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HYDROGEN-FUELLED SHIPS

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RULE NOTE

BUREAU VERITAS

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RULES, RULE NOTES AND GUIDANCE NOTES

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These rules are provided within the scope of the Bureau Veritas Marine & Offshore General Conditions, enclosed at the end of Part A of NR467, Rules for the Classification of Steel Ships. The latest version of these General Conditions is available on the Bureau Veritas Marine & Offshore website.

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HYDROGEN-FUELLED SHIPS

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CHAPTER 1
HYDROGEN-FUELLED SHIPS

Section 1 General

1 General

1.1 Scope

1.1.1 This Rule Note provides requirements for the arrangement, installation, control and monitoring of machinery, equipment and systems using hydrogen as fuel, for power generation.

1.1.2 This Rule Note is applicable to onboard systems used for hydrogen bunkering, storage, preparation, distribution and power generation by an internal combustion engine or a fuel cell. Associated safety, monitoring and control systems, as well as testing and certification requirements are also covered.

1.1.3 In this Rule Note, hydrogen is considered to be stored in gaseous compressed state or liquid state. Other types of storage, e.g. use of metal hydrides, may be considered by the Society on a case-by-case basis. Additionally, the simultaneous use of hydrogen in conjunction with another fuel within a fuel consumer may also be subject to special consideration by the Society.

1.1.4 Except otherwise mentioned, the requirements of this Rule Note apply to both compressed and liquefied hydrogen systems, permanent and portable tanks.

1.2 Classification notation

1.2.1 Ships complying with the requirements of Sec 2 to Sec 8 of this Chapter of this Rule Note will be eligible for assignment of the additional service feature **hydrogenfuel** as defined in NR467, Pt A, Ch 1, Sec 2, [4.16].

The additional service feature **hydrogenfuel** is to be completed by one of the following notations:

singlefuel for ships fitted with engines or fuel cells using only hydrogen

dualfuel for ships fitted with engines using both hydrogen and fuel oil.

The notations singlefuel or dualfuel may be completed by:

-aux, when the ship uses hydrogen only for the generating set

-prop, when the ship uses hydrogen only for the propulsion system.

1.2.2 Ships complying with the requirements of Chapter 2 of this Rule Note will be eligible for assignment of the additional class notation **HYDROGENFUEL-PREPARED** as defined in NR467, Pt A, Ch 1, Sec 2, [6].

1.3 Documentation to be submitted

1.3.1 Documentation to be submitted for assigning the additional service feature **hydrogenfuel** is listed in Tab 1.

1.3.2 Where liquefied hydrogen is used, additional documentation to be submitted is listed in Tab 2.

1.3.3 Where hydrogen is used in an internal combustion engine, additional documentation to be submitted is listed in Tab 3.

1.3.4 Where hydrogen is used in a fuel cell, additional documentation to be submitted is listed in NR547.

1.3.5 Documentation to be submitted for assigning the additional class notation **HYDROGENFUEL-PREPARED** is listed in Chapter 2.

Table 1 : Documentation to be submitted

No.	I/A **(1)**	Documents **(2)**
1	I	General arrangement of the ship showing the location of the bunkering stations, hydrogen tanks, tank connection space (TCS), fuel preparation rooms, vent masts, etc.
2	I	General arrangement of the machinery spaces containing the hydrogen utilization units (e.g. gas combustion units)
3	A	Hazardous area zone plan and hydrogen dispersion analysis
4	A	Airlocks between safe and hazardous zones
5	I	Risk analysis as per Sec 2, [1]and follow-up report of the recommendations
6	A	Leakage scenario and TCS leakage containment analysis, as required by Sec 3, [1.4.2]
7	A	Details of hull structure in way of hydrogen containment system including support arrangement for tanks, saddles, anti-floating, anti-pitching, anti-rolling and anti-pitching devices, deck sealing arrangements, etc

(1) A = to be submitted for approval; I = to be submitted for information
(2) Diagrams are to include also, where applicable, the local and remote control systems and automation systems

No.	I/A **(1)**	Documents **(2)**
8	I	Stress analysis covering the assessment of the structural elements described in item no. 7
9	A	Scantlings, material and arrangement of the hydrogen containment system, including the secondary barrier, if any
10	A	Hull ship motion analysis, where a direct analysis is preferred to the methods referred to in Sec 7, [5]
11	I	Sloshing calculation where relevant
12	A	Stress analysis of the hydrogen containment
13	A	Details of ladders, fittings, swash bulkheads and towers in tanks and relative stress analysis, if any
14	A	Details of tank domes and deck sealings
15	A	Fuel containment system testing and inspection procedures
16	A	Inspection/survey plan for the hydrogen containment system as requested in Sec 7, [1.1.2]
17	A	Vent mast detailed drawing
18	A	Hydrogen tank pressure control philosophy
19	A	Details of insulation
20	A	Plans and calculations of pressure relief devices
21	A	Diagram of the liquefied and/or gaseous hydrogen piping system, including venting systems
22	A	Arrangement of the double piping or duct system
23	A	Specification of the control, monitoring and safety systems for the hydrogen installation (Cause and effect matrix)
24	A	Material, thickness and joints of the hydrogen pipes
25	A	Diagram of the inert gas piping system
26	A	Diagram of the ventilation in all spaces containing gas piping
27	A	Ventilation duct arrangement in hazardous spaces and adjacent zones
28	A	Diagram of the gas detection system
29	A	Diagram of heating media system
30	A	Details of hydrogen fuel pumps and compressors
31	A	Details of process pressure vessels and relative valving arrangement
32	A	Bilge system of the spaces related to hydrogen storage and preparation
33	A	Emergency shutdown system
34	A	Fuel containment system instrumentation, including fuel and hull temperature monitoring system if any
35	A	Details of fire-extinguishing appliances and systems related to hydrogen installation: Water spray system when required to be fitted, Dry chemical powder, Fire Main
36	I	Specification and type-approval reference of the hydrogen utilization units
37	A	Diagram of the gas fuel supply systems, for each hydrogen utilization unit
38	A	Arrangement of the GVUs
39	A	Specification of the control, monitoring and safety systems for each hydrogen utilization unit
40	A	Instrumentation list
41	I	Safety certificates for electrical equipment located in hazardous spaces or areas, where applicable
42	A	Schematic electrical wiring diagram in hazardous areas
43	A	Failure modes and effects of single failure for electrical generation and distribution systems as requested in Sec 2, [1.1.5]
44	A	Arrangement of electrical installation in hazardous areas, including lighting system
45	I	Fuel containment system hydrogen freeing procedure, including emptying, inerting and aerating
46	I	Procedure for maintenance of the hydrogen utilization units and other hydrogen-related equipment, including the steps to be taken prior to servicing the units
47	A	Bunkering procedure
48	I	Ship operating manual
49	I	Hydrogen leakage rate analysis (see Sec 4, [1.1.2]
50	A	Stress analysis of the high pressure piping systems
(1) A = to be submitted for approval; I = to be submitted for information **(2)** Diagrams are to include also, where applicable, the local and remote control systems and automation systems		

Table 2 : Documentation to be submitted for liquefied hydrogen

No.	I/A **(1)**	Documents
1	I	Calculation of the hull temperature and associated distribution of quality and steel grades
2	I	Calculation of the thermal insulation suitability, including boil-off rate and refrigeration plant capability, if any, cooling down and temperature gradients during loading and unloading operations
3	A	Stress analysis of the piping systems, when their design temperature is –110°C or lower
4	A	Hull structure heating system, if any
5	A	FMEA analysis for the systems intended to maintain the hydrogen tank pressure and temperature (see Sec 7, [5.3.6])
6	A	List of failure modes and relevant repair procedures for heat exchangers (see Sec 7, [5.3.7]
7	I	Demonstration of pressure control methods suitability (See Sec 7, [5.3.1]
(1) A= to be submitted for approval; I= to be submitted for information		

Table 3 : Documentation to be submitted for internal combustion engine

No.	I/A **(1)**	Documents
1	A	General arrangement of the machinery spaces containing the hydrogen engines
2	A	Schematic layout or other equivalent documents of hydrogen system on the engine
3	A	Hydrogen supply piping system (including double-walled arrangement where applicable)
4	A	Parts for hydrogen admission system **(2)**
5	A	Diagram of the engine crankcase venting system **(3)**
6	A	Arrangement of explosion relief valves (crankcase **(4)**, charge air manifold, exhaust gas manifold) as applicable
7	A	Diagram of the engine lubricating oil system **(3)**
8	A	Diagram of the engine cooling system **(3)**
9	A	Drawing of the exhaust gas ducts
10	A	List of certified safe equipment and evidence of relevant certification
11	I	Safety concept
12	I	Report of the risk analysis **(5)**
13	I	Hydrogen specification
Documents to be submitted for dual fuel engines only		
14	A	Schematic layout or other equivalent documents of fuel oil system (main and pilot fuel systems) on the engine
15	A	Shielding of high-pressure fuel pipes for pilot fuel system, assembly
16	A	High-pressure parts for pilot fuel oil injection system **(3)**
Documents to be submitted for single fuel engines only		
17	A	Ignition system
(1) A= to be submitted for approval; I= to be submitted for information **(2)** The documentation is to contain specification of pressures, pipe dimensions and materials **(3)** Diagrams are to include also, where applicable, the local and remote control systems and automation systems **(4)** If required by NR467 Rules for Steel Ships, Pt C, Ch 1, Sec 2 **(5)** See Sec 2		

1.4 Definitions

1.4.1 Bunkering

Bunkering means the transfer of liquid or gaseous fuel from land based or floating bunkering facilities into a ships' permanent tanks or connection of portable tanks to the fuel supply system. Bunkering also covers the transfer of fuel vapour from the ship's tank to the bunkering facilities.

1.4.2 Compressed hydrogen cylinders

Compressed hydrogen cylinders are transportable pressure receptacle designed and manufactured to store gaseous compressed hydrogen.

1.4.3 Compressed hydrogen tanks

Compressed hydrogen tanks are pressure vessel that contains gaseous hydrogen stored under high pressure. Compressed hydrogen tanks include cylinders and non-transportable receptacles.

1.4.4 Double block and bleed valve

Double block and bleed valve means a set of two valves in series in a pipe and a third valve enabling the pressure release from the pipe between those two valves. The arrangement may also consist of a two-way valve and a closing valve instead of three separate valves.

