters can withstand the maximum pressure that the pump may develop.

Where necessary, the lubricating oil is to be cooled by means of suitable coolers.

2.5.4 Charge air system

a) Requirements relevant to design, construction, arrangement, installation, tests and certification of exhaust gas turbochargers are given in Sec 14.

b) When two-stroke propulsion engines are supercharged by exhaust gas turbochargers which operate on the impulse system, provision is to be made to prevent broken piston rings entering turbocharger casings and causing damage to blades and nozzle rings.

2.6 Starting air system

2.6.1 The requirements given in [3.1] apply.

2.7 Control and monitoring

2.7.1 General *(1/7/2006)*

In addition to those of this item [2.7], the general requirements given in Chapter 3 apply.

In the case of ships with automation notations, the requirements in Part F, Chapter 3 also apply.

2.7.2 Alarm

The lubricating oil system of diesel engines with a power equal to or in excess of 37 kW is to be fitted with alarms to give audible and visual warning in the event of an appreciable reduction in pressure of the lubricating oil supply.

2.7.3 Governors of main and auxiliary engines

Each engine, except the auxiliary engines for driving electric generators for which [2.7.5] applies, is to be fitted with a speed governor so adjusted that the engine does not exceed the rated speed by more than 15%.

2.7.4 Overspeed protective devices of main and auxiliary engines

In addition to the speed governor, each

- main propulsion engine having a rated power of 220kW and above, which can be declutched or which drives a controllable pitch propeller, and
- auxiliary engine having a rated power of 220kW and above, except those for driving electric generators, for which [2.7.6] applies

is to be fitted with a separate overspeed protective device so adjusted that the engine cannot exceed the rated speed n by more than 20%; arrangements are to be made to test the overspeed protective device.

Equivalent arrangements may be accepted subject to special consideration by the Society in each case.

The overspeed protective device, including its driving mechanism or speed sensor, is to be independent of the governor.

2.7.5 Governors for auxiliary engines driving electric generators *(1/1/2007)*

a) Auxiliary engines intended for driving electric generators are to be fitted with a speed governor which prevents transient frequency variations in the electrical network in excess of ±10% of the rated frequency with a recovery time to steady state conditions not exceeding 5 seconds, when the maximum electrical step load is switched on or off.

When a step load equivalent to the rated output of a generator is switched off, a transient speed variation in excess of 10% of the rated speed may be acceptable, provided this does not cause the intervention of the overspeed device as required by [2.7.4].

b) At all loads between no load and rated power, the permanent speed variation is not to be more than 5% of the rated speed.

c) Prime movers are to be selected in such a way that they meet the load demand within the ship's mains and, when running at no load, can satisfy the requirement in item a) above if suddenly loaded to 50% of the rated power of the generator, followed by the remaining 50% after an interval sufficient to restore speed to steady state. Steady state conditions (see Note 1) are to be achieved in not more than 5 s.

Note 1: Steady state conditions are those at which the envelope of speed variation does not exceed ±1% of the declared speed at the new power.

d) Application of the the electrical load in more than 2 load steps can only be allowed if the conditions within the ship's mains permit the use of those auxiliary engines which can only be loaded in more than 2 load steps (see Fig 1 for guidance) and provided that this is already allowed for in the designing stage.

This is to be verified in the form of system specifications to be approved and to be demonstrated at ship's trials. In this case, due consideration is to be given to the power required for the electrical equipment to be automatically switched on after blackout and to the sequence in which it is connected

This also applies to generators to be operated in parallel and where the power is to be transferred from one generator to another, in the event that any one generator is to be switched off.

e) Emergency generator sets must satisfy the governor conditions as per items a) and b), even when:

1) their total consumer load is applied suddenly, or

2) their total consumer load is applied in steps, provided that:

- the total load is supplied within 45 seconds of power failure on the main switchboard, and
- the maximum step load is declared and demonstrated, and
- the power distribution system is designed such that the declared maximum step loading is not exceeded, and
- compliance of time delays and loading sequence with the above is demonstrated at ship's trials.

f) For alternating current generating sets operating in parallel, the governing characteristics of the prime movers are to be such that, within the limits of 20% and 100% total load, the load on any generating set will not normally differ from its proportionate share of the total load by more than 15% of the rated power in kW of the larg-

est machine or 25% of the rated power in kW of the individual machine in question, whichever is the lesser.

For alternating current generating sets intended to operate in parallel, facilities are to be provided to adjust the governor sufficiently finely to permit an adjustment of load not exceeding 5% of the rated load at normal frequency.

2.7.6 Overspeed protective devices of auxiliary engines driving electric generators

In addition to the speed governor, auxiliary engines of rated power equal to or greater than 220 kW driving electric generators are to be fitted with a separate overspeed protective device, with a means for manual tripping, adjusted so as to prevent the rated speed from being exceeded by more than 15%.

This device is to automatically shut down the engine.

2.7.7 Use of electronic governors *(1/7/2004)*

a) Type approval

Electronic governors and their actuators are to be type approved by the Society, according to Ch 3, Sec 6.

b) Electronic governors for main propulsion engines

If an electronic governor is fitted to ensure continuous speed control or resumption of control after a fault, an additional separate governor is to be provided unless the engine has a manually operated fuel admission control system suitable for its control.

A fault in the governor system is not to lead to sudden major changes in propulsion power or direction of propeller rotation.

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

The acceptance of electronic governors not in compliance with the above requirements will be considered by the Society on a case by case basis, when fitted on ships with two or more main propulsion engines.

c) Electronic governors for auxiliary engines driving electric generators

In the event of a fault in the electronic governor system the fuel admission is to be set to “zero”.

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

The acceptance of electronic governors fitted on engines driving emergency generators will be considered by the Society on a case by case basis.

2.7.8 Alarms and safeguards for emergency diesel engines *(1/1/2006)*

a) These requirements apply to diesel engines required to be immediately available in an emergency (i.e. emergency generating set engine, emergency fire pump engine, etc.) and capable of being controlled remotely or automatically operated.

b) Information demonstrating compliance with these requirements is to be submitted to the Society. The information is to include instructions to test the alarm and safety systems.

c) The alarms and safeguards are to be fitted in accordance with Tab 4.

d) The safety and alarm systems are to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the system and its associated machinery, but also the complete installation, as well as the ship.

e) Regardless of the engine output, if shutdowns additional to those specified inTab 4, except for the overspeed shutdown, are provided, they are to be automatically overridden when the engine is in automatic or remote control mode during navigation.

f) The alarm system is to function in accordance with Part F, Chapter 3 with the additional requirement that grouped alarms are to be arranged on the bridge.

g) In addition to the fuel oil control from outside the space, a local means of engine shutdown is to be provided.

h) Local indications of at least those parameters listed in are Tab 4 to be provided within the same space as the diesel engines and are to remain operational in the event of failure of the alarm and safety systems.

2.7.9 Summary tables *(1/1/2006)*

Diesel engines are to be equipped with monitoring equipment as detailed in Tab 2 and Tab 3, for main propulsion and auxiliary services, respectively.

For ships classed for restricted navigation, the acceptance of a reduction in the monitoring equipment required in Tab 2 and Tab 3 may be considered.

The alarms are to be visual and audible.

The indicators are to be fitted at a normally attended position (on the engine or at the local control station).

In the case of diesel engines required to be immediately available in an emergency and capable of being controlled remotely or automatically operated, Tab 4 applies.

3 Arrangement and installation

3.1 Starting arrangements

3.1.1 Mechanical air starting

a) Air starting the main and auxiliary engines is to be arranged such that the necessary air for the first charge can be produced on board the ship without external aid.

b) The total capacity of air receivers is to be sufficient to provide, without replenishment, not less than 12 consecutive starts alternating between ahead and astern of each main engine of the reversible type, and not less than 6 consecutive starts of each main non-reversible type engine connected to a controllable pitch propeller or other device enabling the start without opposite torque.

The number of starts refers to the engine in cold and ready-to-start condition (all the driven equipment that cannot be disconnected is to be taken into account).

A greater number of starts may be required when the engine is in warm running condition.

When other users such as auxiliary engine starting systems, control systems, whistle etc. are connected to the starting air receivers of main propulsion engines, their air consumption is also to be taken into account.

Regardless of the above, for multi-engine installations the number of starts required for each engine may be reduced subject to the agreement of the Society and depending upon the arrangement of the engines and the transmission of their output to the propellers.

c) The main starting air arrangements for main propulsion or auxiliary diesel engines are to be adequately protected against the effects of backfiring and internal explosion in the starting air pipes. To this end, the following safety devices are to be fitted:

- An isolating non-return valve, or equivalent, at the starting air supply connection to each engine.
- A bursting disc or flame arrester:
  - in way of the starting valve of each cylinder, for direct reversing engines having a main starting air manifold
  - at least at the supply inlet to the starting air manifold, for non-reversing engines.

  The bursting disc or flame arrester above may be omitted for engines having a bore not exceeding 230 mm.

Other protective devices will be specially considered by the Society.

The requirements of this item c) do not apply to engines started by pneumatic motors.

d) Compressed air receivers are to comply with the requirements of Sec 3. Compressed air piping and associated air compressors are to comply with the requirements of Sec 10.

Figure 1 : Limiting curves for loading 4-stroke diesel engines step by step from no load to rated power as a function of the brake mean effective pressure

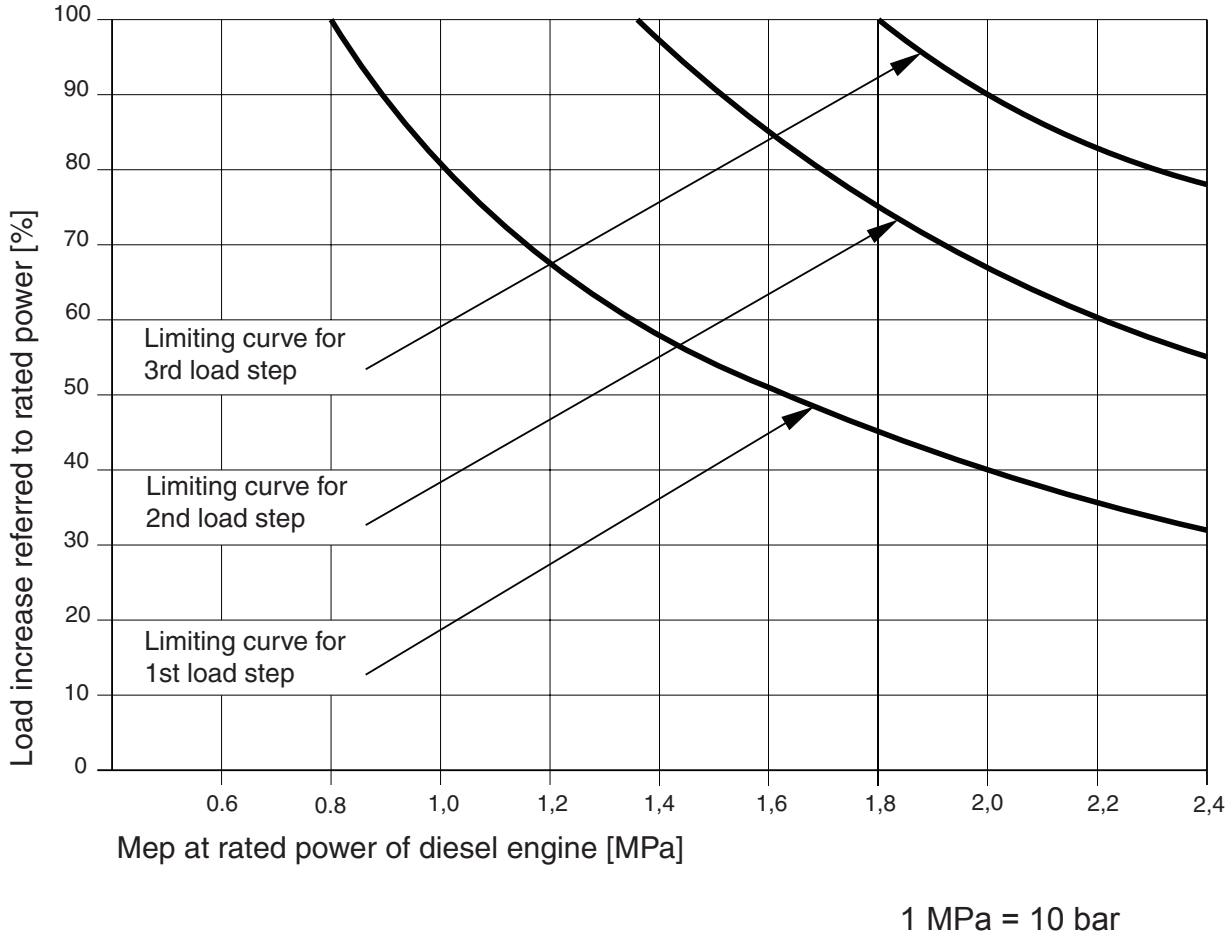


Table 2 : Monitoring of main propulsion diesel engines *(1/7/2006)*

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil pressure after filter (engine inlet)		local					
Fuel oil viscosity before injection pumps or fuel oil temperature before injection pumps (For engine running on heavy fuel)		local					
Leakage from high pressure pipes where required	H						
Lubricating oil to main bearing and thrust bearing pressure	L	local					
	LL			X			
Lubricating oil to cross-head bearing pressure when separate	L	local					
	LL			X			
Lubricating oil to camshaft pressure when separate	L	local					
	LL			X			
Turbocharger lubricating oil inlet pressure		local					
Lubricating oil inlet temperature		local					
Thrust bearing pads or bearing outlet temperature	H	local					
Cylinder fresh cooling water system inlet pressure	L	local **(3)**					
Cylinder fresh cooling water outlet temperature or, when common cooling space without individual stop valves, the common cylinder water outlet temperature		local					
Piston coolant inlet pressure on each cylinder **(1)**	L	local					
Piston coolant outlet temperature on each cylinder **(1)**		local					
Piston coolant outlet flow on each cylinder **(1) (2)**	L						
Scavenging air receiver pressure		local					
Scavenging air box temperature (Detection of fire in receiver)		local					
Exhaust gas temperature		local **(4)**					
Engine speed / direction of speed (when reversible)		local					
	H			X			
Fault in the electronic governor system	X						

(1) Not required, if the coolant is oil taken from the main cooling system of the engine
(2) Where outlet flow cannot be monitored due to engine design, alternative arrangement may be accepted
(3) For engines of 220 kW and above
(4) Indication is required after each cylinder, for engines of 500 kW/cylinder and above

Table 3 : Monitoring of diesel engines used for auxiliary services *(1/1/2006)*

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil viscosity or temperature before injection **(2)**		local					
Fuel oil pressure **(2)**		local					
Fuel oil leakage from pressure pipes	H						
Lubricating oil pressure	L	local		X **(1)**			
Pressure or flow of cooling water, if not connected to main system	L	local					
Temperature of cooling water or cooling air		local					
Engine speed		local					
	H			X **(3)**			
Fault in the electronic governor system	X						

(1) Not acceptable to emergency generator set
(2) Where heavy fuel is used
(3) Only requested for diesel engines having rating of 220 kW and above

Table 4 : Monitoring of diesel engines required to be immediately available in an emergency and capable of being controlled remotely or automatically operated *(1/1/2006)*

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil leakage from pressure pipes	H						
Lubricating oil pressure	L	local					
Lubricating oil temperature **(1)**	H	local					
Pressure or flow of cooling water **(1)**	L	local					
Oil mist concentration in crankcase **(2)**	H	local					
Temperature of cooling water or cooling air	H	local					
Engine speed		local					
	H **(1)**			X **(1)**			
Fault in the electronic governor system	X						

(1) Requested only for diesel engines having rating of 220 kW and above.
(2) Requested only for diesel engines having rating of 2250 kW and above or cylinder bore of 300 mm and above

3.1.2 Electrical starting

a) Where main internal combustion engines are arranged for electrical starting, at least two separate batteries are to be fitted.