1.4.5 Filling limit (FL)

Filling limit (FL) means the maximum liquid volume in a fuel tank relative to the total tank volume when the liquid fuel has reached the reference temperature.

1.4.6 Fuel containment system

Fuel containment system is the arrangement for the storage of fuel including tank connections. It includes where fitted, associated insulation and any intervening spaces, and adjacent structure if necessary for the support of these elements The spaces around the fuel tank are defined as follows:

- Fuel storage hold space is the space enclosed by the ship's structure in which a fuel containment system is situated. If tank connections are located in the fuel storage hold space, it will also be a tank connection space
- Tank connection space (TCS) is a space surrounding all tank connections and tank valves that is required for tanks with such connections in enclosed spaces.

A tank connection space may also contain low pressure gas valve units or other low pressure equipment intended for fuel preparation, such as vaporizers or heat exchangers. Such equipment is considered to only contain potential sources of release, but not sources of ignition.

1.4.7 Fuel preparation room

Fuel preparation room means any space containing pumps, compressors and/or vaporizers for fuel preparation purposes. A tank connection space which has equipment such as vaporizers or heat exchangers installed inside is not regarded as a fuel preparation room. Such equipment is considered to only contain potential sources of release, but not sources of ignition.

1.4.8 Gas valve unit (GVU)

Gas valve unit (GVU) is a set of manual shut-off valves, actuated shut-off and venting valves, gas pressure sensors and transmitters, gas temperature sensors and transmitters, gas pressure control valve and gas filter used to control the gas supply to each gas consumer. It also includes a connection for inert gas purging.

1.4.9 Gas Combustion Unit (GCU)

Gas Combustion Unit (GCU) means a system intended for the combustion of boil-off hydrogen in excess.

1.4.10 High fire risk space

High fire risk space includes as a minimum, but should not be restricted to:

- cargo spaces except cargo tanks for liquids with flashpoint above 60°C and except cargo spaces exempted in accordance with NR467, Pt C, Ch 4, Sec 6, [6.1.2] and [6.1.4]
- vehicle, ro-ro and special category spaces
- service spaces (high risk): galleys, pantries containing cooking appliances, saunas, paint lockers and store-rooms having areas of 4 m2 or more, spaces for the storage of flammable liquids and workshops other than those forming part of the machinery space, as provided in NR467, Pt C, Ch 4, Sec 5, [1.3.4], [1.4.3] and [1.5]; and
- accommodation spaces of greater fire risk: saunas, sale shops, barber shops, beauty parlours and public spaces containing furniture and furnishing of other than restricted fire risk and having deck area of 50 m2 or more, as provided in NR467, Pt C, Ch 4, Sec 5, [1.3.3].

1.4.11 High pressure

High pressure means a maximum working pressure greater than 1,0 MPa.

1.4.12 Hydrogen consumer machinery space

Hydrogen consumer machinery space means a machinery space defined as per NR467 Pt C, Ch 4, Sec 1, [3.28] containing a hydrogen consumer or a machinery space containing a fuel cell space defined as per NR547, Sec 1, [1.5.7].

Note 1: When the hydrogen consumer machinery space is equivalent to the fuel cell space, rules for the fuel cell space take precedence.

1.4.13 Hydrogen-convertible

Hydrogen-convertible applies to engines that are designed and approved for oil fuel operation, capable of being subsequently converted to hydrogen fuel operation, and for which a conversion method has been approved by the Society.

1.4.14 LEL

LEL means the Lower Explosive Limit.

1.4.15 Loading limit

Loading limit means the maximum allowable liquid volume relative to the tank volume to which the tank may be loaded.

1.4.16 MARVS

MARVS means the maximum allowable relief valve setting.

1.4.17 Multiple-element gas containers (MEGCs)

Multiple-element gas containers (MEGCs) are multimodal assemblies of compressed hydrogen cylinders, tubes or bundles of cylinders which are interconnected by a manifold and which are assembled within a framework. The MEGC includes service equipment and structural equipment necessary for the transport of gases.

1.4.18 Pressure relief device

Pressure relief device means a device that, when activated under specified performance conditions, is used to release hydrogen from a pressurized system and thereby prevent failure of the system (e.g. PRV, TPRD).

1.4.19 Pressure Relief Valve (PRV)

Pressure Relief Valve (PRV) means a safety device designed to protect a pressurized vessel or system from overpressurized conditions.

1.4.20 Service equipment

Service equipment of a cylinder or a MEGC means filling and discharge devices, including the manifold, safety devices and measuring instruments.

1.4.21 Test pressure

Test pressure means the pressure to be applied during a pressure test.

1.4.22 Thermally activated Pressure Relief Device (TPRD)

Thermally activated Pressure Relief Device (TPRD) is a pressure relief device activated by temperature to open and release a gas.

1.4.23 Cylinder (type of compressed hydrogen cylinder)

Compressed hydrogen cylinders are categorized in 4 types:

- Cylinder Type 1 Seamless metallic container
- Cylinder Type 2 Hoop wrapped container with a seamless metallic liner
- Cylinder Type 3 Fully wrapped container with a seamless or welded metallic liner
- Cylinder Type 4 Fully wrapped container with a non-metallic liner.

1.4.24 Very high pressure

Very high pressure means a maximum working pressure greater than 2,0 MPa.

1.5 References

1.5.1 References to the following documents are used in this Rule Note:

NR216 : Rules on Materials and Welding for the Classification of Marine Unit
NR266 : Requirements for Survey of Materials and Equipment for the Classification of Ships and Offshore Units
NR320 : Certification Scheme of Materials and Equipment for the Classification of Marine Units
NR467 : Rules for the Classification of Steel Ships
NR529 : Gas-fuelled Ships
NR547 : Ships using Fuel Cells

1.5.2 References to the following standards or external documents are used in this Rule Note:

- ASME B31.12-2019 - Hydrogen Piping and Pipelines
- EN 1797:2001 - Cryogenic vessels. Gas/material compatibility
- EN 13530-2:2003 - Cryogenic vessels - Large transportable vacuum insulated vessels - Part 2: Design, fabrication, inspection and testing
- EN ISO 14726:2008 - Ships and marine technology - Identification colours for the content of piping systems
- EN 17339:2020 - Transportable gas cylinders - Fully wrapped carbon composite cylinders and tubes for hydrogen
- IEC 60079-10-1:2020 - Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres
- IEC 60092-502:1999 - Electrical installations in ships - Part 502: Tankers - Special features
- IEC 60068-2-6:2007 - Environmental testing - Part 2-6: Tests - Test Fc: Vibration (sinusoidal)
- ISO 1496-3:2019 - Series 1 freight containers - Specification and testing - Part 3: Tank containers for liquids, gases and pressurized dry bulk
- ISO 9809 series - Gas cylinders - Design, construction and testing of refillable seamless steel gas cylinders and tubes - Part 4: Stainless steel cylinders with an Rm value of less than 1 100 MPa
- ISO 11114-1:2017 - Gas cylinders. Compatibility of cylinder and valve materials with gas contents - Metallic materials
- ISO 11114-4:2017 - Transportable gas cylinders - Compatibility of cylinder and valve materials with gas contents - Part 4: Test methods for selecting steels resistant to hydrogen embrittlement
- ISO 11119-1:2020 - Gas cylinders. Design, construction and testing of refillable composite gas cylinders and tubes - Hoop wrapped fibre reinforced composite gas cylinders and tubes up to 450 l

- ISO 11119-2:2020 - Gas cylinders. Design, construction and testing of refillable composite gas cylinders and tubes - Fully wrapped fibre reinforced composite gas cylinders and tubes up to 450 l with load-sharing metal liners
- ISO 11119-3:2020 - Gas cylinders - Design, construction and testing of refillable composite gas cylinders and tubes - Part 3: Fully wrapped fibre reinforced composite gas cylinders and tubes up to 450 l with non-load-sharing metallic or non-metallic liners or without liners
- ISO 11623:2015 - Gas cylinders - Composite construction - Periodic inspection and testing
- ISO 13769:2018 - Tracked Changes. Gas cylinders. Stamp marking
- ISO 21028-1: 2016 - Cryogenic vessels. Toughness requirements for materials at cryogenic temperature Temperatures below -80 °C
- ISO 21746:2019 - Composites and metal assemblies. Galvanic corrosion tests of carbon fibre reinforced plastics (CFRPs) related bonded or fastened structures in artificial atmospheres. Salt spray tests
- ISO 26142:2010 - Hydrogen detection apparatus

Section 2 Safety Assessment

1 Hazard identification and risk analysis

1.1 General

1.1.1 A risk assessment is to be conducted in order to ensure that any risks arising from the use of hydrogen affecting persons on board, the environment, the structural strength or the integrity of the ship are addressed. Consideration is to be given to the hazards associated with installation, operation, and maintenance, following any reasonably foreseeable failure. As a minimum, the risk assessment is to include the studies detailed in [1.1.4] to [1.1.6] and further studies may be required by the Society as a complement.

1.1.2 Hazards are to be identified using acceptable and recognised hazard identification techniques. The following hazards are to be considered, as a minimum: loss of function, component damage, operational and environment-related influences, electrical faults, unwanted chemical reactions, auto-ignition of fuels, fire, explosion, short-term power failure (blackout). The effects of the following are to be considered:

- the ship's operational profile
- the ship's operational status
- modes of operation
- environmental conditions
- dependencies - power, fuel, air, cooling, heating, data, human input
- environmental impact and failures - human error, supply failure, system, machinery
- equipment and component failure, random, systematic, common cause.

1.1.3 The risks are to be analysed using acceptable and recognised risk analysis techniques. The analysis is to ensure that risks are eliminated wherever possible. Risks which cannot be eliminated are to be mitigated as necessary. If mitigation solutions are operational, details of risks, and the means by which they are mitigated, are to be included in the operating manual.

1.1.4 An HAZID study is to be carried out for each hydrogen-fuelled ship. The study is to cover at least the following spaces, zones and systems, where relevant:

- tank connection space (TCS) and tank connection on open decks (See Sec 3, [1.4.1])
- enclosed and semi-enclosed fuel preparation rooms
- enclosed and semi-enclosed bunkering stations
- spaces containing very high pressure gas or liquid fuel piping
- GVU spaces (except GVU enclosures)
- machinery spaces containing hydrogen consumers
- zones where vent lines and safety valve discharge lines are led, except where ventilation inlets to accommodation and machinery spaces are provided with gas detection arrangements
- containment systems and adjacent structure
- hydrogen piping, especially gaseous piping without protective enclosure on open deck (see Sec 9, [3.1.1]).

The risks identified by the HAZID study may be mitigated by operational procedures (e.g. stopping ship spaces ventilation during bunkering operations to prevent gas from entering those spaces through openings).

Gas dispersion analysis may be required to better assess the risk associated with gas venting or pressure relief.

1.1.5 An FMECA analysis is to be carried out for electrical generation, distribution systems (see Sec 10, [4.1.2]) and equipment used for essential services.

1.1.6 An HAZOP study is to be carried out for the very high pressure hyfrogen fuel installation.

1.1.7 The risk analysis required is to cover the specific risks arising from the use of portable tanks if any. At least the following events and failures are to be addressed as relevant:

- handling of the tank
- connection / disconnection of the detachable piping systems
- overfilling / over pressurization due to intercommunication of tanks, in case of multi-tanks arrangement
- improper assembly or failure of the tank fixation / lashing
- rupture of a pipe between the tank and the shut-off valve
- rupture of flexible hose
- inadvertent disconnection of a non-permanent connection.

1.1.8 Closed or semi-enclosed bunkering stations are to be subject to special consideration within the risk assessment, which is to include, but not be restricted to, the following design features:

- segregation towards other areas on the ship
- hazardous area definition
- requirements for mechanical ventilation
- requirements for leakage detection
- safety actions related to leakage detection
- requirements for fire detection
- safety actions related to fire detection
- access to bunkering station from non-hazardous areas through airlocks; and
- monitoring of bunkering station by direct line of sight or by CCTV.

1.1.9 For cryogenic tanks and associated insulated pipes, the risk analysis is to include the risks:

- arising from the deterioration of insulation capability by single damage and determine the safety measures to be adopted in such situation
- associated to cryogenic leakages
- associated to oxygen enrichment of the atmosphere.

1.1.10 Machinery spaces combining hydrogen-fuelled engines and other types of engines (conventional or other low-flashpoint-fuelled) are to be subject to special consideration within the risk assessment.

1.1.11 Use of flame arresters is to be subject to special consideration within the risk assessment. See Sec 8, [3.1.2].

1.1.12 For any risk assessment carried out in the scope of the present Rules, a detailed follow-up report of actions and mitigation measures taken in response to any analysis findings is to be submitted to the Society.

This report is to include especially the monitoring and control options mentioned in Sec 11, [1.1.1].

1.2 Limitation of explosion consequences

1.2.1 The risk analysis is to identify the spaces in which explosive mixtures may be encountered, their volumes, their probability of explosion and the associated consequences. An explosion in any space containing any potential sources of release and potential ignition sources is not to:

- cause damage to or disrupt the proper functioning of equipment / systems located in any space other than that in which the incident occurs
- damage the ship in such a way that flooding of water below the main deck or any progressive flooding occur
- damage work areas or accommodation in such a way that people who stay in such areas under normal operating conditions are injured
- disrupt the proper functioning of control stations and switchboard rooms for necessary power distribution
- damage life-saving equipment or associated launching arrangements
- disrupt the proper functioning of fire-fighting equipment located outside the explosion-damaged space, or
- affect other areas in the vessel in such a way that chain reactions involving, inter alia, cargo, gas and bunker oil may arise
- prevent access to life-saving appliances or impede escape routes.

Note 1: Double wall fuel pipes are not considered as potential sources of release.

1.2.2 An explosion analysis is required for ventilated machinery spaces. It may also be required for other hazardous spaces, as a result of the risk assessment. Explosion analyses are to demonstrate that, for the worst case scenario, the maximum pressure built-up in case of explosion does not exceed the design pressure of the space, taking into account the venting arrangement and the explosion pressure relief devices, where provided.

Section 3 Arrangement on Board

1 General

1.1 General arrangement

1.1.1 The arrangement and location of spaces for hydrogen storage, distribution and use are to be such that the number and extent of hazardous areas is kept to a minimum. These spaces are to be arranged to avoid the accumulation of hydrogen by having simple geometrical shape and no obstructing structures in the upper part. Large spaces are to be arranged with a smooth ceiling sloping up towards the ventilation outlet. Ceiling under deck covering support structure is not acceptable.

1.1.2 Direct access is not to be permitted from a non-hazardous area to a hazardous area. Where such openings are necessary for operational reasons, an airlock is to be provided.

1.1.3 For inerted spaces, access arrangements are to be such that unintended entry by personnel is prevented. If access to such spaces is not from an open deck, sealing arrangements are to ensure that leakages of inert gas to adjacent spaces are prevented.

1.1.4 Safe access to all components of the hydrogen installation is to be possible for inspection and maintenance.

1.1.5 The layout of equipment is to be such that escape routes are not impacted from potential jet fires.

1.2 Hydrogen fuel tanks location

1.2.1 The location of hydrogen fuel tanks is to comply with the following:

a) The fuel tank(s) shall be protected from external damage caused by collision or grounding in the following way:

1) The fuel tanks shall be located at a minimum distance of B/5 or 11,5 m, whichever is less, measured inboard from the ship side at right angles to the centreline at the level of the summer load line draught, where:

   B : Greatest moulded breadth of the ship at or below the deepest draught (summer load line draught) (refer to SOLAS regulation II-1/2.8).

2) The boundaries of each fuel tank shall be taken as the extreme outer longitudinal, transverse and vertical limits of the tank structure including its tank valves.

3) For independent tanks the protective distance shall be measured to the tank shell (the primary barrier of the tank containment system). For membrane tanks the distance shall be measured to the bulkheads surrounding the tank insulation.

4) In no case shall the boundary of the fuel tank be located closer to the shell plating or aft terminal of the ship than as follows:

   - i) For passenger ships: B/10 but in no case less than 0,8 m. However, this distance need not be greater than B/15 or 2 m whichever is less where the shell plating is located inboard of B/5 or 11,5 m, whichever is less, as required by item a) 1)

     The transition between the minimum protective distances B/10 and B/15 is to be in compliance with Tab 1.

   - ii) For cargo ships:
     - for $V_c \leq 1000$ m³: 0,8 m
     - for 1000 m³ $< V_c <$ 5000 m³: $0,75 + V_c \cdot 0,2 / 4000$ m
     - for 5000 m³ $\leq V_c <$ 30000 m³: $0,8 + V_c / 25000$ m
     - for $V_c \geq 30000$ m³: 2,0 m

     where:

     V_c : Corresponds to 100% of the gross design volume of the individual fuel tank at 20°C, including domes and appendages.

5) The lowermost boundary of the fuel tank(s) shall be located above the minimum distance of B/15 or 2,0 m, whichever is less, measured from the moulded line of the bottom shell plating at the centreline.

6) For multihull ships the value of B may be specially considered.

7) The fuel tank(s) shall be abaft a transverse plane at 0,08 L measured from the forward perpendicular in accordance with SOLAS regulation II-1/8.1 for passenger ships, and abaft the collision bulkhead for cargo ships, where:

   L : Length as defined in the International Convention on Load Lines (refer to SOLAS regulation II-1/2.5).

8) For ships with a hull structure providing higher collision and/or grounding resistance, fuel tank location regulations may be specially considered in accordance with the alternative design process.

b) As an alternative to item a) 1), the following calculation method may be used to determine the acceptable location of the fuel tanks:

1) The value f_{CN} calculated as described in the following shall be less than 0,02 for passenger ships and 0,04 for cargo ships.

Note 1: The value f_{CN} accounts for collision damages that may occur within a zone limited by the longitudinal projected boundaries of the fuel tank only, and cannot be considered or used as the probability for the fuel tank to become damaged given a collision. The real probability will be higher when accounting for longer damages that include zones forward and aft of the fuel tank.

2) f_{CN} is calculated by the following formulation:

$f_{CN} = f\ell \ f_t \ f_v$

where:

- $f\ell$: Calculated by use of the formulations for factor p contained in SOLAS regulation II-1/7-1.1.1.1. The value of x1 shall correspond to the distance from the aft terminal to the aftmost boundary of the fuel tank and the value of x2 shall correspond to the distance from the aft terminal to the foremost boundary of the fuel tank
- f_t : Calculated by use of the formulations for factor r contained in SOLAS regulation II-1/7-1.1.2, and reflects the probability that the damage penetrates beyond the outer boundary of the fuel tank. The formulation is:

  $f_t = 1 - r(x1, x2, b)$

Note 2: When the outermost boundary of the fuel tank is outside the boundary given by the deepest subdivision waterline the value of b should be taken as 0.

- f_v : Calculated by use of the formulations for factor v contained in SOLAS regulation II-1/7-2.6.1.1 and reflects the probability that the damage is extending vertically above the lowermost boundary of the fuel tank. The formulations to be used are:
  - $f_v = 1,0 - 0,8\ ((H - d) / 7,8)$

    if $(H - d) \le 7,8$ m: f_v shall not be taken greater than 1,0
  - $f_v = 0,2 - 0,2\ ((H - d) - 7,8) / 4,7$

    in all other cases, f_v shall not be taken less than 0
- H : Distance from baseline, in m, to the lowermost boundary of the fuel tank
- d : Deepest draught (summer load line draught).

3) The boundaries of each fuel tank shall be taken as the extreme outer longitudinal, transverse and vertical limits of the tank structure including its tank valves.

4) For independent tanks the protective distance shall be measured to the tank shell (the primary barrier of the tank containment system). For membrane tanks the distance shall be measured to the bulkheads surrounding the tank insulation.

5) In no case shall the boundary of the fuel tank be located closer to the shell plating or aft terminal of the ship than as follows:

- For passenger ships: B/10 but in no case less than 0,8 m. However, this distance need not be greater than B/15 or 2,0 m whichever is less where the shell plating is located inboard of B/5 or 11,5 m, whichever is less, as required by item a) 1).
- For cargo ships:
  - for $V_c \le 1000$ m^3: 0,8 m
  - for 1000 m^3 < V_c < 5000 m^3: $0,75 + V_c \times 0,2/4000$ m
  - for 5000 m^3 ≤ V_c < 30000 m^3: $0,8 + V_c/25000$ m, and
  - for $V_c \ge 30000$ m^3: 2,0 m,

  where:

  V_c : Corresponds to 100% of the gross design volume of the individual fuel tank at 20°C, including domes and appendages.