The arrangement is to be such that the batteries cannot be connected in parallel.

Each battery is to be capable of starting the main engine when in cold and ready to start condition.

The combined capacity of batteries is to be sufficient to provide within 30 min, without recharging, the number of starts required in [3.1.1] (b) in the event of air starting.

b) Electrical starting arrangements for auxiliary engines are to have two separate storage batteries or may be supplied by two separate circuits from main engine storage

batteries when these are provided. In the case of a single auxiliary engine, one battery is acceptable. The combined capacity of the batteries is to be sufficient for at least three starts for each engine.

c) The starting batteries are only to be used for starting and for the engine's alarm and monitoring. Provision is to be made to maintain the stored energy at all times.

d) Each charging device is to have at least sufficient rating for recharging the required capacity of batteries within 6 hours.

3.1.3 Special requirements for starting arrangements for emergency generating sets

a) Emergency generating sets are to be capable of being readily started in their cold condition at a temperature of 0°C. If this is impracticable, or if lower temperatures are likely to be encountered, provision acceptable to the Society shall be made for the maintenance of heating arrangements, to ensure ready starting of the generating sets.

b) Each emergency generating set arranged to be automatically started shall be equipped with starting devices approved by the Society with a stored energy capability of at least three consecutive starts.

The source of stored energy shall be protected to preclude critical depletion by the automatic starting system, unless a second independent means of starting is provided. In addition, a second source of energy shall be provided for an additional three starts within 30 minutes, unless manual starting can be demonstrated to be effective.

c) The stored energy is to be maintained at all times, as follows:

- *electrical and hydraulic starting systems shall be maintained from the emergency switchboard*
- *compressed air starting systems may be maintained by the main or auxiliary compressed air receivers through a suitable non-return valve or by an emergency air compressor which, if electrically driven, is supplied from the emergency switchboard*
- *all of these starting, charging and energy storing devices are to be located in the emergency generator space; these devices are not to be used for any purpose other than the operation of the emergency generating set. This does not preclude the supply to the air receiver of the emergency generating set from the main or auxiliary compressed air system through the non-return valve fitted in the emergency generator space.*

d) Where automatic starting is not required, manual starting, such as manual cranking, inertia starters, manually charged hydraulic accumulators, or powder charge cartridges, is permissible where this can be demonstrated as being effective.

e) When manual starting is not practicable, the requirements of (b) and (c) are to be complied with, except that starting may be manually initiated.

3.2 Turning gear

3.2.1 Each engine is to be provided with hand-operated turning gear; where deemed necessary, the turning gear is to be both hand and mechanically-operated.

The turning gear engagement is to inhibit starting operations.

3.3 Trays

3.3.1 Trays fitted with means of drainage are to be provided in way of the lower part of the crankcase and, in general, in way of the parts of the engine, where oil is likely to spill in order to collect the fuel oil or lubricating oil dripping from the engine.

3.4 Exhaust gas system

3.4.1 In addition to the requirements given in Sec 10, the exhaust system is to be efficiently cooled or insulated in such a way that the surface temperature does not exceed 220°C (see also Sec 1, [3.7]).

4 Type tests, material tests, workshop inspection and testing, certification

4.1 Type tests - General

4.1.1 Upon finalisation of the engine design for production of every new engine type intended for installation on board ships, one engine is to be presented for type testing as required below.

A type test carried out for a particular type of engine at any place in any manufacturer's works will be accepted for all engines of the same type (see [1.3.4]) built by licensees and licensors.

In any case, one type test suffices for the whole range of engines having different numbers of cylinders.

Engines which are subjected to type testing are to be tested in accordance with the scope specified below, it being taken for granted that:

- the engine is optimised as required for the conditions of the type test
- the investigations and measurements required for reliable engine operation have been carried out during preliminary internal tests by the engine Manufacturer
- the documentation to be submitted as required in [1.2] has been examined and, when necessary, approved by the Society and the latter has been informed about the nature and extent of investigations carried out during pre-production stages.

4.1.2 At the request of the Manufacturer, an increase in power and/or mean effective pressure up to a maximum of 10% may be accepted by the Society for an engine previously subjected to a type test without any further such test being required, provided the engine reliability has been

proved successfully by the service experience of a sufficient number of engines of the same type.

For the purpose of the acceptance of the above performance increase, the Manufacturer is in any case to submit for examination and, where necessary, approval, the documentation listed in [1.2] relevant to any components requiring modification in order to achieve the increased performance.

4.2 Type tests of engines not admitted to an alternative inspection scheme

4.2.1 General

Engines which are not admitted to testing and inspections according to an alternative inspection scheme (see Pt D, Ch 1, Sec 1, [3.2]) are to be type tested in the presence of a Surveyor in accordance with the requirements of this item [4.2].

The type test is subdivided into three stages, namely:

a) Stage A - Preliminary internal tests carried out by the Manufacturer.

Stage A includes functional tests and collection of operating values including the number of testing hours during the internal tests, the results of which are to be presented to the Surveyor during the type test. The number of testing hours of components which are inspected according to [4.2.5] is to be stated by the Manufacturer.

b) Stage B - Type approval test

The type approval test is to be carried out in the presence of the Surveyor.

c) Stage C - Inspection of main engine components.

After completion of the test programme, the main engine components are to be inspected.

The engine Manufacturer is to compile all results and measurements for the engine tested during the type test in a type test report, which is to be submitted to the Society.

4.2.2 Stage A - Internal tests (function tests and collection of operating data)

During the internal tests the engine is to be operated at the load points considered important by the engine Manufacturer and the relevant operating values are to be recorded (see item (a)).

The load points may be selected according to the range of application (see Fig 2).

If an engine can be satisfactorily operated at all load points without using mechanically driven cylinder lubricators, this is to be verified.

For engines which may operate on heavy fuel oil, their suitability for this is to be proved to the satisfaction of the Society.

a) Functional tests under normal operating conditions

Functional tests under normal operating conditions include:

1) The load points 25%, 50%, 75%, 100% and 110% of the maximum continuous power for which type approval is requested, to be carried out:
   - along the nominal (theoretical) propeller curve and at constant speed, for propulsion engines
   - at constant speed, for engines intended for generating sets.
2) The limit points of the permissible operating range.

   These limit points are to be defined by the engine Manufacturer.

The maximum continuous power P is defined in [1.3.2].

b) Tests under emergency operating conditions

For turbocharged engines, the achievable continuous output is to be determined for a situation when one turbocharger is damaged, i.e.:

- for engines with one turbocharger, when the rotor is blocked or removed;
- for engines with two or more turbochargers, when the damaged turbocharger is shut off.

4.2.3 Stage B - Type approval tests in the presence of the Surveyor

During the type test, the tests listed below are to be carried out in the presence of the Surveyor and the results are to be recorded in a report signed by both the engine Manufacturer and the Surveyor.

Any departures from this programme are to be agreed upon by the engine Manufacturer and the Society.

a) Load points

The load points at which the engine is to be operated according to the power/speed diagram (see Fig 2) are those listed below. The data to be measured and recorded when testing the engine at various load points are to include all necessary parameters for engine operation.

The operating time per load point depends on the engine characteristics (achievement of steady-state condition) and the time for collection of the operating values.

Normally, an operating time of 0,5 hour per load point can be assumed.

At the maximum continuous power as per the following item (1) an operating time of two hours is required. Two sets of readings are to be taken at a minimum interval of one hour.

1) Test at maximum continuous power P: i.e. 100% output at 100% torque and 100% speed, corresponding to load point 1 in the diagram in Fig 2.
2) Test at 100% power at maximum permissible speed, corresponding to load point 2 in the diagram in Fig 2.
3) Test at maximum permissible torque (normally 110% of nominal torque T) at 100% speed, corresponding to load point 3 in the diagram in Fig 2; or test at maximum permissible power (normally 110% of P) and speed according to the nominal propeller

curve, corresponding to load point 3a in the diagram in Fig 2.

4) Test at minimum permissible speed at 100% of torque T, corresponding to load point 4 in the diagram in Fig 2.

5) Test at minimum permissible speed at 90% of torque T, corresponding to load point 5 in the diagram in Fig 2.

6) Tests at part loads, e.g. 75%, 50%, 25% of maximum continuous power P and speed according to the nominal propeller curve, corresponding to load points 6, 7 and 8 in the diagram in Fig 2; and tests at the above part loads and at speed n with constant governor setting, corresponding to load points 9, 10 and 11 in the diagram in Fig 2.

b) Tests under emergency operating conditions

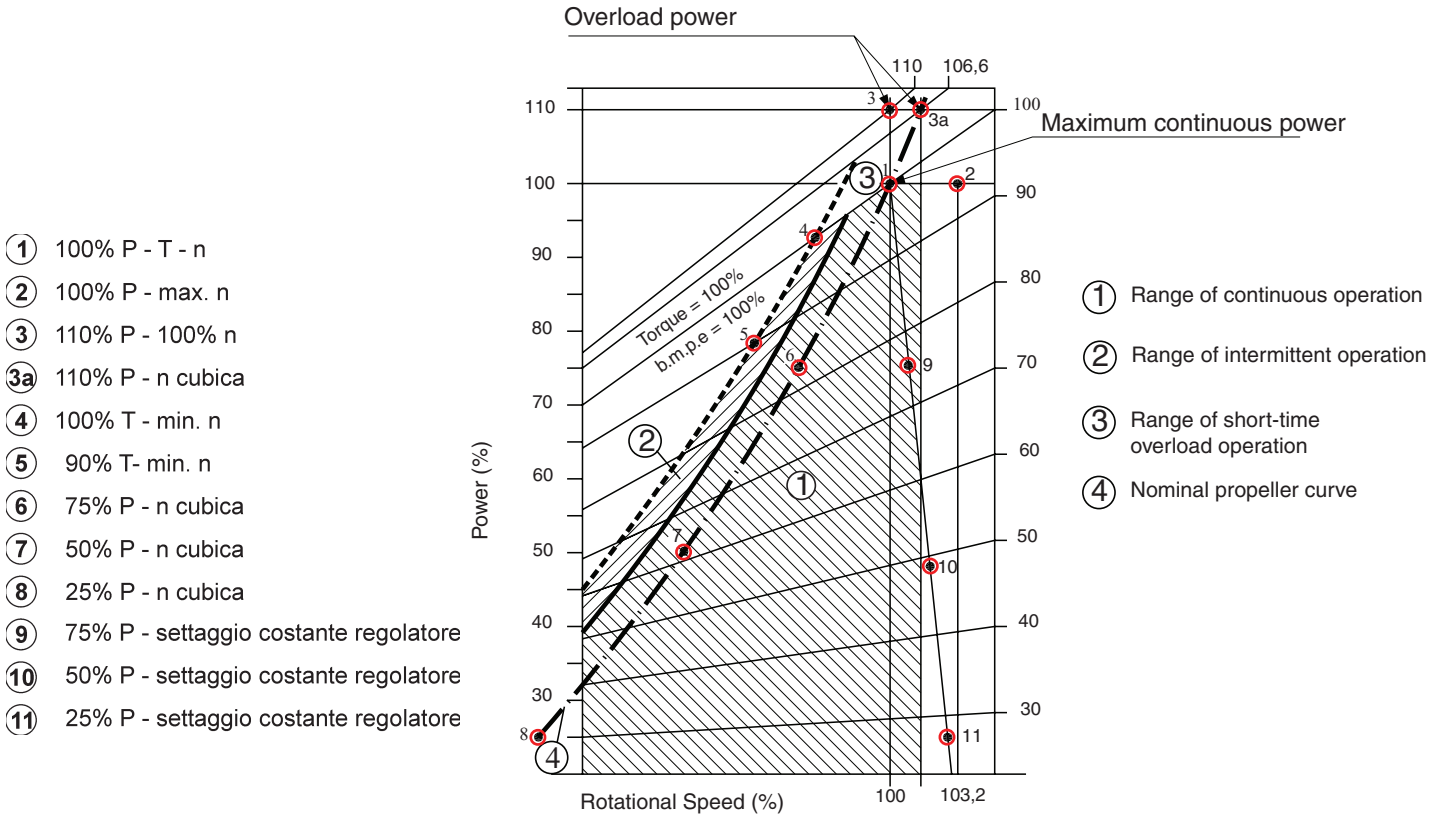
These are tests at maximum achievable power when operating along the nominal propeller curve and when operating with constant governor setting for speed n, in emergency operating conditions as stated in [4.2.2] (b).

c) Additional tests

- Test at lowest engine speed according to the nominal propeller curve.
- Starting tests for non-reversible engines, or starting and reversing tests for reversible engines.
- Governor tests.
- Testing of the safety system, particularly for overspeed and low lubricating oil pressure.

For engines intended to be used for emergency services, supplementary tests may be required to the satisfaction of the Society. In particular, for engines intended to drive emergency generating sets, additional tests and/or documents may be required to prove that the engine is capable of being readily started at a temperature of 0°C.

Figure 2 : Power/speed diagram



4.2.4 Evaluation of test results

The results of the tests and checks required by [4.2.3] will be evaluated by the attending Surveyor. Normally the main operating data to be recorded during the tests are those listed in [4.3.4].

In particular, the maximum combustion pressure measured with the engine running at the maximum continuous power P is not to exceed the value taken for the purpose of checking the scantlings of the engine crankshaft, according to the applicable requirements of Chapter 1, Appendix 1.

The values of temperatures and pressures of media, such as cooling water, lubricating oil, charge air, exhaust gases, etc., are to be within limits which, in the opinion of the Surveyor, are appropriate for the characteristics of the engine tested.

4.2.5 Stage C - Inspection of main engine components

Immediately after the test run as per [4.2.3], the components of one cylinder for in-line engines, and two cylinders

for V-type engines, are to be presented for inspection to the Surveyor.

The following main engine components are to be inspected:

- piston removed and dismantled
- crosshead bearing, dismantled
- crank bearing and main bearing, dismantled
- cylinder liner in the installed condition
- cylinder head and valves, disassembled
- control gear, camshaft and crankcase with opened covers.

Where deemed necessary by the Surveyor, further dismantling of the engine may be required.

4.3 Type tests of engines admitted to an alternative inspection scheme

4.3.1 General

Engines for which the Manufacturer is admitted to testing and inspections according to an alternative inspection scheme (see Pt D, Ch 1, Sec 1, [3.2]) and which have a cylinder bore not exceeding 300 mm are to be type tested in the presence of a Surveyor in accordance with the requirements of this item [4.3].

The selection of the engine to be tested from the production line is to be agreed upon with the Surveyor.

4.3.2 Type test

The programme of the type test is to be in general as specified below, P being the maximum continuous power and n the corresponding speed. The maximum continuous power is that stated by the engine Manufacturer and accepted by the Society, as defined in [1.3.2].

a) 80 hours at power P and speed n

b) 8 hours at overload power (110% of power P)

c) 10 hours at partial loads (25%, 50%, 75% and 90% of power P)

d) 2 hours at intermittent loads

e) starting tests

f) reverse running for direct reversing engines

g) testing of speed governor, overspeed device and lubricating oil system failure alarm device;

h) testing of the engine with one turbocharger out of action, when applicable

i) testing of the minimum speed along the nominal (theoretical) propeller curve, for main propulsion engines driving fixed pitch propellers, and of the minimum speed with no brake load, for main propulsion engines driving controllable pitch propellers or for auxiliary engines.

The tests at the above-mentioned outputs are to be combined together in working cycles which are to be repeated in succession for the entire duration within the limits indicated.

In particular, the overload test, to be carried out at the end of each cycle, is to be of one hour's duration and is to be carried out alternately:

- at 110% of the power P and 103% of the speed n
- at 110% of the power P and 100% of the speed n.

The partial load tests specified in (c) are to be carried out:

- along the nominal (theoretical) propeller curve and at constant speed, for propulsion engines
- at constant speed, for engines intended for generating sets.

For engines intended to be used for emergency services, supplementary tests may be required, to the satisfaction of the Society. In particular, for engines intended to drive emergency generating sets, additional tests and/or documents may be required to prove that the engine is capable of being readily started at a temperature of 0°C, as required in [3.1.3].

In the case of prototype engines, the duration and programme of the type test will be specially considered by the Society.

4.3.3 In cases of engines for which the Manufacturer submits documentary evidence proving successful service experience or results of previous bench tests, the Society, at its discretion, may allow a type test to be carried out in the presence of the Surveyor according to a programme to be agreed upon in each instance.

In the case of engines which are to be type approved for different purposes and performances, the programme and duration of the type test will be decided by the Society in each case to cover the whole range of engine performances for which approval is requested, taking into account the most severe values.

4.3.4 During the type test, at least the following particulars are to be recorded:

a) ambient air temperature, pressure and atmospheric humidity in the test room

b) cooling raw water temperature at the inlet of heat exchangers

c) characteristics of fuel and lubricating oil used during the test

d) engine speed

e) brake power

f) brake torque

g) maximum combustion pressure

h) indicated pressure diagrams, where practicable

i) exhaust smoke (with a smoke meter deemed suitable by the Surveyor)

j) lubricating oil pressure and temperature

k) cooling water pressure and temperature

l) exhaust gas temperature in the exhaust manifold and, where facilities are available, from each cylinder

m) minimum starting air pressure necessary to start the engine in cold condition.

In addition to the above, for supercharged engines the following data are also to be measured and recorded:

- turbocharger speed
- air temperature and pressure before and after turbocharger and charge air coolers
- exhaust gas temperatures and pressures before and after turbochargers and cooling water temperature at the inlet of charge air coolers.

4.3.5 Inspection of main engine components and evaluation of test results

The provisions of [4.2.4] and [4.2.5] are to be complied with, as far as applicable.

4.4 Material and non-destructive tests

4.4.1 Material tests

Engine components are to be tested in accordance with Tab 5 and in compliance with the requirements of Part D.

Magnetic particle or liquid penetrant tests are required for the parts listed in Tab 5 and are to be effected in positions mutually agreed upon by the Manufacturer and the Society Surveyor, where experience shows defects are most likely to occur.

The magnetic particle test of tie rods/stay bolts is to be carried out at each end, for a portion which is at least twice the length of the thread.

For important structural parts of engines, in addition to the above-mentioned non-destructive tests, examination of welded seams by approved methods of inspection may be required.

Where there is evidence to doubt the soundness of any engine component, non-destructive tests using approved detecting methods may be required.

Engines of a cylinder diameter not exceeding 300 mm may be tested according to an alternative survey scheme.

Table 5 : Material and non-destructive tests *(1/7/2001)*

Engine component	Material tests **(1)** (Mechanical properties and chemical composition)	Non-destructive tests	
		Magnetic particle or liquid penetrant	Ultrasonic
1) Crankshaft	all	all	all
2) Crankshaft coupling flange (non-integral) for main power transmissions	if bore > 400 mm	-	-
3) Coupling bolts for crankshaft	if bore > 400 mm	-	-
4) Steel piston crowns **(2)**	if bore > 400 mm	if bore > 400 mm	all
5) Piston rods	if bore > 400 mm	if bore > 400 mm	if bore > 400 mm
6) Connecting rods, together with connecting rod bearing caps	all	all	if bore > 400 mm
7) Crossheads	if bore > 400 mm	-	-
8) Cylinder liners	if bore > 300 mm	-	-
9) Steel cylinder covers **(2)**	if bore > 300 mm	if bore > 400 mm	all
10) Bedplates of welded construction; plates and transverse bearing girders made of forged or cast steel **(2) (3)**	all	all	all
11) Frames and crankcases of welded construction **(3)**	all	-	-
12) Entablatures of welded construction **(3)**	all	-	-
13) Tie rods	all	if bore > 400 mm	-
14) Shafts and rotors, including blades, for turbochargers **(4)**	(see Sec 14)	-	-
15) Bolts and studs for cylinder covers, crossheads, main bearings and connecting rod bearings; nuts for tie rods	if bore > 300 mm	if bore > 400 mm	-
16) Steel gear wheels for camshaft drives	if bore > 400 mm	if bore > 400 mm	-

(1) In addition, material tests may also be required, at the Society's discretion, for piping and valves for starting air lines and any other pressure piping fitted on the engines.

(2) For items 4), 9) and 10), it is implicit that as well as for steel parts, material tests are also required for parts made of other materials which are comparable to steel on account of their mechanical properties in general and their ductility in particular: e.g. aluminium and its alloys, ductile and spheroidal or nodular graphite cast iron.

(3) Material tests for bedplates, frames, crankcases and entablatures are required even if these parts are not welded and for any material except grey cast iron.

(4) Turbocharger is understood as turbocharger itself and engine driven compressor (incl. "Root blowers", but not auxiliary blowers)

4.4.2 Hydrostatic tests

Parts of engines under pressure are to be hydrostatically tested at the test pressure specified for each part in Tab 6.

The following parts of auxiliaries which are necessary for operation of engines as per [1.1.1] a), b) and c):

- cylinders, cylinder covers, coolers and receivers of independent air compressors
- water, oil and air coolers (tube bundles or coils, shells and heads) not fitted on the engine and filters
- independently driven lubricating oil, fuel oil and water pumps
- pressure pipes (water, lubricating oil, fuel oil, and compressed air pipes), valves and other fittings

are to be subjected to hydrostatic tests at 1,5 times the maximum working pressure, but not less than 0,4 MPa.

4.5 Workshop inspections and testing

4.5.1 General

In addition to the type test, diesel engines are to be subjected to works trials, which are to be witnessed by the Surveyor except where an Alternative Inspection Scheme has been granted or where otherwise decided by the Society on a case by case basis.

For all stages at which the engine is to be tested, the relevant operating values are to be measured and recorded by the engine Manufacturer.

In each case all measurements conducted at the various load points are to be carried out at steady operating conditions.

The readings for 100% of the rated power P at the corresponding speed n are to be taken twice at an interval of at least 30 minutes.

At the discretion of the Surveyor, the programme of trials given in [4.5.2], [4.5.3] or [4.5.4] may be expanded depending on the engine application.

Table 6 : Test pressure of engine parts

	Parts under pressure	Test pressure (MPa) **(1) (2)**
1	Cylinder cover, cooling space **(3)**	0,7
2	Cylinder liner, over the whole length of cooling space	0,7
3	Cylinder jacket, cooling space	0,4 (but not less than 1,5 p)
4	Exhaust valve, cooling space	0,4 (but not less than 1,5 p)
5	Piston crown, cooling space **(3) (4)**	0,7
6	Fuel injection system a) Fuel injection pump body, pressure side b) Fuel injection valve c) Fuel injection pipes	 1,5 p (or p + 30, if lesser) 1,5 p (or p + 30, if lesser) 1,5 p (or p + 30, if lesser)
7	Hydraulic system • Piping, pumps, actuators etc. for hydraulic drive of valves	 1,5 p
8	Scavenge pump cylinder	0,4
9	Turbocharger, cooling space	0,4 (but not less than 1,5p)
10	Exhaust pipe, cooling space	0,4 (but not less than 1,5 p)
11	Engine driven air compressor (cylinders, covers, intercoolers and aftercoolers) a) Air side b) Water side	 1,5 p 0,4 (but not less than 1,5 p)
12	Coolers, each side **(5)**	0,4 (but not less than 1,5 p)
13	Engine driven pumps (oil, water, fuel, bilge)	0,4 (but not less than 1,5 p)

(1) In general, parts are to be tested at the hydraulic pressure indicated in the Table. Where design or testing features may call for modification of these testing requirements, special consideration will be given by the Society.

(2) p is the maximum working pressure, in MPa , in the part concerned.

(3) For forged steel cylinder covers and forged steel piston crowns, test methods other than hydrostatic testing may be accepted, e.g. suitable non-destructive tests and documented dimensional tests.

(4) Where the cooling space is sealed by the piston rod, or by the piston rod and the shell, the pressure test is to be carried out after assembly.

(5) Turbocharger air coolers need to be tested on the water side only.

4.5.2 Main propulsion engines driving propellers

Main propulsion engines are to be subjected to trials to be performed as follows:

a) at least 60 min, after having reached steady conditions, at rated power P and rated speed n

b) 30 min, after having reached steady conditions, at 110% of rated power P and at a speed equal to 1,032 of rated speed

c) tests at 90% (or normal continous cruise power), 75%, 50% and 25% of rated power P, carried out:

- at the speed corresponding to the nominal (theoretical) propeller curve, for engines driving fixed pitch propellers
- at constant speed, for engines driving controllable pitch propellers

d) idle run

e) starting and reversing tests (when applicable)

f) testing of the speed governor and of the independent overspeed protective device

g) testing of alarm and/or shutdown devices.

Note 1: After running on the test bed, the fuel delivery system is to be so adjusted that the engine cannot deliver more than 100% of the rated power at the corresponding speed (overload power cannot be obtained in service).

4.5.3 Engines driving electric generators used for main propulsion purposes

Engines driving electric generators are to be subjected to trials to be performed with a constant governor setting, as follows:

a) at least 60 min, after having reached steady conditions, at 100% of rated power P and rated speed n

b) 45 min, after having reached steady conditions, at 110% of rated power and rated speed

c) 75%, 50% and 25% of rated power P, carried out at constant rated speed n

d) idle run

e) starting tests

f) testing of the speed governor ([2.7.5]) and of the independent overspeed protective device (when applicable)

g) testing of alarm and/or shutdown devices.

Note 1: After running on the test bed, the fuel delivery system of diesel engines driving electric generators is to be adjusted such that overload (110%) power can be produced but not exceeded in service after installation on board, so that the governing characteristics, including the activation of generator protective devices, can be maintained at all times.

4.5.4 Engines driving auxiliary machinery

Engines driving auxiliary machinery are to be subjected to the tests stated in [4.5.2] or [4.5.3] for variable speed and constant speed drives, respectively.

Note 1: After running on the test bed, the fuel delivery system of diesel engines driving electric generators is to be adjusted such that overload (110%) power can be produced but not exceeded in service after installation on board, so that the governing characteristics, including the activation of generator protective devices, can be fulfilled at all times.