6) In case of more than one non-overlapping fuel tank located in the longitudinal direction, f_{CN} shall be calculated in accordance with item b) 2) for each fuel tank separately. The value used for the complete fuel tank arrangement is the sum of all values for f_{CN} obtained for each separate tank.

7) In case the fuel tank arrangement is unsymmetrical about the centreline of the ship, the calculations of f_{CN} shall be calculated on both starboard and port side and the average value shall be used for the assessment. The minimum distance as set forth in item b) 5) shall be met on both sides.

8) For ships with a hull structure providing higher collision and/or grounding resistance, fuel tank location regulations may be specially considered in accordance with the alternative design process.

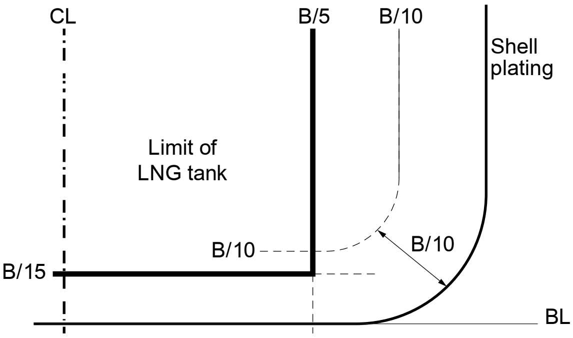
1.2.2 Portable hydrogen fuel tanks are to be located in dedicated spaces or areas. If located in an enclosed space, the space is to be considered as a tank connection space.

1.2.3 Hydrogen fuel tanks are not to be located within machinery spaces of category A, cargo spaces, services spaces or accommodation spaces. Open deck areas dedicated to hydrogen fuel tanks are not considered as cargo spaces.

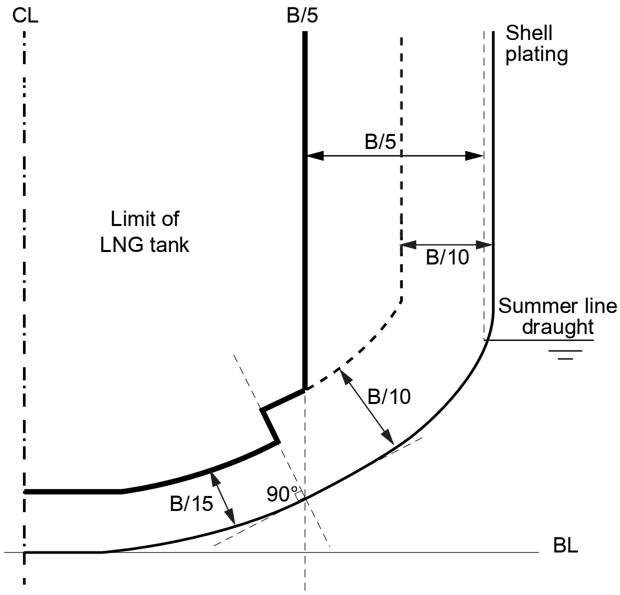
Table 1 : Location of fuel storage tanks

Prescriptive method:
see [1.2.1], item a) 1) and [1.2.1], item a) 4) i)

bilge turn radius ≤ B/5

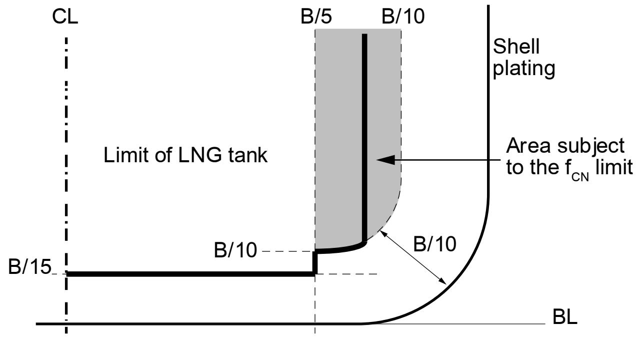


bilge turn radius > B/5

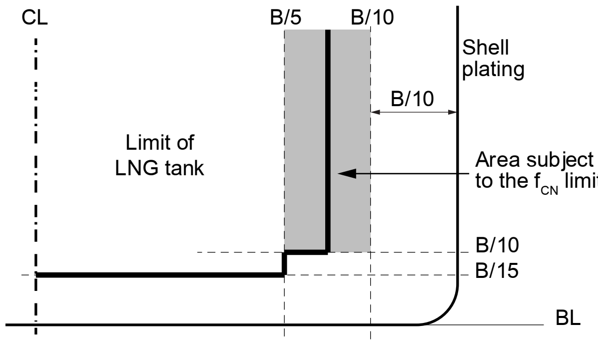


Probabilistic method:
see [1.2.1], item b)

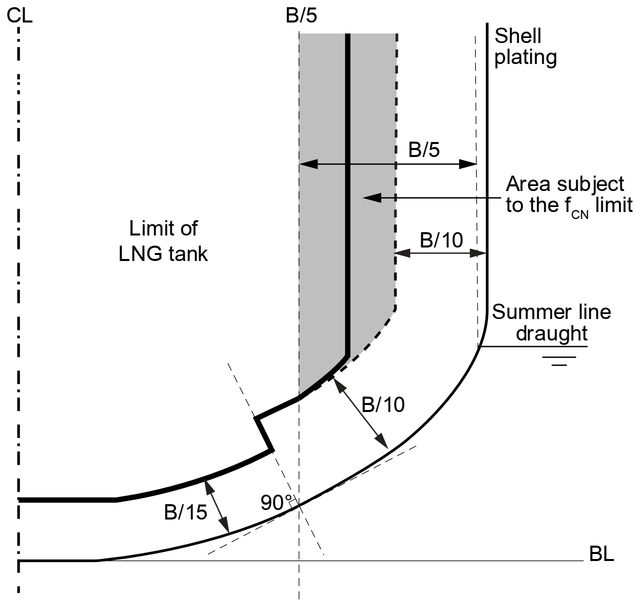
B/10 < bilge turn radius ≤ B/5



bilge turn radius ≤ B/10



bilge turn radius > B/5



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see [1.2.1], item a) 1) and [1.2.1], item a) 4) i)</td><td>Probabilistic method:
see [1.2.1], item b)</td></tr>
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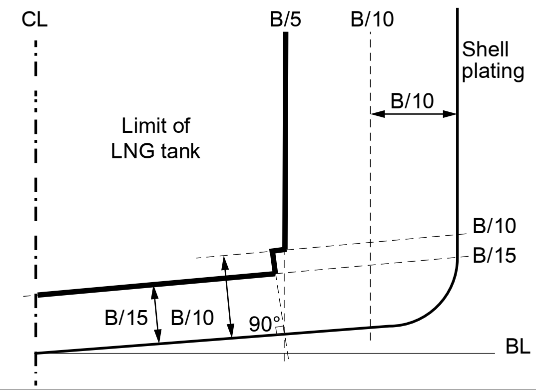
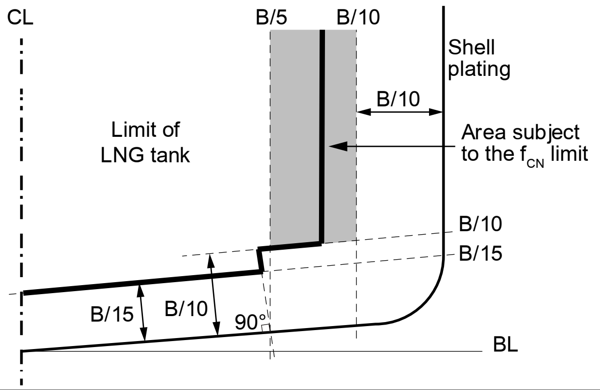
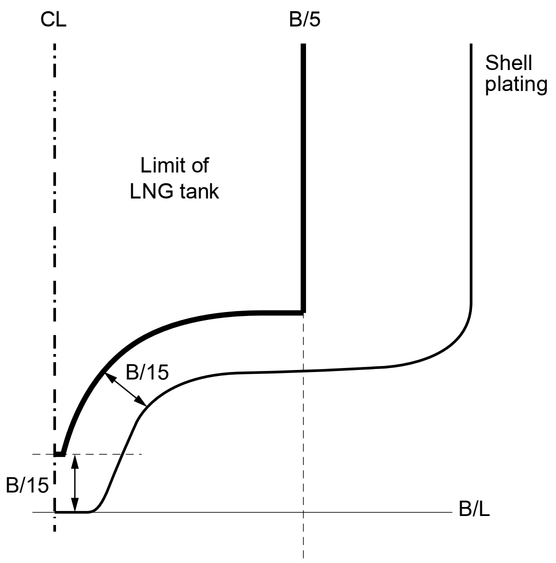
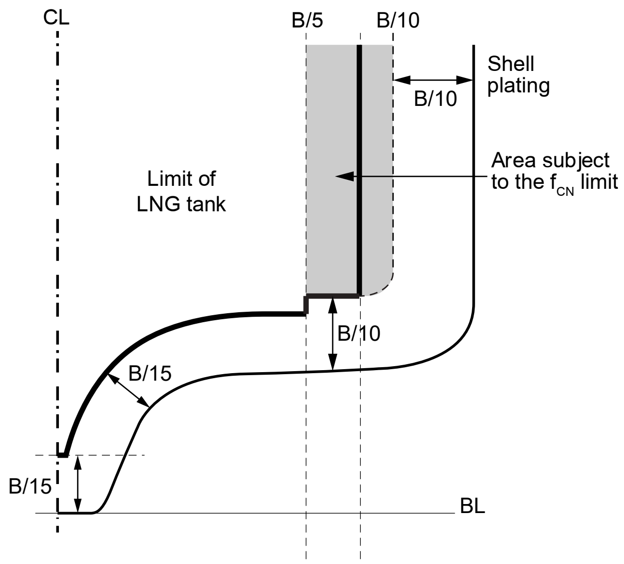
<tr><td>
</td><td>
</td></tr>
<tr><td>fore and aft sections</td><td>fore and aft sections</td></tr>
<tr><td>
</td><td>
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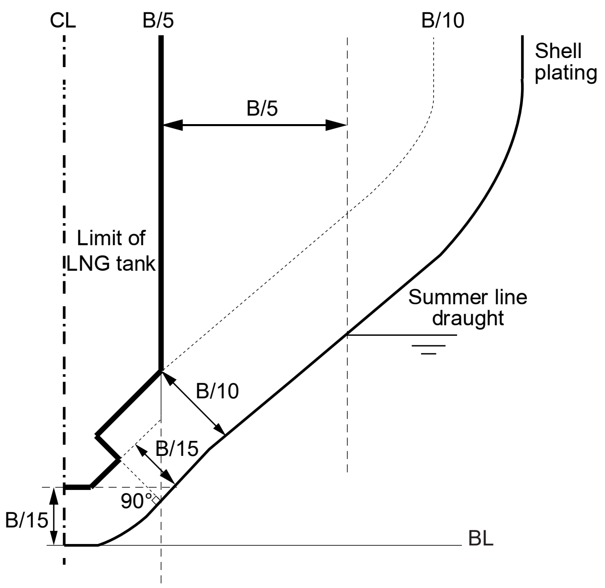
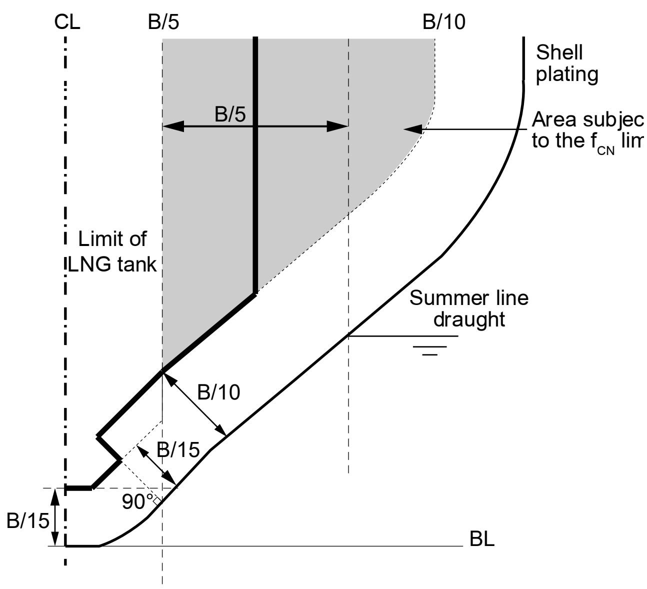
<tr><td>
</td><td>
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1.3 Hydrogen fuel storage arrangement

1.3.1 Hydrogen fuel tanks are to be protected against mechanical damage.

1.3.2 Hydrogen fuel tanks are not to be installed in congested areas. Hydrogen fuel tanks and / or equipment located on open deck are to be located in order to ensure sufficient natural ventilation, so as to prevent accumulation of escaped hydrogen. A space naturally ventilated through with permanent side openings, having a combined area of at least 75% of the total side surface of the space, may be considered as an open deck for the purpose of the present requirement.

Note 1: Containerized hydrogen fuel tanks (e.g. MEGC) on open decks are to be specially considered. If ventilation is not sufficient around the tank, the container is considered as an enclosed or semi-enclosed space.

1.3.3 For liquid hydrogen fuel tanks and tank connections located on open deck, the ship structure is to be protected from potential leakages from tank connections and other sources of leakage. The material is to have a design temperature corresponding to the temperature of the hydrogen fuel carried at atmospheric pressure. The normal operation pressure of the tanks is to be taken into consideration for protecting the steel structure of the ship.

Arrangements are to be made for safe management of hydrogen fuel spills. Drip trays, in accordance with [1.10], with sufficient free field to avoid liquefied hydrogen accumulation, are to be provided or other arrangements agreed by the Society.

The volume of the drip tray is to be determined in accordance with [1.10.5].

Protective screens are to be provided to avoid liquefied hydrogen spray or spills onto surfaces not designed for cryogenic temperatures.

A gas dispersion analysis may be required, in particular as an HAZID study outcome.

1.3.4 Compressed hydrogen tanks

a) Storage of compressed hydrogen in enclosed spaces is normally not acceptable, but may be permitted after special consideration by the Society provided the following, as a minimum, is fulfilled in addition to [1.4.1], [1.4.2] and Sec 7, [5.1.3]:
   - adequate means are provided to depressurize the tank in case of a fire which can affect the tank. Means are to be provided to avoid a hazardous atmosphere in the tank.
   - all surfaces within such enclosed spaces containing the tank are provided with suitable thermal protection against any lost high-pressure hydrogen gas unless the bulkheads are designed for the lowest temperature that can arise from hydrogen expansion leakage
   - a fixed fire-extinguishing system is installed in the enclosed spaces containing the compressed hydrogen storage. Special consideration is to be given to the extinguishing of jet-fires
   - adequate fire insulation is provided to ensure protection of the adjacent spaces
   - an effective mechanical forced ventilation system of extraction type is provided. The ventilation rate is to be sufficient to dilute the average gas/vapour concentration below 25% of the LEL in all maximum probable leakage scenarios due to technical failures.

b) Sources of heat are to be kept clear of spaces used for the storage of compressed hydrogen and “No Smoking” and “No Naked Light” notices are to be displayed in a prominent position.

c) Compartments used for the storage of compressed hydrogen are not to be used for storage of other combustible products nor for tools or objects not part of the hydrogen distribution system.

d) On open decks, cylinders are to be properly secured, and all valves, pressure regulators and pipes leading from such cylinders are to be protected against mechanical damage. Cylinders are to be protected against excessive variations in temperature and accumulation of snow.

1.4 Tank connection space

1.4.1 All tank connections, fittings, flanges and tank valves are to be enclosed in gastight tank connection spaces, unless the tank connections are on open deck. The space is to be able to safely contain leakage from the tank in case of leakage from the tank connections.

A tank connection space may be required also for tanks on open deck:

- for ships where restriction of hazardous areas is deemed necessary; or
- in order to provide environmental protection for essential safety equipment related to the hydrogen fuel system like tank valves, safety valves and instrumentation; or
- as a result of the risk analysis required in Sec 2, [1.1.4].

1.4.2 The ability of the tank connection space to withstand a leakage is to be analyzed as follows:

a) A leakage scenario is to be determined and submitted to the Society. For cryogenic tanks, complete failure (rupture) needs to be considered only for the pipes located downstream of the first valve.

Note 1: A risk analysis may be carried out to demonstrate that the leakage scenarios are relevant.

b) The following parameters are to be evaluated:
   - amount of liquid hydrogen spilled and/or gaseous hydrogen released until the automatic closing of the valve required in Sec 9, [1.1.8]
   - pressure built up due to the hydrogen leakage and/or liquefied hydrogen vaporization, taking into account the ventilation system required in Sec 4, [1.4.1] and the pressure relief device fitted to the tank connection space
   - hydrogen concentration in the tank containment space
   - temperature reached in the tank connection space and in the tank hold space.

1.4.3 The tank connection space is to be arranged to prevent the hull structure from being exposed to unacceptable cooling in case of leakage of liquefied hydrogen. The material of the bulkheads of the tank connection space is to have a design temperature corresponding with the lowest temperature it can be subject to in a probable maximum leakage scenario.

1.4.4 The tank connection space is to be designed to withstand the maximum pressure build up during such a leakage. Alternatively, pressure relief venting to a safe location (mast) can be provided.

1.4.5 Unless access to the tank connection space is independent and direct from open deck, it is to be arranged as a bolted hatch or a gastight door and an airlock. Authorized access to the tank connection space during normal operation of the hydrogen system cannot be granted.

1.5 Fuel preparation room

1.5.1 Fuel preparation rooms are to be located on an open deck unless:

- the fuel preparation rooms are arranged and fitted in accordance with the requirements for tank connection spaces in [1.4]; and
- for fuel preparation rooms containing high pressure systems, a specific analysis is submitted demonstrating that, for the worst leakage scenario, they can withstand the maximum pressure build up in the space, taking into account the pressure relief devices, where fitted.

1.5.2 The fuel preparation room may be located below deck upon special consideration by the Society based on the risk analysis results. In such case, the room is to have an independent access direct from the open deck as far as practicable. Where a separate access from deck is not practicable, an airlock is to be provided.

1.5.3 Fuel preparation rooms are to be arranged to safely contain cryogenic leakages regardless of the room's location. The material of the boundaries of the fuel preparation room is to be selected considering a design temperature corresponding to the lowest temperature reached in a probable maximum leakage scenario unless the boundaries of the space, i.e. bulkheads and decks, are provided with suitable thermal protection. The fuel preparation room is to be arranged to prevent the surrounding hull structure from being exposed to unacceptable cooling, in case of leakage of liquefied hydrogen.

1.5.4 The fuel preparation room is to be designed to withstand the maximum pressure build up during a probable maximum cryogenic leakage scenario. Alternatively, pressure relief venting to a safe location (mast) may be provided.

1.5.5 If compressors are driven by shafting passing through a bulkhead or deck, the bulkhead penetration is to be of gastight type.

1.6 Fuel bunkering station

1.6.1 The bunkering station is to be located on open deck so that sufficient natural ventilation is provided. Closed or semi-enclosed bunkering stations are to be subject to special consideration within the risk assessment.

1.6.2 Entrances, air inlets and openings to control stations, accommodation, service and machinery spaces are not to face the bunkering station.

1.6.3 Closed or semi-enclosed bunkering stations are to be surrounded by gas and liquid-tight boundaries against enclosed spaces.

1.6.4 Arrangement is to be made in order to prevent hull or deck structures from being exposed to excessive low temperature in case of leakage of liquefied hydrogen.

1.6.5 Arrangements are to be made for safe management of fuel spills. Drip trays, in accordance with [1.10], with sufficient free field to avoid liquefied hydrogen accumulation, are to be provided below the bunkering connections or other arrangements agreed by the Society.

1.6.6 For compressed hydrogen bunkering stations, low temperature steel shielding is to be considered if the escape of cold jets impinging on surrounding hull structure is possible.

1.7 Machinery spaces

1.7.1 The access to GVU rooms from gas-safe hydrogen consumer machinery spaces is to be arranged through an airlock.

1.8 Gas valve units spaces

1.8.1 Gas valve units may be located in:

- the tank connection space of cryogenic tanks, except for high pressure fuel systems
- the tank connection space of compressed hydrogen tanks
- the fuel preparation room
- an enclosure located within the machinery space
- an independent space, provided it fulfils the criteria applicable to fuel preparation rooms, with respect to location, access, ventilation and gas detection. See [1.5], Sec 4, [1.5] and Sec 11, [2.1].