4.5.5 Inspection of engine components

After the works trials, several components are to be selected for inspection by the Manufacturer or by the Surveyor if the works trials are witnessed.

4.5.6 Parameters to be measured

The data to be measured and recorded, when testing the engine at various load points, are to include all necessary parameters for engine operation. The crankshaft deflection is to be verified when this check is required by the Manufacturer during the operating life of the engine.

4.5.7 Testing report

In the testing report for each engine the results of the tests carried out are to be compiled and the reference number and date of issue of the Type Approval Certificate (see [4.6]), relevant to the engine type, are always to be stated; the testing report is to be issued by the Manufacturer and enclosed with the testing certificate as per [4.6].

4.6 Certification

4.6.1 Type Approval Certificate and its validity

After the satisfactory outcome of the type tests and inspections specified in [4.2] or [4.3], the Society will issue to the engine manufacturer a "Type Approval Certificate" valid for all engines of the same type.

The Society reserves the right to consider the test carried out on one engine type valid also for engines having a different cylinder arrangement, following examination of suitable, detailed documentation submitted by the Manufacturer and including bench test results.

4.6.2 Testing certification

a) Engines admitted to an alternative inspection scheme

Works' certificates (W) (see Pt D, Ch 1, Sec 1, [4.2.3]) are required for components and tests indicated in Tab 5 and 5 and for works trials as per [4.5].

b) Engines not admitted to an alternative inspection scheme

Society's certificates (C) (see Pt D, Ch 1, Sec 1, [4.2.1]) are required for material tests of components in Tab 5 and for works trials as per [4.5].

Works' certificates (W) (see Pt D, Ch 1, Sec 1, [4.2.3]) are required for non-destructive and hydrostatic tests of components in Tab 5 and Tab 6.

In both cases a) and b), the Manufacturer is to supply:

a) the following information:

- engine type
- rated power
- rated speed
- driven equipment
- operating conditions
- list of auxiliaries fitted on the engine

b) a statement certifying that the engine is in compliance with that type tested. The reference number and date of the Type Approval Certificate are also to be indicated in the statement.

Impianti di propulsione navale

Protezione incendio

Parte C – Capitolo 4 – Sezione 4
Rilevazione e allarme incendio per navi da passeggeri con più di 36 passeggeri

4.2.1 *(1/7/2002)*
A fixed fire detection and fire alarm system shall be installed and arranged as to provide smoke detection in service spaces, control stations and accommodation spaces, including corridors, stairways and escape routes within accommodation spaces

Data: 15/01/2007

Impianti di propulsione navale

Parte C – Capitolo 4 – Sezione 4
Rilevazione e allarme incendio per navi da passeggeri con più di 36 passeggeri

Centrale antincendio

8.2 Passenger ships carrying more than 36 passengers

8.2.1 *Passenger ships carrying more than 36 passengers shall have the detection alarms for the systems required by [4.2] centralized in a continuously manned central control station.*
In addition, controls for remote closing of the fire doors and shutting down the ventilation fans shall be centralized in the same location..
The ventilation fans shall be capable of reactivation by the crew at the continuously manned control station.
The control panels in the central control station shall be capable of indicating open or closed positions of fire doors, closed or off status of the detectors, alarms and fans. The control panel shall be continuously powered and shall have an automatic change-over to standby power supply in the event of loss of normal power supply.
The control panel shall be powered from the main source of electrical power and the emergency source of electrical power in Pt E, Ch 11, Sec 5, [2] unless other arrangements are permitted by the Rules, as applicable.

Parte C – Capitolo 4 – Sezione 4
Rilevazione e allarme incendio nei locali apparato motore

3 Protection of machinery spaces
3.1 Installation
3.1.1 *A fixed fire detection and fire alarm system shall be installed in:*
a) periodically unattended machinery space;
b) machinery spaces where:

- *the installation of automatic and remote control systems and equipment has been approved in lieu of continuous manning of the space, and*

- *the main propulsion and associated machinery including sources of main electrical supply are provided with various degrees of automatic or remote control and are under continuous manned supervision from a control room.*

The requirements of this item apply to machinery spaces of category A.

Impianti di propulsione navale

Parte C – Capitolo 4 – Sezione 7
Impianto antincendio ad acqua mare

1 Water supply systems
1.1 General
1.1.1 *Ship shall be provided with fire pumps, fire mains, hydrants and hoses complying as applicable with the requirements of this Section.*

1.2.2 Ready availability of water supply *(1/7/2002)*
The arrangements for the ready availability of water supply shall be:

a) in passenger ships
1) of 1000 tons 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 a required fire pump; only one of the required fire pumps needs to be provided with automatic starting

b) in cargo ships
1) to the satisfaction of the Society.
Immediate availability of water supply can be achieved either by automatic starting of at least one fire pump or by remote starting from the navigation bridge of at least one fire pump.

Parte C – Capitolo 4 – Sezione 7
Impianto antincendio ad acqua mare

1.2.3 Diameter of the 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/hour.

1.2.6 Pressure at hydrants *(1/1/2001)*

With the two pumps simultaneously delivering, through nozzles specified in [1.4.3], the quantity of waterspecified in [1.2.3], through any adjacent hydrants, the following minimum pressures shall be maintained at all hydrants:
a)for passenger ships,

- *4000 tons gross tonnage and upwards: ..... 0,4 MPa*
- *under 4000 tons gross tonnage: ..... 0,3 MPa*

b)for cargo ships,

- *6000 tons gross tonnage and upwards: ...0,27 MPa*
- *under 6000 tons gross tonnage: ..... 0,25 MPa*

Parte C – Capitolo 4 – Sezione 7
Impianto antincendio ad acqua mare

1.2.7 International shore connection

a) Ships of 500 tons gross tonnage and upwards shall be provided with at least one international shore connection, complying with Sec 13.

b) Facilities shall be available enabling such a connection to be used on either side of the ship.

Parte C – Capitolo 4 – Sezione 7
Impianto antincendio ad acqua mare

1.3.2 Number of fire pumps

Ships shall be provided with independently driven fire pumps as follows:

a) in passenger ships of:

- *4000 tons gross tonnage and upwards: .... at least 3*
- *less than 4000 tons gross tonnage:..... at least 2*

b) in cargo ships of:

- *1000 tons gross tonnage and upwards: .... at least 2*
- *less than 1000 tons gross tonnage: .....* at least 2 *power driven pumps.*
  In this case, only one of these pumps is required to be indipendently driven.

Parte C – Capitolo 4 – Sezione 7
Impianto antincendio ad acqua mare

Sistemazione pompe e collettore incendio. Pompa incendio d'emergenza

1.3.3 Arrangement of fire pumps and fire mains *(1/7/2003)*

a)Fire pumps

> *The arrangement of sea connections, fire pumps and their sources of power shall be as to ensure that:*

1)in passenger ships of 1000 tons 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

Unless the two main fire pumps, their sea suctions and the fuel supply or source of power for each pump are situated within compartments separated at least by an A-0 class division, so that a fire in any one compartment will not render both fire pumps inoperable, an emergency fire pump is to be fitted. An arrangement in which one main fire pump is located in a compartment having more than one bulkhead or deck adjacent to the compartment containing the other main fire pump will also require an emergency fire pump.

Parte C – Capitolo 4 – Sezione 7
Impianto antincendio ad acqua mare

Pompa incendio d'emergenza

Secondo quanto prescritto nella sezione 13, la pompa di emergenza deve avere un'aspirazione dal mare che rimanga sotto il galleggiamento in ogni possibile situazione di sbandamento ed assetto.

L'azionamento della pompa deve essere effettuato tramite motore diesel indipendente o motore elettrico alimentato dal quadro di emergenza.

Impianti di propulsione navale

Parte C – Capitolo 4 – Sezione 7
Impianto antincendio ad acqua mare

1.3.4 Capacity of fire pumps *(1/7/2002)*

a) 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 [1.2.6], as follows:

1) 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

2) pumps in cargo ships, other than any emergency pump, the quantity of water is not less than four thirds of the quantity required in Ch 1, Sec 10 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 /hour.

Impianti di propulsione navale

Parte C – Capitolo 4 – Sezione 7
Mezzi di spegnimento incendio nei locali apparato motore
Locali apparato motore di categoria A :

4.2.1 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 in [3.1].
4.3.1 Fixed fire-extinguishing systems
Machinery spaces of category A containing internal combustion machinery shall be provided with one of the fireextinguishing systems required in [3.1].
3.1 Types of fixed fire-extinguishing systems
3.1.1 *A fixed fire extinguishing system required in [2.3.1] may be any of the following systems:*
a)a fixed gas fire-extinguishing system complying with the provisions of Sec 13 , or equivalent
b)a fixed high expansion foam fire-extinguishing system complying with the provisions of Sec 13
c)a fixed pressure water-spraying fire-extinguishing system complying with the provisions of Sec 13.

Oltre all'impianto fisso di estinzione incendio, devono essere previsti estintori portatili a schiuma, a polvere e a CO_2 di capacità e posizione approvata.

Impianti di propulsione navale

Parte C – Capitolo 4 – Sezione 7
Mezzi di spegnimento incendio nei locali apparato motore
I locali dedicati agli impianti di trattamento nafta (depurazione e alimento nafta) sono soggetti a prescrizioni ulteriori :

(1/7/2002)

a) The system (such as purifiers) for preparing flammable liquids for use in boilers and machinery, and separate oil systems with working pressure above 1,5 MPa and which are not part of the main engines, auxiliary engines or boilers etc., are subject to the following additional requirements.

b) The main components in the systems as per a) are to be placed in a separate room, enclosed by steel bulkheads extending from deck to deck and provided with selfclosing steel doors.

c) Rooms in which flammable liquids are handled as specified in a) above are to be provided with:
- independent mechanical ventilation or ventilation arrangements which can be isolated from the machinery space ventilation
- a fire detecting system
- a fixed fire-extinguishing installation. The extinguishing installation is to be capable of being activated from outside the room. The extinguishing system is to be separated from the room, but may be a part of the main fire-extinguishing system for the machinery space. Closing of ventilation openings is to be effected from a position close to where the extinguishing system is activated.

Impianti di propulsione navale

Parte C – Capitolo 4 – Sezione 13
Impianto estinzione incendio a CO_2

5.1.1 General *(1/7/2002)*

2) Means shall be provided for automatically giving audible warning of the release of fire-extinguishing medium into any ro-ro spaces and other spaces inwhich personnel normally work or to which they have access.

The pre-discharge alarm shall be automatically activated (e.g., by opening of the release cabinet door).

The alarm shall operate for the length of time needed to evacuate the space, but in no case less than 20 s before the medium is released.

5.2.1 General

2) For machinery spaces the quantity of carbon dioxide carried shall be sufficient to give a minimum volume of free gas equal to the larger of the following volumes, either:

•40 per cent of the gross volume of the largest machinery space so protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 40 per cent or less of the horizontal area of the space concerned taken midway between the tank top and the lowest part of the casing, or

•35 per cent of the gross volume of the largest machinery space protected, including the casing.

Parte C – Capitolo 4 – Sezione 13
Impianto estinzione incendio a CO_2

5.2.2 High-pressure carbon dioxide systems *(1/7/2005)*

f) Alarm devices

In addition to the requirements in item c)2) of [5.1.1], the alarm system is to be approved by the Society;
the alarm sounding during the discharge may be of pneumatic type (e.g. CO2, nitrogen) or of electrical type.

Impianto estinzione incendio a schiuma ad alta espansione

6.1.2 Fixed high expansion foam fire-extinguishing systems *(1/7/2002)*
a) Quantity and performance of foam concentrates

4)

A quantity of foam-forming liquid sufficient to produce a volume of foam not less than 5 times the volume of the largest space to be protected shall be available on board.

Impianti di propulsione navale

Parte C – Capitolo 4 – Sezione 13
Impianto estinzione incendio tipo "water mist"
7.1.1 Fixed pressure water-spraying fire extinguishing systems *(1/7/2002)*

a) Nozzles and pumps

1) The number and arrangement of the nozzles shall be to the satisfaction of the Society and shall be such as to ensure an effective average distribution of water of at least 5 l/m2 per minute in the spaces to be protected

b) Installation requirements for machinery spaces

1) Nozzles shall be fitted above bilge, tank tops and other areas over which fuel oil is liable to spread and also above other specific fire hazards in the machinery spaces.
2) The system may be divided into sections, the distribution valves of which shall be operated from easily accessible positions outside the spaces to be protected and will not be readily cut off by a fire in the protected space.
3) The pump and its controls shall be installed outside the space or spaces to be protected. It shall not be possible for a fire in the space or spaces protected by the water-spraying system to put the system out of action.

Parte C – Capitolo 4 – Sezione 13
Impianto estinzione incendio tipo "water mist"
7.1.1 Fixed pressure water-spraying fire extinguishing systems *(1/7/2002)*

d)System control requirements

The system shall be kept charged at the necessary pressure and the pump supplying the water for the system shall be put automatically into action by a pressure drop in the system.

Impianti di propulsione navale

Parte C – Capitolo 4 – Sezione 13

Nella sezione 13 – 9 : requisiti dei dispositivi rilevatori incendio e del loro collegamento in “loops” (circuiti elettrici che collegano in sequenza i rilevatori di varie sezioni e li connettono alle unità di segnalazione).

Nella sezione 13 – 3 : requisiti degli equipaggiamenti individuali per i vigili del fuoco (tuta protettiva, stivali, elmetto, cintura, autorespiratore, ascia, lampada di sicurezza).

Nella sezione 13 – 4 : requisiti per le attrezzature antincendio portatili (estintori a polvere, a CO_2, a schiuma).

Impianti di propulsione navale

Automazione – Requisiti di progetto - Parte C, Capitolo 3, Sezione 2

❑ Override del controllo automatico in emergenza

1.1.2 Controlled systems are to have manual operation.
Failure of any part of such systems shall not prevent the use of the manual override.