1.8.2 Gas valve units are to be located as close as possible to the hydrogen consumers so as to reduce the response time in case of load variation and limit the amount of hydrogen released in case of leakage. Relevant requirements from hydrogen consumer manufacturers are to be fulfilled.

1.8.3 Where an enclosure is provided for the gas valve unit, the enclosing pipes or ducts provided for the hydrogen fuel pipe located upstream and downstream of the gas valve unit may be connected to the enclosure.

1.8.4 Where provided, gas valve unit enclosures are to be gastight. The access to the enclosure is to be possible only through a bolted hatch, for maintenance or repair purposes. The enclosure is to be designed to withstand the maximum pressure in case of hydrogen leakage, taking into account the pressure relief devices, where fitted. The enclosure is to be ventilated and provided with gas detection arrangements. Inerting of the GVU enclosure may be accepted as an alternative to ventilation, upon special consideration by the Society. Manual shut off valves are to be capable of being operated from outside the enclosure.

1.8.5 The ventilation system is to be of the under pressure type, providing a ventilation capacity sufficient to dilute the average gas/vapour concentration below 25% of the LEL in all maximum probable leakage scenarios due to technical failures.

1.9 Bilge system

1.9.1 Bilge systems installed in areas where hydrogen can be present are to be segregated from the bilge system of spaces where hydrogen cannot be present. Areas where hydrogen can be present include:

- fuel storage hold spaces
- fuel preparation rooms
- GVU spaces.

1.9.2 Where hydrogen fuel is carried in a fuel containment system with a secondary barrier, suitable drainage arrangements for dealing with any leakage into the hold or insulation spaces through the adjacent ship structure is to be provided. The bilge system is not to lead to pumps in safe spaces. Means of detecting such leakage is to be provided.

1.10 Drip trays

1.10.1 Drip trays are to be fitted where leakage may occur which can cause damage to the ship structure or where limitation of the area which is affected by a spill is necessary. Drip trays are to be fitted in particular in the following locations:

- in way of the hydrogen fuel tanks located on open deck (see [1.3.3])
- at the bunkering station (see [1.6.5])
- in fuel preparation rooms, in way of possible liquefied hydrogen leakage sources including detachable pipe connections, pumps, valves and heat exchangers.

1.10.2 Drip trays are to be made of stainless steel or other material suitable for design temperature corresponding to the temperature of the hydrogen fuel in the storage tank.

1.10.3 The drip tray is to be thermally insulated from the ship's structure so that the surrounding hull or deck structures are not exposed to unacceptable cooling, in case of leakage of liquefied hydrogen except for drip trays which are:

- an integral part of the ship structure, provided that this structure is designed for low temperatures with corresponding evidences submitted to the Society (e.g. thermal calculations), or
- located far enough from the ship's structure.

1.10.4 Each tray located on open decks is to be fitted with a drain valve to enable rain water to be drained over the ship's side. The drain valve is to be of self-closing type and suitable for contact with liquefied hydrogen.

1.10.5 Each tray is to have a sufficient capacity to ensure that the maximum amount of spill according to the risk assessment can be handled without accumulation of liquefied hydrogen. The capacity of the drip tray is to be determined on the basis of the worst expected leakage scenario and agreed by the Society. For each case, the amount of spill is to be calculated based on the time necessary for leakage detection, ESD activation and effective shutdown of the pressure source and shut off of the isolating valve. Vaporization rate may be taken into account in the calculation based on scenario agreed with the Society.

Section 4 Control of Atmosphere

1 Ventilation

1.1 General

1.1.1 Due consideration is to be given to ventilation in areas with liquefied or cold hydrogen where condensation might occur to avoid the stratification of oxygen-enriched atmosphere.

1.1.2 The hydrogen leakage rate in normal operation for each space is to be determined by measures or estimation based on manufacturer values for calculating the ventilation needs. This leakage rate is to be included when considering a leakage scenario due to technical failure.

1.2 Ventilation of hazardous areas

1.2.1 Ducts used for ventilation of hazardous spaces are to be designed and arranged such that any possibility for hydrogen to accumulate is avoided. In this purpose, they are to run continuously upward from the ventilated space up to the ventilation outlet, without small radii of curvatures.

1.2.2 Fans serving spaces containing hydrogen sources of leakage are to be of a non-sparking type as defined in NR467, Pt C, Ch 4, Sec 1, [3.28] and of a Type approved by the Society.

1.2.3 Electric motors for ventilation fans are not to be located in ventilation ducts for hazardous spaces unless the motor is certified for the same hazard zone as the space served.

1.2.4 Ventilation systems required to avoid any hydrogen accumulation are to consist of independent fans, each of sufficient capacity, unless otherwise specified.

1.2.5 The required capacity of the ventilation plant is normally based on the total volume of the room. An increase in required ventilation capacity may be necessary for rooms having a complicated form.

1.2.6 Non-hazardous spaces with entry openings to a hazardous area are to be arranged with an airlock and be maintained at an overpressure relative to the external hazardous area.

1.2.7 Non-hazardous spaces with entry openings to a hazardous enclosed space are to be arranged with an airlock and the hazardous space is to be maintained at under pressure relative to the non-hazardous space.

1.2.8 Performance of the ventilation is to be monitored according to the provisions in Sec 11, [3.1].

1.3 Ventilation openings and duct arrangements

1.3.1 Any ducting used for the ventilation of hazardous spaces is to be separated from that used for the ventilation of non-hazardous spaces.

1.3.2 The ventilation inlet for the double wall piping or duct is to be located in a non-hazardous area in the open air away from ignition sources. The inlet opening is to be fitted with a wire mesh guard and protected from ingress of water.

1.3.3 Air inlets for hazardous enclosed spaces are to be taken from areas that, in the absence of the considered inlet, would be non-hazardous. Air inlets for non-hazardous enclosed spaces are to be taken from non-hazardous areas at least 1,5 m away from the boundaries of any hazardous area. Where the inlet duct passes through a more hazardous space, the duct is to be gas-tight and have over-pressure relative to this space.

1.3.4 Air outlets from non-hazardous spaces are to be located outside hazardous areas.

1.3.5 Air outlets from hazardous enclosed spaces are to be located in an open area that, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space.

1.4 Tank connection space

1.4.1 The tank connection space is to be provided with an effective mechanical forced ventilation system of extraction type. The ventilation rate is to be sufficient to dilute the average gas/vapour concentration below 25% of the LEL in all maximum probable leakage scenarios due to technical failures.

1.4.2 The number and power of the ventilation fans are to be such that the full required ventilation capacity remains available after failure of a fan with a separate circuit from the main switchboard or emergency switchboard or of a group of fans with common circuit from the main switchboard or emergency switchboard.

1.4.3 Automatic fail-safe fire dampers are to be fitted in the ventilation trunk for tank connection space and of a type approved by the Society.

1.5 Fuel preparation room

1.5.1 Fuel preparation rooms are to be fitted with effective mechanical ventilation system of the under pressure type, providing a ventilation capacity sufficient to dilute the average gas/vapour concentration below 25% of the LEL in all maximum probable leakage scenarios due to technical failures.

1.5.2 The number and power of the ventilation fans are to be such that the capacity is not reduced by more than 50%, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable.

1.5.3 Ventilation systems for fuel preparation rooms are to be in operation when pumps or compressors are working. The ventilation systems are to remain in operation as long as parts of the fuel piping and equipment are under pressure.

2 Inerting

2.1 Inert gas supply

2.1.1 The inert gas supply line is to be fitted with double block and bleed valves. In addition a closable non-return valve is to be installed between the double block and bleed arrangement and the fuel system. These valves are to be located outside non-hazardous spaces.

Note 1: The space containing the non-return valve and double-block and bleed valve will be categorized as hazardous area Zone 1 according to Sec 10, [2.2.2].

2.1.2 Where the connections to the fuel piping systems are non-permanent, two non-return valves may be substituted for the valves required in [2.1.1].

2.1.3 The arrangements are to be such that each space being inerted can be isolated and the necessary controls and relief valves, etc. are provided for controlling pressure in these spaces.

2.1.4 Where spaces are continually supplied with an inert gas as part of a leak detection system, means are to be provided to monitor the quantity of gas being supplied to individual spaces.

2.1.5 Arrangements are to be provided so that the inerting medium is not in direct contact with liquid hydrogen or cold hydrogen vapours or with surfaces below its freezing or liquefying point.

Note 1: At liquefied hydrogen temperature, only Helium can be used as an inert medium.

2.2 Inert gas production and storage

2.2.1 The equipment is to be capable of producing inert gas so that the space is inerted with an oxygen content lower than 3% by volume.

A continuous-reading oxygen content meter is to be fitted to the inert gas supply from the equipment and is to be provided with an alarm set at a maximum of 1% oxygen content by volume.

2.2.2 The inert gas system is to have pressure controls and monitoring arrangements appropriate to the fuel containment system.

2.2.3 Where a nitrogen generator or nitrogen storage facilities are installed in a separate compartment outside of the engine-room, the separate compartment is to be fitted with an independent mechanical extraction ventilation system, providing a minimum of 6 air changes per hour. A low oxygen alarm is to be fitted.

2.2.4 Nitrogen piping is to be led only through well ventilated spaces. Nitrogen piping in enclosed spaces is to:

- be assembled with welded joints
- have only a minimum of flange connections as needed for fitting of valves, and
- be as short as possible.

Section 5 Materials

1 General

1.1

1.1.1 All equipment and components are to be made of materials, including filler materials for welding that are suitable for the range of process fluids and conditions expected during both normal operation and fault management.

1.1.2 Materials for fuel containment and piping systems are to be in accordance with the requirements of NR216 Materials and Welding unless otherwise specified.

1.1.3 Components in contact with hydrogen are to be made of material compatible with hydrogen use, in particular with respect to embrittlement and hydrogen attack phenomena. 304/304L and 316/316L austenitic stainless steel may be used. Other materials may be approved upon special consideration. The demonstration of the suitability of materials is to be performed by tests according to a recognized standard accepted by the Society (e.g. ISO 11114-1:2017 or 11114-4:2017).