❑ Separazione funzioni di monitoraggio / allarme

1.1.4 Safety functions are to be independent of control and monitoring functions. As far as practicable, control and monitoring functions are also to be independent.

❑ Affidabilità del sistema di automazione

1.1.3 Automation systems are to have constant performance.

❑ Auto diagnosi del sistema di controllo

1.1.5 Control, monitoring and safety systems are to have self-check facilities. In the event of failure, an alarm is to be activated.
In particular, failure of the power supply of the automation system is to generate an alarm.

Data: 15/01/2007

Impianti di propulsione navale

Automazione – Requisiti di progetto - Parte C, Capitolo 3, Sezione 2

❑ Ridondanza dell'alimentazione di potenza

2.1.1 The source of power supply of automation systems is to be duplicated. Batteries or pneumatic or hydraulic accumulators, installed to allow the system to be continuously powered, are not considered as a duplication of the power supply. Failure of these power supplies is to generate an alarm.

3 Control systems
3.1 General
3.1.1 In the case of failure, the control systems used for essential services are to remain in their last position they had before the failure.

❑ Possibilità di controllare localmente i macchinari

3.2 Local control
3.2.1 Each system is to be able to be operated manually from a position located so as to enable visual control of operation. For detailed instrumentation for each system, refer to Chapter 1and Chapter 2.
It shall also be possible to control the auxiliary machinery, essential for the propulsion and safety of the ship, at or near the machinery concerned.

Impianti di propulsione navale

Automazione – Requisiti di progetto - Parte C, Capitolo 3, Sezione 2

3.3 Remote control systems

3.3.1 When several control stations are provided, control of machinery is to be possible at one station at a time.

3.3.2 *At each location there shall be an indicator showing which location is in control of the propulsion machinery.*

Impianti di propulsione navale

Automazione – Requisiti di progetto - Parte C, Capitolo 3, Sezione 2

❑ Telecomando da ECR e plancia, trasferimento funzioni, comando locale

4.2.1 Where propulsion machinery is controlled from the navigating bridge, the remote control is to include an automatic device such that the number of operations to be carried out is reduced and their nature is simplified and such that control is possible in both the ahead and astern directions. Where necessary, means for preventing overload and running in critical speed ranges of the propulsion machinery is to be provided.
4.2.2 On board ships fitted with remote control, direct control of the propulsion machinery is to be provided locally. The local direct control is to be independent from the remote control circuits, and takes over any remote control when in use.
4.2.3 Each local control position, including partial control (e.g. local control of controllable pitch propellers or clutches) is to be provided with means of communication with each remote control position. The local control positions are to be independent from remote control of propulsion machinery and continue to operate in the event of a blackout
4.2.4 *Remote control of the propulsion machinery shall be possible only from one location at a time; at such locations interconnected control positions are permitted.*

Impianti di propulsione navale

Automazione – Requisiti di progetto - Parte C, Capitolo 3, Sezione 2

❑ Telecomando da ECR e plancia, trasferimento funzioni, comando locale

4.2.5 *The transfer of control between the navigating bridge and machinery spaces shall be possible only in the main machinery space or the main machinery control room. The system shall include means to prevent the propelling thrust from altering significantly, when transferring control from one location to another*

4.2.6 At the navigating bridge, the control of the routine manoeuvres for one line of shafting is to be performed by a single control device: a lever, a handwheel or a push-button board.
However each mechanism contributing directly to the propulsion, such as the engine, clutch, automatic brake or controllable pitch propeller, is to be able to be individually controlled, either locally or at a central monitoring and control position in the engine room

4.2.7 Remote starting of the propulsion machinery is to be automatically inhibited if a condition exists which may damage the machinery, e.g. shaft turning gear engaged, drop of lubrication oil pressure or brake engaged.

4.2.8 As a general rule, the navigating bridge panels are not to be overloaded by alarms and indications which are not required.

Impianti di propulsione navale

Automazione – Requisiti di progetto - Parte C, Capitolo 3, Sezione 2

❑ Fail-safe 4.3.3

4.3.3 The automatic control system is to be designed on a fail safe basis, and, in the event of failure, the system is to be adjusted automatically to a predetermined safe state.

❑ Attivazione allarme

6.2 Alarm functions
6.2.1 Alarm activation
Alarms are to be activated when abnormal conditions appear in the machinery, which need the intervention of personnel on duty, and on the automatic change-over, when standby machines are installed.
An existing alarm is not to prevent the indication of any further fault.

Impianti di propulsione navale

Automazione – Requisiti di progetto - Parte C, Capitolo 3, Sezione 2

❑ **Riconoscimento allarme**

6.2.2 Acknowledgement of alarm

The acknowledgment of an alarm consists in manually silencing the audible signal and additional visual signals (e.g. rotating light signals) while leaving the visual signal on the active control station.
Acknowledged alarms are to be clearly distinguishable from unacknowledged alarms.
Acknowledgement should not prevent the audible signal to operate for new alarm.
Alarms shall be maintained until they are accepted and visual indications of individual alarms shall remain until the fault has been corrected, when the alarm system shall automatically reset to the normal operating condition.
Acknowledgement of alarms is only to be possible at the
active control station.

Impianti di propulsione navale

Automazione – Requisiti di progetto - Parte C, Capitolo 3, Sezione 2

❑ **Interventi automatici di sicurezza. Shutdown.**

7.2.2 Safety indication
When the safety system has been activated, it is to be possible to trace the cause of the safety action. This is to be accomplished by means of a central or local indication.
When a safety system is made inoperative by a manual override, this is to be clearly indicated at corresponding control stations.
Automatic safety actions are to activate an alarm at predefined control stations.

7.3 Shutdown
7.3.1 For shutdown systems of machinery, the following requirements are to be applied:

- when the system has stopped a machine, the latter is not to be restarted automatically before a manual reset of the safety system has been carried out
- the shutdown of the propulsion system is to be limited to those cases which could lead to serious damage, complete breakdown or explosion.

Impianti di propulsione navale

Automazione – Requisiti di progetto - Parte C, Capitolo 3, Sezione 2

❑ **Avviamento automatico sistemi standby**

7.4 Standby systems

7.4.1 For the automatic starting system of the standby units, the following requirements are to be applied:

• faults in the electrical or mechanical system of the running machinery are not to prevent the standby machinery from being automatically started

• when a machine is on standby, ready to be automatically started, this is to be clearly indicated at its control position

• the change-over to the standby unit is to be indicated by a visual and audible alarm

• means are to be provided close to the machine, to prevent undesired automatic or remote starting (e.g. when the machine is being repaired)

• automatic starting is to be prevented when conditions are present which could endanger the standby machine.

Impianti di propulsione navale

Automazione – Notazioni di classe - Parte A, Capitolo 1, Sezione 2

6.4 Automated machinery systems (AUT)

6.4.1 General

The notations dealt with under this heading are relevant to automated machinery systems installed on board ships.

6.4.2 Unattended machinery space (AUT-UMS)

The additional class notation **AUT-UMS** is assigned to ships which are fitted with automated installations enabling machinery spaces to remain periodically unattended in all sailing conditions including manoeuvring.

6.4.3 Centralised control station (AUT-CCS)

The additional class notation **AUT-CCS** is assigned to ships which are fitted with machinery installations operated and monitored from a centralised control station.

Impianti di propulsione navale

Automazione – Notazioni di classe - Parte A, Capitolo 1, Sezione 2

6.4.4 Automated operation in port (AUT-PORT)
The additional class notation **AUT-PORT** is assigned to ships which are fitted with automated installations enabling ship's operation in port or at anchor without personnel specially assigned for the watch-keeping of the machinery in service.

6.4.5 Integrated machinery system (AUT-IMS)
The additional class notation **AUT-IMS** is assigned to ships which are fitted with automated installations enabling machinery spaces to remain periodically unattended in all sailing conditions including manoeuvring, and additionally provided with integrated systems enabling to handle control, safety and monitoring of machinery.

Impianti di propulsione navale

Automazione – Requisiti per notazione AUT-UMS - Parte F, Capitolo 3, Sezione 1

1.1 Application

1.1.1 The additional class notation **AUT-UMS** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.4.2] to ships fitted with automated installations enabling periodically unattended operation of machinery spaces, and complying with the requirements of this Section.

1.3 Communication system

1.3.1 *A reliable means of vocal communication shall be provided between the main machinery control room or the propulsion machinery control position as appropriate, the navigation bridge and the engineer officers' accommodation.*

This means of communication is to be foreseen in collective or individual accommodation of engineer officers.

3.4 Protection against flooding

3.4.2 *Where the bilge pumps are capable of being started automatically, means shall be provided to indicate when the influx of liquid is greater than the pump capacity or when the pump is operating more frequently than would normally be expected.*

Automazione – Requisiti per notazione AUT-UMS - Parte F, Capitolo 3, Sezione 1

4 Control of machinery
4.1 General
4.1.1 *Under all sailing conditions, including manoeuvring, the speed, direction of thrust and, if applicable, the pitch of the propeller shall be fully controllable from the navigation bridge.*

4.1.2 All manual operations or services expected to be carried out with a periodicity of less than 24 h are to be eliminated or automated, particularly for: lubrication, topping up of make up tanks and filling tanks, filter cleaning, cleaning of centrifugal purifiers, drainage, load sharing on main engines and various adjustments. Nevertheless, the transfer of operation mode may be effected manually.

4.1.3 *A centralised control position shall be arranged with the necessary alarm panels and instrumentation indicating any alarm.*

4.1.4 Parameters for essential services which need to be adjusted to a preset value are to be automatically controlled.

4.1.5 *The control system shall be such that the services needed for the operation of the main propulsion machinery and its auxiliaries are ensured through the necessary automatic arrangements.*

Impianti di propulsione navale

Automazione – Requisiti per notazione AUT-UMS - Parte F, Capitolo 3, Sezione 1

4.1.6 *It shall be possible for all machinery essential for the safe operation of the ship to be controlled from a local position, even in the case of failure in any part of the automatic or remote control systems.*

4.1.7 *The design of the remote automatic control system shall be such that in the case of its failure an alarm will be given. Unless impracticable, the preset speed and direction of thrust of the propeller shall be maintained until local control is in operation.*

4.1.8 Critical speed ranges, if any, are to be rapidly passed over by means of an appropriate automatic device.

4.1.9 Propulsion machinery is to stop automatically only in exceptional circumstances which could cause quick critical damage, due to internal faults in the machinery. The design of automation systems whose failure could result in an unexpected propulsion stop is to be specially examined.
An overriding device for cancelling the automatic shutdown is to be considered.

Impianti di propulsione navale

Automazione – Requisiti per notazione AUT-UMS - Parte F, Capitolo 3, Sezione 1

4.1.10 Where the propulsive plant includes several main engines, a device is to be provided to prevent any abnormal overload on each of them.

4.1.11 *Where standby machines are required for other auxiliary machinery essential to propulsion, automatic changeover devices shall be provided.*

Impianti di propulsione navale

Automazione – Requisiti per notazione AUT-UMS - Parte F, Capitolo 3, Sezione 1

4.5 Electrical propulsion plant

4.5.1 Documents to be submitted

The following additional documents are to be submitted to the Society:

- A list of the alarms and shutdowns of the electrical propulsion system
- When the control and monitoring system of the propulsion plant is computer based, a functional diagram of the interface between the programmable logic controller and computer network.

Impianti di propulsione navale

Automazione – Requisiti per notazione AUT-UMS - Parte F, Capitolo 3, Sezione 1

4.7 Auxiliary systems

4.7.1 *Where standby machines are required for other auxiliary machinery essential to propulsion, automatic changeover devices shall be provided.*

Change-over restart is to be provided for the following systems:

- cylinder, piston and fuel valve cooling
- cylinder cooling of diesel generating sets (where the circuit is common to several sets)
- main engine fuel supply
- diesel generating sets fuel supply (where the circuit is common to several sets)
- sea water cooling for propulsion plant
- sea water to main condenser (main turbines)
- hydraulic control of clutch, CPP or main thrust unit
- thermal fluid systems (thermal fluid heaters).

4.7.4 *Means shall be provided to keep the starting air pressure at the required level where internal combustion engines are used for main propulsion.*

Impianti di propulsione navale

Automazione – Requisiti per notazione AUT-UMS - Parte F, Capitolo 3, Sezione 1

4.8 Control of electrical installation

4.8.1 *Where the electrical power can normally be supplied by one generator, suitable load shedding arrangement shall be provided to ensure the integrity of supplies to services required for propulsion and steering as well as the safety of the ship.*

4.8.2 *In the case of loss of the generator in operation, adequate provision shall be made for automatic starting and connecting to the main switchboard of a standby generator of sufficient capacity to permit propulsion and steering and to ensure the safety of the ship with automatic restarting of the essential auxiliaries including, where necessary, sequential operations.*

4.8.3 The standby electric power is to be available in not more than 45 seconds.

Impianti di propulsione navale

Automazione – Requisiti per notazione AUT-UMS - Parte F, Capitolo 3, Sezione 1

4.8.4 *If the electrical power is normally supplied by more than one generator simultaneously in parallel operation, provision shall be made, for instance by load shedding, to ensure that, in the case of loss of one of these generating sets, the remaining ones are kept in operation without overload to permit propulsion and steering, and to ensure the safety of the ship.*

4.8.5 Following a blackout, automatic connection of the standby generating set is to be followed by an automatic restart of the essential electrical services. If necessary, time delay sequential steps are to be provided to allow satisfactory operation.

Impianti di propulsione navale

Automazione – Requisiti per notazione AUT-UMS - Parte F, Capitolo 3, Sezione 1

5 Alarm system
5.1 General
5.1.1 A system of alarm displays and controls is to be provided which readily allows identification of faults in the machinery and satisfactory supervision of related equipment.
This may be arranged at a main control station or, alternatively, at subsidiary control stations. In the latter case, a master alarm display is to be provided at the main control station showing which of the subsidiary control stations is indicating a fault condition.