1.1.4 Requirements for materials intended to be used in applications with design temperature lower than -165°C are to be agreed with the Society. Where minimum design temperature is lower than -196°C, materials are to meet the toughness requirements of ISO 21028-1: 2016 and testing for insulation materials is to be carried out with the appropriate medium, over a range of temperatures expected in service.

1.1.5 Material of construction and ancillary equipment such as insulation is to be resistant to the effect of high oxygen concentrations caused by condensation and enrichment at the low temperatures attained in parts of the cryogenic hydrogen containment system. Suitability of material is to be demonstrated in accordance with a recognized standard accepted by the Society such as EN 1797:2001.

1.1.6 Equipment is to be marked in accordance with NR467 Pt C. Fuel pipes and all the other piping needed for operation and maintenance are to be colour marked in accordance with EN ISO 14726:2008 Ships and marine technology - Identification colours for the content of piping systems.

2 Piping systems

2.1 Classes of hydrogen fuel piping systems

2.1.1 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.

Piping classes I, II and III are to be determined in accordance with the provisions of Tab 1 for hydrogen fuel piping systems and in accordance with Tab 2 for all vent pipes and open ended lines, including:

- discharge lines from thermal relief valves
- discharge lines from tank pressure relief devices
- venting lines from “bleed” valves
- purging lines from engines and other gas consumers
- vent line from tank connection spaces.

Table 1 : Classes of liquid and gas hydrogen piping systems

Piping system		Design conditions		Class of the gas piping		
		Design pressure	Design temperature	Single wall arrangement	Double wall arrangement	
					Inner pipe	Outer pipe **(1)**
Gaseous H_2	Low pressure lines	P = 10 bar **(2)**	any	I	II	II
	High pressure lines	P > 10 bar	any	I	I	II
Liquefied H_2		any	any	I	I	II

(1) The design pressure of the outer pipe or duct of fuel systems is to comply with Sec 9, [2.1.3]
(2) The design pressure is not to be taken less than 10 bar. (see Sec 9, [2.1.2], item g))

Table 2 : Classes of vent pipes and bleed lines

Design conditions		Class of the vent pipe		
Vent pipe design pressure	Vent pipe design temperature	Single wall arrangement	Double wall arrangement	
			Inner pipe	Outer pipe **(1)**
P = 5 bar **(2)**	any	III	III	III
P > 5 bar and P ≤ 10 bar **(3)**	any	II	III	III
P > 10 bar **(3)**	any	I	II	III

(1) The design pressure of the outer pipe or duct of fuel systems is to comply with Sec 9, [2.1.3]
(2) The design pressure of vent pipes or open ended lines is not to be taken less than 5 bar. (see Sec 9, [2.1.2], item g))
(3) The design pressure of the vent pipes or open ended lines is not to be less than the maximum expected pressure, which is to be justified

Section 6 Bunkering Equipment

1 Bunkering hoses

1.1

1.1.1 Liquid and vapour hoses used for fuel transfer are to be compatible with the fuel and suitable for the fuel temperature.

1.1.2 Hoses for liquefied hydrogen subject to tank pressure, or the discharge pressure of pumps or vapour compressors, are to be designed for a bursting pressure not less than five times the maximum pressure the hose can be subjected to during bunkering.

2 Manifold

2.1

2.1.1 The bunkering manifold is to be designed to withstand the external loads during bunkering. This is to include the forces on the manifold in a scenario where the bunkering line is released by a breakaway coupling. The connections at the bunkering station are to be of dry-disconnect type equipped with additional safety dry break-away coupling/self-sealing quick release. The couplings are to be of a standard type.

2.1.2 The dry break-away coupling / self-sealing quick release may be permanently attached to the bunkering manifold of the ship or part of the fuel transfer system supplied by the bunkering facility. Where the dry break-away coupling/self-sealing quick release coupling is not fitted directly to the bunkering connection, the pressure relief device required in [3.1.5] is to be so designed that, in the event of break-away of the coupling, the pressure built-up in the part of the fuel transfer system located between the bunkering connection and the coupling does not exceed its design pressure. Relevant justifications are to be provided.

3 Bunkering system

3.1

3.1.1 The bunkering system is to be so arranged that no hydrogen is discharged to the atmosphere during filling of storage tanks.

3.1.2 If flexible hoses are used, these are to be supported in such a way that the allowable bending radius is satisfied. They are not normally to lay directly on the ground. They are to be arranged with enough slack to allow for all possible movements between the ship and the bunkering unit.

3.1.3 Bunkering connections and piping are to be so positioned and arranged that any damage to the fuel piping does not cause damage to the ship's fuel containment system resulting in an uncontrolled hydrogen discharge.

3.1.4 A manually operated stop valve and a remotely operated shutdown valve in series, or a combined manually and remotely operated valve are to be fitted in every bunkering line close to the connecting point. It is to be possible to operate the remotely operated valve in the control location for bunkering operations and/or from another safe location.

3.1.5 Means are to be provided to relieve the pressure and remove liquefied hydrogen contents from pump suctions and bunker lines. Liquefied hydrogen is to be discharged to the hydrogen fuel tanks or other suitable location.

3.1.6 An arrangement for purging fuel bunkering lines with inert gas is to be provided. Fuel purged from bunkering lines is to discharge to the bunkering facility or to other suitable location (e.g. GCU).

3.1.7 Where bunkering lines are arranged with a crossover, isolation arrangements are to be provided to ensure that fuel cannot be transferred inadvertently to the ship side not in use for bunkering.

3.1.8 To ensure a rapid and safe shutdown of the bunker supply system without any release of liquid or vapour, a ship-shore link (SSL) or an equivalent means for automatic and manual ESD communication to the bunkering source operable from the bunker supply facility and the ship control station is to be provided.

Section 7 Fuel Containment System

1 General

1.1 General arrangement

1.1.1 The fuel containment system is to be designed and constructed according to one of the following options:

- Compressed hydrogen cylinders complying with Article [2]
- Compressed hydrogen MEGC complying with Article [3]
- Compressed hydrogen tank other than cylinders complying with Article [4]
- Cryogenic tank complying with Article [5].

In addition, portable hydrogen tanks, if provided, are to comply with the requirements of [1.6].

Other types of containment systems may be considered on a case-by-case basis by the Society.

1.1.2 An inspection/survey plan for the hydrogen fuel containment system is to be developed by the manufacturer and submitted to the Society. The inspection/survey plan is to identify aspects to be examined and/or validated during surveys for the construction, installation and operation of the fuel containment system and, in particular, any necessary in-service survey, maintenance and testing that was assumed when selecting fuel containment system design parameters.

1.1.3 Hydrogen fuel containment systems are to be efficiently protected against corrosion, particularly in their most exposed parts, either by selection of their constituent materials, or by an appropriate coating or treatment. Contact between dissimilar metals which could result in damage by galvanic action is to be avoided.

1.1.4 Enclosed spaces where parts of the hydrogen fuel containment system are located are to be gas tight towards adjacent spaces.

1.2 Design loads

1.2.1 General

Tanks, together with their supporting structure and other fixtures, are to be designed taking into account relevant combinations of the loads described below.

1.2.2 Permanent loads

a) The weight of tank, thermal insulation, loads caused by towers and other attachments are to be considered.

b) Gravity loads of structures and equipment acting externally on the tank are to be considered.

1.2.3 Functional loads

Loads arising from the operational use of the tank system are to be classified as functional loads.

All functional loads that are essential for ensuring the integrity of the tank system, during all design conditions, are to be considered.

As a minimum, the effects from the following loads, as applicable, are to be considered when establishing functional loads:

- Internal pressure
- External pressure
- Thermally induced loads for liquefied hydrogen
- Vibration, if relevant depending on the ship operation
- Interaction loads
- Test loads
- Static heel loads for liquefied hydrogen
- Weight of fuel
- Sloshing for liquefied hydrogen
- Wind impact, wave impacts and green sea effect for tanks installed on open deck.

1.2.4 Functional loads: Internal pressure

a) Internal pressure for compressed hydrogen tanks:

   P_0 is to be taken as the maximum developed pressure in the tank considering the different operating conditions (e.g. environmental condition, temperature increase during bunkering…)

b) Internal pressure for liquefied hydrogen:

P_0 means the design vapour pressure

1) In all cases, including item 2), P_0 is not to be less than MARVS.
2) For cryogenic tanks where there is no temperature control and where the pressure of the liquefied hydrogen is dictated only by the ambient temperature, P_0 is not to be less than the gauge vapour pressure of the liquefied hydrogen at a temperature of 45°C except as follows:
   - Lower values of ambient temperature may be accepted by the Society for ships operating in restricted areas. Conversely, higher values of ambient temperature may be required.
   - For ships on voyages of restricted duration, P_0 may be calculated based on the actual pressure rise during the voyage and account may be taken of any thermal insulation of the tank.
3) Subject to special consideration by the Society, a vapour pressure P_h higher than P_0 may be accepted for site specific conditions (harbour or other locations), where dynamic loads are reduced.
4) The internal pressure P_{eq} resulting from the vapour pressure P_o or P_h plus the maximum associated dynamic liquid pressure P_{gd}, but not including the effects of liquid sloshing loads, is to be calculated as the greater of P_{eq1} and P_{eq2}:

   $P_{eq1} = P_0 + (P_{gd})max$

   $P_{eq2} = P_h + (P_{gd\ site})max$

   where:

   $(P_{gd\ site})max$: The associated liquid pressure determined using site specific accelerations.

   $(P_{gd})max$: The associated liquid pressure determined using the maximum design accelerations.
5) The internal liquid pressures are those created by the resulting acceleration of the centre of gravity of the liquefied hydrogen fuel due to the motions of the ship referred to in [1.2.12]. The value of internal liquid pressure P_{gd} resulting from combined effects of gravity and dynamic accelerations is to be calculated, in MPa, as follows:

$$P_{gd} = \frac{\alpha_\beta Z_\beta \rho}{1,02 \cdot 10^5}$$

where:

α_β : Dimensionless acceleration (i.e. relative to the acceleration of gravity), resulting from gravitational and dynamic loads, in an arbitrary direction; (see Fig 1).

For large tanks, an acceleration ellipsoid, taking account of transverse vertical and longitudinal accelerations, is to be used.

ρ : Maximum liquefied hydrogen fuel density, in kg/m³, at the design temperature.