5.1.2 Unless otherwise justified, separation of monitoring and control systems is to be provided.

5.1.3 The alarm system is to be designed to function independently of control and safety systems, so that a failure or malfunction of these systems will not to prevent the alarm system from operating. Common sensors for alarms and automatic slowdown functions are acceptable as specified in each specific table.

Impianti di propulsione navale

Automazione – Requisiti per notazione AUT-UMS - Parte F, Capitolo 3, Sezione 1

5.1.4 *The alarm system shall be continuously powered and shall have an automatic change-over to a standby power supply in the case of loss of normal power supply.*

5.2 Alarm system design

5.2.1 The alarm system and associated sensors are to be capable of being tested during normal machinery operation.

5.2.2 Insulation faults on any circuit of the alarm system are to generate an alarm, when an insulated earth distribution system is used.

5.2.3 An engineers' alarm is to be activated when the machinery alarm has not been accepted in the machinery spaces or control room within 2 minutes.

5.2.4 *The alarm system is to have a connection to the engineers' public rooms and to each of the engineers' cabins through a selector switch, to ensure connection to at least one of those cabins.*

Impianti di propulsione navale

Automazione – Requisiti per notazione AUT-UMS - Parte F, Capitolo 3, Sezione 1

5.4 Alarm system on navigating bridge
5.4.1 Alarms associated with faults requiring speed reduction or automatic shutdown are to be separately identified on the bridge.

5.4.3 Individual alarms are to be provided at the navigation bridge indicating any power supply failures of the remote control of propulsion machinery.

6 Safety systems
6.1 General
6.1.2 In order to avoid undesirable interruption in the operation of machinery, the system is to intervene sequentially after the operation of the alarm system by:

- starting of standby units
- load reduction or shutdown, such that the least drastic action is taken first.

6.1.3 The arrangement for overriding the shutdown of the main propelling machinery is to be such as to preclude inadvertent operation.

Impianti di propulsione navale

Automazione – Requisiti per notazione AUT-UMS - Parte F, Capitolo 3, Sezione 1
Prove mare

7.1.3 Sea trials are used to demonstrate the proper operation of the automated machinery and systems. For this purpose, for instance, the following tests are to be carried out:

- Test of the remote control of propulsion:
  - checking of the operation of the automatic control system: programmed or unprogrammed starting speed increase, reversal, adjusting of the propeller pitch, failure of supply sources, etc.
  - checking of the crash astern sequence, to ensure that the reversal sequence is properly performed from full away, the ship sailing at its normal operation speed. The purpose of this check is not to control the nautical performances of the ship (such as stopping distance, etc.)
  - finally, checking of the operation of the whole installation in normal working conditions, i.e. as a general rule without watch-keeping personnel for the monitoring and/or running of the machinery during 6 h at least

Prove mare – 7.1.3

- The following procedure may, for instance, be chosen: «underway» during 3 h, then increasing to «full ahead». Staying in that position during 5 min. Then stopping for 15 min. Then, putting the control lever in the following positions, staying 2 minutes in each one: astern slow, astern half, astern full, full ahead, half ahead, stop, full astern, stop, ahead dead slow, half ahead, then increasing the power until «underway » position.

• Test of the operating conditions of the electrical production :
  - automatic starting of the generating set in the event of a blackout
  - automatic restarting of auxiliaries in the event of a blackout
  - load-shedding in the event of generating set overload
  - automatic starting of a generating set in the event of generating set overload.
• Test of fire and flooding system:
  - Test of normal operation of the fire detection system (detection, system faults)
  - Test of detection in the scavenging air belt and boiler air duct
  - Test of the fire alarm system
  - Test of protection against flooding.
• Test of operating conditions, including manoeuvring, of the whole machinery in an unattended situation for 6 h.

Impianti di propulsione navale

Vedere inoltre :

Impianti elettrici – Requisiti di progetto - Parte C, Capitolo 2, Sezione 2

- **Condizioni ambientali : 1.2 –1.3 – 1.4**
- **Suscettibilità elettromagnetica : 3**

Impianti di propulsione navale

Impianti Elettrici - Generalità - Parte C - Capitolo 2 - Sezione 1

3.2 Essential services

3.2.1 Essential services are those services essential for propulsion and steering, and the safety of the ship, and services to ensure minimum comfortable conditions of habitability and necessary for special purposes connected with ships specifically intended for such purposes (e.g. cargo pumps on tankers, cargo refrigerating systems, air conditioning systems on passenger ships).

3.3 Primary essential services

3.3.1 Primary essential services are those which need to be in continuous operation to maintain propulsion and steering.

Examples of equipment for primary essential services are the following:

- Steering gear
- Pumps for controllable pitch propellers
- Scavenging air blowers, fuel oil supply pumps, fuel valve cooling pumps, lubricating oil pumps and cooling water pumps for main and auxiliary engines and turbines necessary for the propulsion

Data: 15/01/2007

Examples of equipment for primary essential services are the following:

- Forced draught fans, feed water pumps, water circulating pumps, condensate pumps, oil burning installations, for steam plants or steam turbines ship, and also for auxiliary boilers on ship where steam is used for equipment supplying primary essential services
- Azimuth thrusters which are the sole means for propulsion/ steering with lubricating oil pumps, cooling water pumps
- Electrical equipment for electric propulsion plant with lubricating oil pumps and cooling water pumps
- Electric generators and associated power sources supplying the above equipment
- Hydraulic pumps supplying the above equipment
- Viscosity control equipment for heavy fuel oil
- Control, monitoring and safety devices/systems for equipment for primary essential services
- Speed regulators dependent on electrical energy for main or auxiliary engines necessary for propulsion.

The main lighting system for those parts of the ship normally accessible to and used by personnel and passengers is also considered (included as) a primary essential service.

Impianti Elettrici - Generalità - Parte C - Capitolo 2 - Sezione 1

3.4 Secondary essential services

3.4.1 Secondary essential services are those services which need not necessarily be in continuous operation to maintain propulsion and steering but which are necessary for maintaining the vessel's safety.

Examples of equipment for secondary essential services are the following:

- Windlasses
- Fuel oil transfer pumps and fuel oil treatment equipment
- Lubrication oil transfer pumps and lubrication oil treatment equipment
- Preheaters for heavy fuel oil
- Sea water pumps
- Starting air and control air compressors
- Bilge, ballast and heeling pumps
- Fire pumps and other fire-extinguishing medium pumps
- Ventilation fans for engine and boiler rooms

Impianti Elettrici - Generalità - Parte C - Capitolo 2 - Sezione 1

Examples of equipment for secondary essential services are the following:

- Services considered necessary to maintain dangerous cargo in a safe condition
- Navigation lights, aids and signals
- Internal safety communication equipment
- Fire detection and alarm systems
- Electrical equipment for watertight closing appliances
- Electric generators and associated power supplying the above equipment
- Hydraulic pumps supplying the above equipment
- Control, monitoring and safety for cargo containment systems
- Control, monitoring and safety devices/systems for equipment for secondary essential services.

3.4.2 Services for habitability are those which need to be in operation to maintain the vessel's minimum comfort conditions for people on board.
Examples of equipment for maintaining conditions of habitability:

- Cooking
- Heating
- Domestic refrigeration
- Mechanical ventilation
- Sanitary and fresh water
- Electric generators and associated power sources supplying the above equipment.

Impianti di propulsione navale

Impianti elettrici - Requisiti di progetto - Parte C - Capitolo 2 - Sezione 2

Condizioni ambientali

1.2 Ambient air temperatures

1.2.1 For ships classed for unrestricted navigation, the ambient air temperature ranges shown in Tab 1 are applicable in relation to the various locations of installation.

Table 1 : Ambient air temperature *(1/7/2004)*

Location	Temperature range, in °C	
Enclosed spaces	+ 5	+ 45
Inside consoles or fitted on combustion engines and similar	+ 5	+ 55
Exposed decks	- 25	+ 45

Impianti elettrici - Requisiti di progetto - Parte C - Capitolo 2 - Sezione 2

Condizioni ambientali

1.3 Humidity

1.3.1 For ships classed for unrestricted service, the humidity ranges shown in Tab 2 are applicable in relation to the various locations of installation.

Table 2 : Humidity

Location	Humidity
General	95% at 55 °C
Air conditioned areas	Different values may be considered on a case by case basis

Impianti elettrici - Requisiti di progetto - Parte C - Capitolo 2 - Sezione 2

Condizioni ambientali

1.4 Cooling water temperatures

1.4.1 The temperatures shown in Tab 3 are applicable to ships classed for unrestricted service.

1.4.2 For ships classed for service in specific zones, the Society may accept different values for the cooling water temperature (e.g. for ships operating outside the tropical belt, the maximum cooling water temperature may be assumed as equal to + 25 °C instead of + 32 °C).

Table 3 : Water temperature

Coolant	Temperature range, in °C
Sea water	0 + 32

Impianti elettrici - Requisiti di progetto - Parte C - Capitolo 2 - Sezione 2

1.7 Vibrations

Table 5 : Vibration levels

Location	Frequency range Hz	Displacement amplitude mm	Acceleration amplitude g
Machinery spaces, command and control stations, accommodation spaces, exposed decks, cargo spaces	from 2,0 to 13,2 from 13,2 to 100	1,0 -	- 0,7
On air compressors, on diesel engines and similar	from 2,0 to 25,0 from 25,0 to 100	1,6 -	- 4,0
Masts	from 2,0 to 13,2 from 13,2 to 50	3,0 -	- 2,1

Impianti elettrici - Requisiti di progetto - Parte C - Capitolo 2 - Sezione 2

2.1 Voltage and frequency variation

Table 6 : Voltage and frequency variations for a.c. distribution systems *(1/7/2004)*

Quantity in operation	Variations	
	Continuous	Transient
Voltage	+ 6% - 10%	± 20% (recovery time: 1,5 s)
Frequency	± 5%	± 10% (recovery time: 5 s)

Impianti elettrici - Requisiti di progetto - Parte C - Capitolo 2 - Sezione 2

2.2 Harmonic distortions

2.2.1 For components intended for systems without substantially static converter loads and supplied by synchronous generators, it is assumed that the total voltage harmonic distortion does not exceed 5%, and the single harmonic does not exceed 3% of the nominal voltage.

2.2.2 For components intended for systems fed by static converters, and/or systems in which the static converter load predominates, it is assumed that:

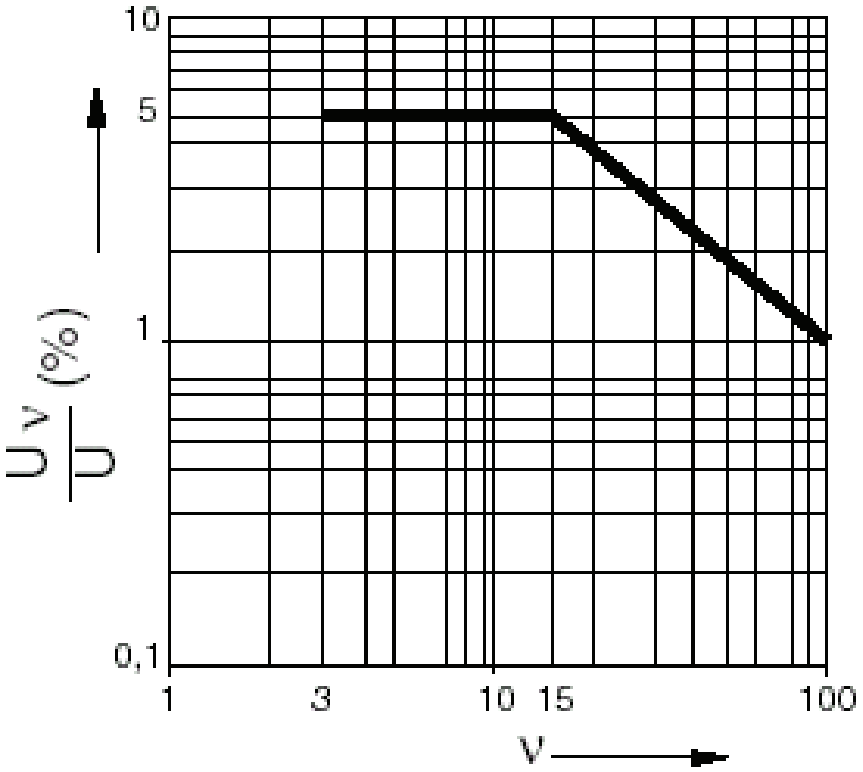
- the single harmonics do not exceed 5% of the nominal voltage up to the 15th harmonic of the nominal frequency, decreasing to 1% at the 100th harmonic (see Fig 1), and that

- the total harmonic distortion does not exceed 10%.

Impianti elettrici - Requisiti di progetto - Parte C - Capitolo 2 - Sezione 2

2.2 Harmonic distortions

Figure 1



Impianti elettrici - Requisiti di progetto - Parte C - Capitolo 2 - Sezione 2

3 Electromagnetic susceptibility

3.1

3.1.1 For electronic type components such as sensors, alarm panels, automatic and remote control equipment, protective devices and speed regulators, the conducted and radiated disturbance levels to be assumed are those given in Chapter 3.

Impianti elettrici - Requisiti di progetto - Parte C - Capitolo 2 - Sezione 2

4.2 Insulating materials for windings

4.2.1 Insulated windings are to be resistant to moisture, sea air and oil vapour unless special precautions are taken to protect insulants against such agents.

Impianti elettrici - Requisiti di progetto - Parte C - Capitolo 2 - Sezione 2

4.2 Insulating materials for windings

4.2.2 *(1/7/2006)*

The insulation classes given in Tab 9 may be used.

Table 9 : Insulation Classes

Class	Maximum continuous operating temperature °C
A	105
E	120
B	130
F	155
H	180

Impianti elettrici – System Design - Parte C - Capitolo 2 - Sezione 3

1 Supply systems and characteristics of the supply
1.1 Supply systems
1.1.1 The following distribution systems may be used:

a) on d.c. installations:

- two-wire insulated
- two-wire with one pole earthed

a) on a.c. installations:

- three-phase three-wire with neutral insulated
- three-phase three-wire with neutral directly earthed or earthed through an impedance
- three-phase four-wire with neutral directly earthed or earthed through an impedance
- single-phase two-wire insulated
- single-phase two-wire with one phase earthed.

Impianti elettrici – System Design - Parte C - Capitolo 2 - Sezione 3

2.2 Main source of electrical power

2.2.3 The main source of electrical power is to consist of at least two generating sets.

The capacity of these generating sets is to be such that in the event of any one generating set being stopped it will still be possible to supply those services necessary to provide:

a) normal operational conditions of propulsion and safety (see [2.2.4])

b) minimum comfortable conditions of habitability (see Sec 1, [3.4.2])

c) preservation of the cargo.

Such capacity is, in addition, to be sufficient to start the largest motor without causing any other motor to stop or having any adverse effect on other equipment in operation.

2.2.4 Those services necessary to provide normal operational conditions of propulsion and safety include primary and secondary essential services.

2.2.5 The services in [2.2.4] do not include:

- thrusters not forming part of the main propulsion
- cargo handling gear
- cargo pumps
- refrigerators for air conditioning.

Impianti elettrici – System Design - Parte C - Capitolo 2 - Sezione 3

2.2 Main source of electrical power

.

2.2.6 *Further to the provisions above, the generating sets shall be such as to ensure that with any one generator or its primary source of power out of operation, the remaining generating sets shall be capable of providing the electrical services necessary to start the main propulsion plant from a "dead ship" condition.*

2.2.8 *The arrangement of the ship's main source of electrical power shall be such that essential services can be maintained regardless of the speed and direction of rotation of the main propulsion machinery or shafting.*

Impianti elettrici – System Design - Parte C - Capitolo 2 - Sezione 3

2.2 Main source of electrical power

.

Requisiti per i generatori mossi dall'impianto di propulsione e facenti parte della centrale elettrica principale (2.2.9) : sono, p. es., i generatori asse mossi da impianti con elica a pale orientabili.

2.2.9 Generators driven by the propulsion plant (shaft generators) which are intended to operate at constant speed (e.g. a system where vessel speed and direction are controlled by varying propeller pitch) may be accepted as forming part of the main source of electrical power if, in all sailing and manoeuvring conditions including the propeller being stopped, the capacity of these generators is sufficient to provide the electrical power to comply with [2.2.3] and all further requirements, especially those of [2.2.6].
They are to be not less effective and reliable than the independent generating sets.

Impianti elettrici – System Design - Parte C - Capitolo 2 - Sezione 3

2.2 Main source of electrical power

Requisiti per i generatori mossi dall'impianto di propulsione e non facenti parte della centrale elettrica principale (2.2.10) : sono, p. es., i generatori asse mossi da impianti con elica a pale fisse.
Possono essere usati in navigazione a patto che siano rispettate alcune condizioni, fra cui vengono qui riportate la a), b), f)

2.2.10 *(1/7/2003)*
Generators and generator systems, having the ship's propulsion machinery as their prime moverbut not forming part of the ship's main source of electrical power (see Note 1) may be usedwhilst the ship is at sea to supply electrical services required for normal operational andhabitable conditions, provided that:

a)there are sufficient and adequately rated additional generators fitted, which constitute the main source of electrical power required by [2.2.1], meeting the provisions of [2.2.8]

Impianti elettrici – System Design - Parte C - Capitolo 2 - Sezione 3

2.2 Main source of electrical power

2.2.10 *(1/7/2003)*

b) arrangements are fitted to automatically start one or more of the generators constituting the main source of electrical power required by [2.2.1], in compliance with [3.4.5] and also in the event of frequency variations exceeding ± 10% of the limits specified below

f) on ships having remote control of the propulsion machinery from the navigating bridge, means are provided or procedures are in place so as to ensure that supplies to essential services are maintained during manoeuvring conditions in order to avoid a blackout situation (see Note 4).

Impianti elettrici – System Design - Parte C - Capitolo 2 - Sezione 3

2.3 Emergency source of electrical power

2.3.1 *A self-contained emergency source of electrical power shall be provided.*

2.3.2 *Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used, exceptionally, and for short periods, to supply non-emergency circuits.*

Exceptionally is understood to mean conditions, while the vessel is at sea, such as:

a) blackout situation
b) dead ship situation
c) routine use for testing
d) short-term parallel operation with the main source of electrical power for the purpose of load transfer.

2.3.3 *The electrical power available shall be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously.*

Vedi : SOLAS – Chapter II-1 – Part D – Electrical Installations – Regulation 42

Impianti elettrici – System Design - Parte C - Capitolo 2 - Sezione 3

3.7 Shore supply

3.7.1 Where arrangements are made for supplying the electrical installation from a source on shore or elsewhere, a suitable connection box is to be installed on the ship in a convenient location to receive the flexible cable from the external source.

Impianti elettrici – System Design - Parte C - Capitolo 2 - Sezione 3

4 Degrees of protection of the enclosures

4.1 General

4.1.1 The minimum required degree of protection for electrical equipment, in relation to the place of installation, is generally that specified in Tab 2.

L'esecuzione delle apparecchiature elettriche deve essere tale da garantire una protezione contro la penetrazione di solidi e acqua adeguata all'ubicazione e al tipo di apparecchiatura.

Impianti elettrici – System Design - Parte C - Capitolo 2 - Sezione 3

4 Degrees of protection of the enclosures

	Grado di protezione delle apparecchiatura elettriche IP xx			
1ª cifra				
0	Non protetto			
1	Protetto contro corpi solidi di grandi dimensioni	Corpi con diametro	≥ 52.5 mm	
2	Protetto contro corpi solidi di medie dimensioni	Corpi con diametro	≥ 12.5 mm	
3	Protetto contro corpi solidi di piccole dimensioni	Corpi con diametro	≥ 2.5 mm	
4	Protetto contro corpi solidi di piccolissime dimensioni	Corpi con diametro	≥ 1 mm	
5	Parzialmente protetto contro la polvere			
6	Protetto contro la polvere			
2ª cifra				
0	Non protetto			
1	Protetto contro lo stillicidio verticale	Caduta di gocce	verticale	
2	Protetto contro lo stillicidio inclinato	Caduta di gocce	inclinata sulla verticale	15°
3	Protetto contro la pioggia	Liquido cadente	inclinato sulla verticale	60°
4	Protetto contro gli spruzzi	Liquido proiettato	qualsiasi direzione	
5	Protetto contro i getti	Liquido lanciato	qualsiasi direzione	da 3 m con p = 1 kg/cm2
6	Protetto contro le ondate	Liquido lanciato	qualsiasi direzione	da 1.5 m con p = 1 kg/cm2
7	Protetto contro l'immersione	Immersione	30 min. con battente di 1 m	
8	Stagno all'immersione	Immersione	tempo indefinito con battente > 1 m specificato	

Impianti elettrici – System Design - Parte C - Capitolo 2 - Sezione 3

4 Degrees of protection of the enclosures – Tab. 2

Condizione	Esempi di ubicazione	Grado di protezione
Pericolo di contatto con parti in tensione	Locali asciutti / Alloggi e servizi	IP 20
Pericolo di stillicidi e/o moderati danni meccanici	Locale AM sopra cielo doppio fondo, depositi, sale di controllo	IP 22
Pericolo notevole per liquidi o danni meccanici	Locale trattamento nafta, spazi sotto pagliolo, cucine, bagni,	IP 34 - 55
Pericolo di spruzzi liquidi, presenza di polveri del carico, gravi danni meccanici, fumi aggressivi	Galleria assi, stive carico, trunk di ventilazione	IP 55 - 56
Pericolo di masse d'acqua in quantità rilevante	Ponti aperti	IP 56

Impianti elettrici – System Design - Parte C - Capitolo 2 - Sezione 3

7 Electrical protection

7.1 General requirements for overcurrent protection

7.1.1 Electrical installations are to be protected against accidental overcurrents including short-circuit.

The choice, arrangement and performance of the various protective devices are to provide complete and coordinated automatic protection in order to ensure as far as possible:

- continuity of service in the event of a fault, through coordinated and discriminative action of the protective devices
- elimination of the effects of faults to reduce damage to the system and the hazard of fire as far as possible.

Note 1: An overcurrent is a current exceeding the nominal current.

Note 2: A short-circuit is the accidental connection by a relatively low resistance or impedance of two or more points in a circuit which are normally at different voltages.

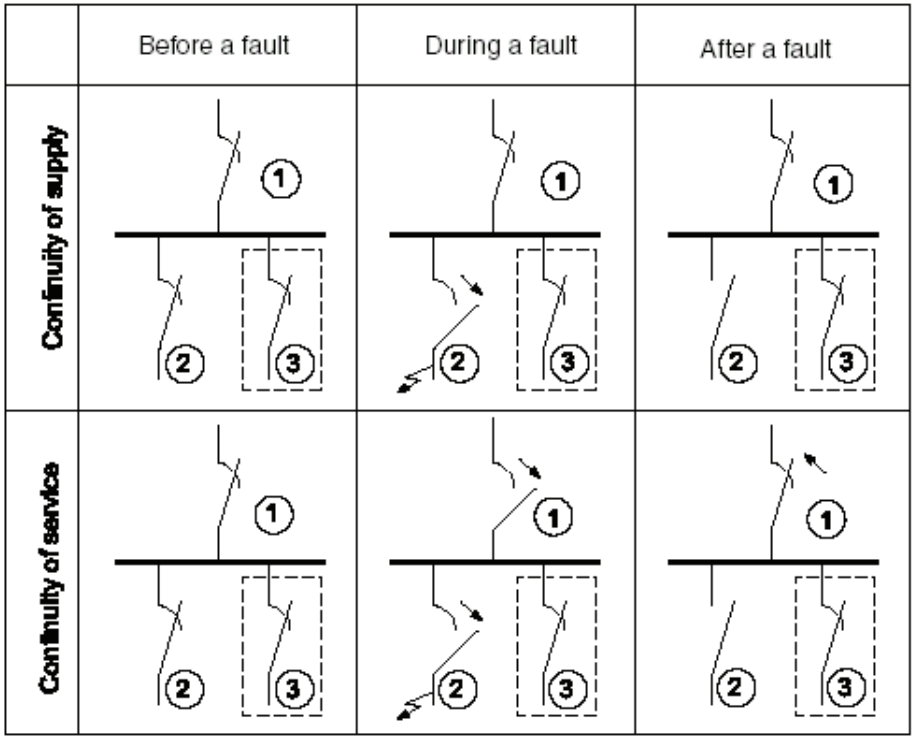
Impianti elettrici – System Design - Parte C - Capitolo 2 - Sezione 3

7 Electrical protection - Definitions

The continuity of supply is the condition for which during and after a fault in a circuit, the supply to the healthy circuits (see circuit 3 in Fig 2) is permanently ensured.

The continuity of service is the condition for which after a fault in a circuit has been cleared, the supply to the healthy circuits (see circuit 3 in Fig 2) is re-established.

Figure 2



Impianti elettrici – System Design - Parte C - Capitolo 2 - Sezione 3

10 Electrical installations in hazardous areas

10.1 Electrical equipment

10.1.1 No electrical equipment is to be installed in hazardous areas unless the Society is satisfied that such equipment is:

- essential for operational purposes,
- of a type which will not ignite the mixture concerned,
- appropriate to the space concerned, and
- appropriately certified for safe usage in the dusts, vapours or gases likely to be encountered.

La norma si applica anche alle navi per trasporto autoveicoli con carburante a bordo (traghetti) e riguarda, fra l'altro, la ventilazione del garage.

Impianti elettrici – Installazione - Parte C - Capitolo 2 - Sezione 12

2 Earthing of non-current carrying parts

2.1 Parts which are to be earthed

2.1.1 Exposed metal parts of both fixed and portable electrical machines or equipment which are not intended to be live but which are liable under fault conditions to become live and similar metal parts inside non-metallic enclosures are to be earthed unless the machines or equipment are:

a) supplied at a voltage not exceeding 50 V direct current or 50 V, root mean square between conductors, achieved without the use of auto-transformers (safety voltage); or

b) supplied at a voltage not exceeding 250 V by safety isolating transformers supplying one consuming device only; or

c) constructed in accordance with the principle of double insulation.

Impianti elettrici- Installazioni in alta tensione
Parte C - Capitolo 2 - Sezione 13

1 General
1.1 Field of application
1.1.1 *(1/1/2002)*
The following requirements apply to a.c. three-phase systems with nominal voltage exceeding 1kV, the nominal voltage being the voltage between phases.

1.2 Nominal system voltage
1.2.1 *(1/1/2002)*
The nominal system voltage is not to exceed 15 kV.

Note 1: Where necessary for special application, higher voltages may be accepted by the Society.

Tecnicamente si definisce "media tensione" la tensione compresa fra 1 e 11 kV, attualmente la massima adottata a bordo di navi mercantili

Impianti di Propulsione Elettrica - Parte C - Capitolo 2 - Sezione 14

- **Motori primi : devono corrispondere a tutte le norme valide per gli altri tipi di motori di propulsione**

1 General

1.1 Applicable requirements

1.2.1 The normal torque available on the electric propulsion motors for manoeuvring is to be such as to enable the vessel to be stopped or reversed when sailing at its maximum service speed.

1.2.2 Adequate torque margin is to be provided for three phase synchronous motors to avoid the motor pulling out of synchronism during rough weather and when turning.

1.2.3 When an electric generating plant has a continuous rating greater than the electric propulsion motor rating, means are to be provided to limit the continuous input to the motor. This value is not to exceed the continuous full load torque for which motor and shafts are designed.

1.2.4 The plant as a whole is to have sufficient overload capacity to provide the torque, power and reactive power needed during starting and manoeuvring conditions.
Locked rotor torque which may be required in relation to the operation of the vessel (e.g. for navigation in ice) is to be considered.

2 Design of the propulsion plant

2.1 General

2.1.2 For plants having only one propulsion motor controlled via a static convertor, a standby convertor which it is easy to switch over to is to be provided. Double stator windings with one convertor for each winding are considered as an alternative solution.

2.1.3 In electric propulsion plants having two or more constant voltage propulsion generating sets, the electrical power for the ship's auxiliary services may be derived from this source. Additional ship's generators for auxiliary services need not be fitted provided that effective propulsion and the services mentioned in Sec 3, [2.2.3] are maintained with any one generating set out of service.
Where transformers are used to supply the ship's auxiliary services, see Sec 5.

2.1.4 Plants having two or more propulsion generators, two or more static convertors or two or more motors on one propeller shaft are to be so arranged that any unit may be taken out of service and disconnected electrically, without affecting the operation of the others.

2.4 Electrical Protection

2.4.1 Automatic disconnections of electric propulsion plants which adversely affect the manoeuvrability of the ship are to be restricted to faults liable to cause severe damage to the equipment.

3 Construction of rotating machines and semiconductor convertors

3.1 Ventilation

3.1.1 Where electrical machines are fitted with an integrated fan and are to be operated at speeds below the rated speed with full load torque, full load current, full load excitation or the like, the design temperature rise is not to be exceeded.

3.1.2 Where electrical machines or convertors are forceventilated, at least two fans, or other suitable arrangements, are to be provided so that limited operation is possible in the event of one fan failing.

4 Control and monitoring

4.2.2 The automatic control systems are to be such that, in the event of a fault, the propeller speed and direction of thrust do not undergo substantial variations.

4.2.3 Failure of the power plant control system is not to cause complete loss of generated power (i.e. blackout) or loss of propulsion.

4.2.8 The risk of blackout due to electric propulsion operation is to be eliminated. At the request of the Society, a failure mode and effects analysis is to be carried out to demonstrate the reliability of the system.

4.5 Reduction of power

4.5.1 Power is to be automatically reduced in the following cases:

- low lubricating oil pressure of bearings of propulsion generators and motors
- high winding temperature of propulsion generators and motors
- fan failure in machines and convertors provided with forced ventilation, or failure of cooling system
- lack of coolant in machines and semiconductor convertors
- load limitation of generators or inadequate available power.

Impianti di propulsione navale

Robustezza delle pale dell'elica

La pala dell'elica è sollecitata dalla forza centrifuga, costante durante la rotazione, e dai momenti flettenti determinati dalla spinta assiale e dalla forza trasversale dovuta alla resistenza che l'acqua oppone alla rotazione dell'elica.

Spinta assiale e resistenza variano nel corso della rotazione a causa della disuniformità del campo della scia. Nei casi più sfavorevoli, la fluttuazione delle suddette forze attorno al loro valore medio può raggiungere il +/- 80%.
Incrementi transitori del carico sulla pala si possono avere a seguito di manovre brusche, come ad esempio il "crash astern" effettuato quando la nave è all'andatura di tutta forza avanti.
Carichi d'urto si verificano quando la pala colpisce oggetti solidi, ad esempio nella navigazione fra i ghiacci.

Da un punto di vista strutturale, la pala viene considerata come una mensola incastrata e la sollecitazione viene calcolata alla sezione cilindrica corrispondente al raggio 0.25 R per le eliche a pale fisse e 0.35 R per le eliche a pale orientabili.
Il metodo di calcolo tradizionale comporta alcune semplificazioni.

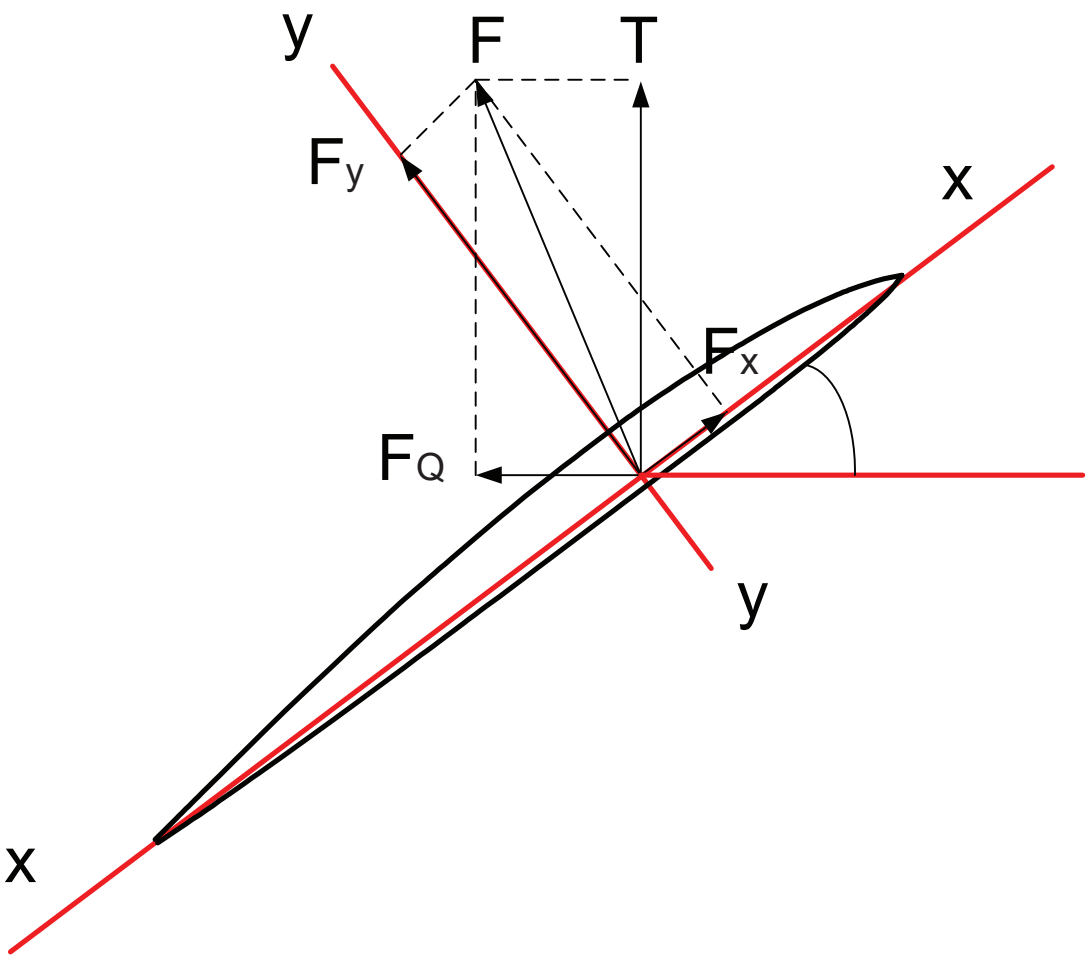
Robustezza delle pale dell'elica

Nel caso di pale fortemente sollecitate e di pale aventi geometrie complesse (alti angoli di skew), è opportuno ricorrere a metodi di calcolo agli elementi finiti.
In ogni caso è necessario conoscere in dettaglio la distribuzione dei carichi agenti sulla pala. Ciò non è sempre possibile, specie per le situazioni "off-design".

Consideriamo dapprima il calcolo delle sollecitazioni dovute alle forze stazionarie, ossia la forza centrifuga e i valori medi della spinta e della forza trasversale dovuta al momento torcente.
La forza centrifuga agisce nel baricentro della parte di pala esterna rispetto alla sezione resistente e provoca una sollecitazione di trazione.
La risultante della spinta T e della forza trasversale F_Q ha il suo punto di applicazione presso la sezione a 0.7 R.
Detta risultante può essere scomposta in una forza F_y diretta perpendicolarmente alla corda della sezione resistente (a 0.25 R o a 0.35 R) e in una forza F_x diretta nel senso della corda suddetta.
F_y determina un momento flettente attorno all'asse x-x della sezione mentre F_x determina un momento flettente attorno all'asse minore y-y. Quest'ultimo dà un contributo scarso alla sollecitazione da flessione e può essere quindi trascurato.

Robustezza delle pale dell'elica

Forze applicate alla pala dell'elica



Robustezza delle pale dell'elica

Lo spessore in corrispondenza della sezione resistente della pala è determinato per mezzo di formule stabilite nei regolamenti dei Registri di Classifica.

I dati di input fondamentali sono :

- **diametro dell'elica,**
- **rapporto passo / diametro,**
- **lunghezza della corda della sezione resistente,**
- **potenza applicata all'elica,**
- **velocità di rotazione dell'elica,**
- **carico di rottura del materiale dell'elica.**

Sono in alcuni casi previsti fattori correttivi che tengono conto della grandezza dell'elica (considerando la qualità della fusione), la sollecitazione a fatica e la possibilità che l'elica sia impiegata in navigazioni con rimorchio.

Le formule del RINa sono riportate nella Parte C, Capitolo 1, Sezione 8.

Impianti di propulsione navale

Robustezza delle pale dell'elica

2.2 Solid propellers - Blade thickness

2.2.1 *(1/7/2002)*

a) The maximum thickness $t_{0,25}$, in mm, of the solid propeller blade at the section at 0,25 radius from the propeller axis is not to be less than that obtained from the following formula:

$$t_{0,25} = 3,2\left[f \cdot \frac{1,5.10^6.\rho.M_T + 51.\delta.\left(\frac{D}{100}\right)^3.B.l.N^2.h}{l \cdot z \cdot R_m}\right]^{0,5}$$

where:

f : Material factor as indicated in Tab 3

ρ : D/H

H : Mean pitch of propeller, in m. When H is not known, the pitch $H_{0.7}$ at 0,7 radius from the propeller axis, may be used instead of H.

D : Propeller diameter, in m

M_T : Continuous transmitted torque, in kN.m; where not indicated, the value given by the following formula may be assumed for M_T :

$$M_T = 9,55 \cdot \left(\frac{P}{N}\right)$$

P : Maximum continuous power of propulsion machinery, in kW

N : Rotational speed of the propeller, in rev/min

δ : Density of blade material, in kg/dm³, as indicated in Tab 3

B : Expanded area ratio

h : Rake, in mm

l : Developed width of blade section at 0,25 radius from propeller axis, in mm

z : Number of blades

R_m : Minimum tensile strength of blade material, in N/mm².

Robustezza delle pale dell'elica

b) The maximum thickness $t_{0,6}$, in mm, of the solid propeller blade at the section at 0,6 radius from the propeller axis is not to be less than that obtained from the following formula:

$$t_{0,6} = 1,9\left[f\,\frac{1,5.10^6.\rho_{0,6}.M_T + 18,4.\delta.\left(\frac{D}{100}\right)^3.B.I.N^2.h}{l_{0,6}\cdot z\cdot R_m}\right]^{0,5}$$

where:

$\rho_{0,6}$: $D/H_{0.6}$

$H_{0.6}$: Pitch at 0,6 radius from the propeller axis, in m

$l_{0.6}$: Developed width of blade section at 0,6 radius from propeller axis, in mm.

Table 3 : Normally used materials for propeller blades and hub

Material	R_m	δ	f
Common brass	400	8,3	7,6
Manganese brass (Cu1)	440	8,3	7,6
Nickel-manganese brass (Cu2)	440	8,3	7,9
Aluminium bronze (Cu3 and Cu4)	590	7,6	8,3
Steel	440	7,9	9,0

Robustezza delle pale dell'elica

Lo spessore della sezione resistente calcolato con le formule dei Registri comporta una sollecitazione statica di 50 – 60 N/mm^2.
I materiali normalmente usati per le eliche sono il bronzo e l'acciaio inossidabile, entrambi con un carico di rottura pari a 620 – 640 N/mm^2. Il coefficiente di sicurezza è pertanto maggiore di 10, a prima vista alquanto elevato. Bisogna comunque considerare, in aggiunta al carico medio stazionario, la presenza di fenomeni di fatica.
In passato, il carico statico massimo ammissibile era stabilito con criteri empirici. L'incremento di potenza e velocità delle navi provocò, negli anni '60, un numero crescente di rotture delle pale delle eliche, non attribuibili ad urti accidentali o al ghiaccio. A seguito di ciò vennero intrapresi studi approfonditi sui fenomeni di fatica e si trovò che, specie per eliche operanti in campi di scia con forti variazioni locali, lo spessore delle pale andava aumentato oltre al valore corrispondente alle sollecitazioni normali ammissibili.

Materiale dell'elica

La quasi totalità delle eliche a pale fisse è costruita in leghe di bronzo.
Le eliche a pale orientabili sono costruite per l'80% in bronzo e per il 20% in acciaio inox.

Si usano tre tipi di leghe di bronzo :

- **bronzo al nichel – alluminio,**
- **bronzo al manganese – alluminio,**
- **bronzo ad alta resistenza**

Composizione e caratteristiche meccaniche delle leghe di bronzo e dell'acciaio inox sono riportate nelle tabelle seguenti (fonte : Rolls-Royce – KaMeWa)

Materiale dell'elica

	Bronzo Ni-Al	Bronzo Mn-Al	Bronzo alta resistenza
	%	%	%
Alluminio	8 - 10	5 - 9	0.5 - 2
Nichel	2 - 5	1.5 - 4	1 - 5
Manganese	1 - 10	11 - 20	2 - 4
Ferro	2 - 5	2 - 4	1 - 3
Zinco	-	(3 – 9)	Rimanente
Rame	Rimanente	Rimanente	55 - 62

Materiale dell'elica

	Acciaio inox
	%
Carbonio	0.03 – 0.12
Silicio	0.5 – 0.8
Manganese	ca. 1
Cromo	13 - 22
Nichel	1 - 6
Molibdeno	ca. 1
Ferro	Rimanente

Materiale dell'elica

		Bronzo Ni - Al	Bronzo Mn - Al	Bronzo alta resistenza	Acciaio inox
Carico di rottura	N/mm2	600 - 750	650 - 700	450 - 550	600 - 700
Snervamento	N/mm2	200 - 300	250 - 350	170 - 250	350 - 500
Allungamento	%	18 - 30	19 - 35	20 - 30	15 - 20
Durezza	HB	150 - 210	160 - 210	120 - 140	200 - 300
Limite di fatica	N/mm2	160 - 170	ca. 140	80 - 100	60 - 80