Z_β : Largest liquid height (m) above the point where the pressure is to be determined measured from the tank shell in the β direction (see Fig 2).

Tank domes considered to be part of the accepted total tank volume are to be taken into account when determining Z_β unless the total volume of tank domes V_d does not exceed the following value:

$$V_d = V_t \frac{100 - FL}{FL}$$

with:

V_t : Tank volume without any domes

FL : Filling limit according to [5.1.4].

The direction that gives the maximum value $(P_{gd})max$ or $(P_{gd\ site})max$ is to be considered. Where acceleration components in three directions need to be considered, an ellipsoid is to be used instead of the ellipse in Fig 1.

The above formula applies only to full tanks.

1.2.5 Functional loads: External pressure

External design pressure loads are to be based on the difference between the minimum internal pressure and the maximum external pressure to which any portion of the tank may be simultaneously subjected.

1.2.6 Functional loads: Thermally induced loads for liquefied hydrogen

Transient thermally induced loads during cooling down periods are to be considered for tanks intended for liquefied hydrogen.

Stationary thermally induced loads are to be considered for liquefied hydrogen fuel containment systems where the design supporting arrangements or attachments and operating temperature may give rise to significant thermal stresses.

1.2.7 Functional loads: Vibration

The potentially damaging effects of vibration on the fuel containment system are to be considered, if relevant depending on the ship operation.

1.2.8 Functional loads: Interaction loads

The static component of loads resulting from interaction between fuel containment system and the hull structure, as well as loads from associated structure and equipment, is to be considered.

1.2.9 Functional loads: Test loads

Account is to be taken of the loads corresponding to the testing of the fuel containment system referred to in Sec 12, [1.2].

1.2.10 Functional loads: Static heel loads for liquefied hydrogen

Loads corresponding to the most unfavourable static heel angle within the range 0° to 30° are to be considered. See Guidance to detailed calculation of pressure for a static heel angle of 30°, as given in NR467, Pt D, Ch 9, App 1, [3].

1.2.11 Functional loads: Other loads

Any other loads not specifically addressed, which could have an effect on the fuel containment system, are to be taken into account.

Figure 1 : Acceleration elipsoid

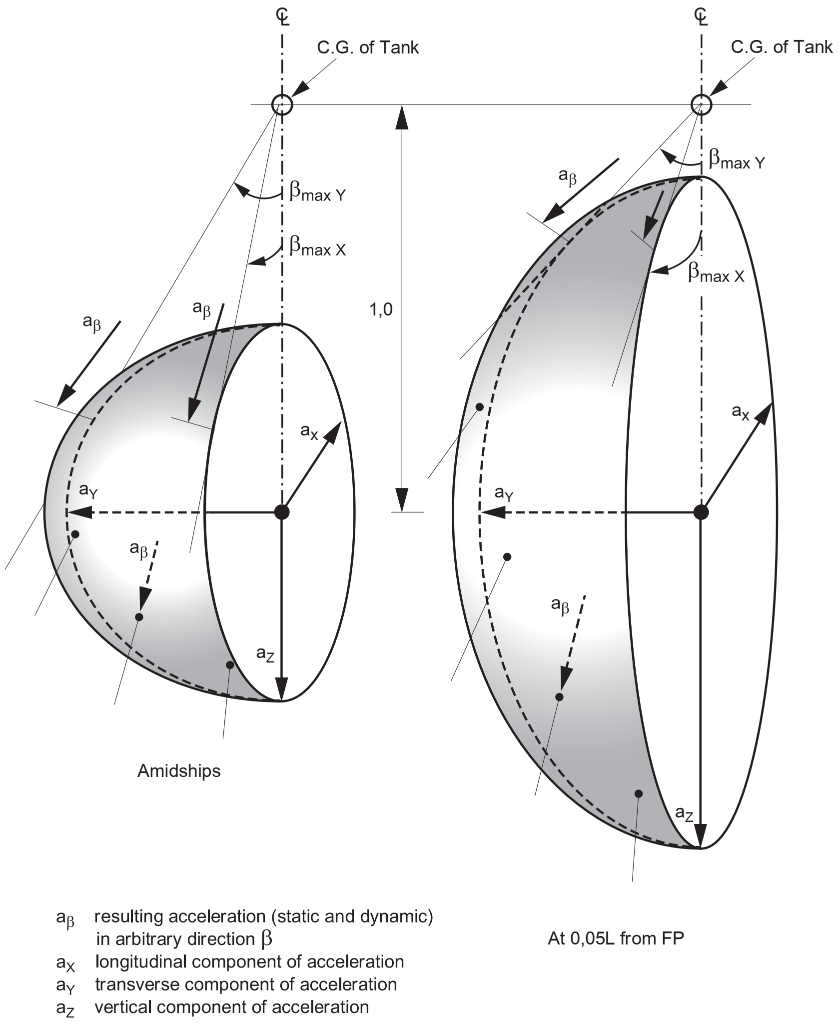
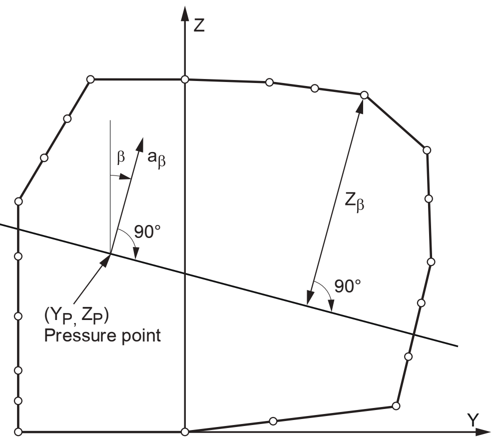


Figure 2 : Determination of internal pressure heads



1.2.12 Environmental loads

Environmental loads are defined as those loads on the liquefied hydrogen fuel containment system that are caused by the surrounding environment and that are not otherwise classified as a permanent, functional or accidental load.

a) Loads due to ship motion:

The determination of dynamic loads is to take into account the long-term distribution of ship motion in irregular seas, which the ship will experience during its operating life. Account may be taken of the reduction in dynamic loads due to necessary speed reduction and variation of heading. The ship's motion is to include surge, sway, heave, roll, pitch and yaw. The accelerations acting on tanks are to be estimated at their centre of gravity and include the following components:

- vertical acceleration: motion accelerations of heave, pitch and, possibly roll (normal to the ship base)
- transverse acceleration: motion accelerations of sway, yaw and roll and gravity component of roll, and
- longitudinal acceleration: motion accelerations of surge and pitch and gravity component of pitch.

The accelerations are to be taken as defined in NR467, Pt B, Ch 5, Sec 3.

As an alternative, guidance formulae for acceleration components are given in NR467, Pt D, Ch 9, App 1, [1.2].

Ships for restricted service may be given special consideration.

b) Dynamic interaction loads:

Account is to be taken of the dynamic component of loads resulting from interaction between fuel containment systems and the hull structure, including loads from associated structures and equipment.

c) Sloshing loads for liquefied hydrogen:

The sloshing loads on a hydrogen containment system and its internal components are to be evaluated for the full range of intended filling levels.

Hydrogen fuel tanks are to be checked for several relevant partial filling levels. CFD calculation or test campaign is to be carried out for verification of sloshing pressure without any limitation on the filling level.

d) Snow and ice loads:

Snow and icing are to be considered, if relevant. For ships operating in low air temperature, unless otherwise specified, the ice loads to be considered for tanks located on exposed decks are those of NR467, Pt F, Ch 8, Sec 4, [5.2.2].

e) Loads due to navigation in ice:

Loads due to navigation in ice are to be considered for vessels intended for such service.

f) Green sea loading:

Account is to be taken of loads due to water on deck. Water pressure due to green seas is to be calculated, for tanks located on exposed decks, in accordance with NR467, Pt B, Ch 5, Sec 5.

g) Wind loads:

Account is to be taken of wind generated loads as relevant. Wind pressure is to be taken equal to 2,5 kN/m^2.

1.2.13 Accidental loads

Accidental loads are defined as loads that are imposed on a fuel containment system and its supporting arrangements under abnormal and unplanned conditions.

a) Collision load:

The collision load is to be determined based on the fuel containment system under fully loaded condition with an inertial force corresponding to:

- in the forward direction: “a” with the value of the design acceleration a, as defined in Tab 1
- in the aft direction: a/2 with the value of the design acceleration a, as defined in Tab 1.

Special consideration is to be given to ships with Froude number (Fn) > 0,4.

The dynamic pressure P_w resulting from collision loads is to be calculated as follows:

$$P_w = \rho a |x - x_b|$$

where:

a	:	Longitudinal acceleration in m.s^{-2} as defined in Tab 1
x_b	:	x co-ordinate, in m, of aft bulkhead of the tank in the case of forward acceleration, or of the fore bulkhead of the tank in the case of aftward acceleration
ρ	:	Maximum fuel density, in kg.m^{-3}, at the design temperature.

b) Loads due to flooding on ship:

For independent tanks, loads caused by the buoyancy of a fully submerged empty tank are to be considered in the design of anti-flotation chocks and the supporting structure in both the adjacent hull and tank structure.

Table 1 : Design acceleration a

Ship length L **(1)**	Design acceleration a **(2)**
L > 100 m	a = 0,5 g
60 < L ≤ 100 m	$a = \left(2 - \frac{3(L-60)}{80}\right) g$
L ≤ 60 m	a = 2 g

(1) L is the load line length as defined in NR467, Ch1, Sec 3, [2.1.2]
(2) g is the gravitational acceleration

1.3 Supporting arrangements

1.3.1 The hydrogen fuel tanks are to be supported by the hull in a manner that prevents bodily movement of the tank under the static and dynamic loads defined in [1.2], where applicable, while allowing contraction and expansion of the tank under temperature variations and hull deflections without undue stressing of the tank and the hull.

1.3.2 Anti-flotation arrangements are to be provided for independent tanks and capable of withstanding the loads defined in [1.2.13], item b) without plastic deformation likely to endanger the hull structure.

1.3.3 Supports and supporting arrangements are to withstand the loads defined in [1.2.10] and [1.2.13], but these loads need not be combined with each other or with wave-induced loads.

1.4 Associated structure and equipment

1.4.1 The fuel containment system is to be designed for the loads imposed by associated structure and equipment.

1.5 Thermal insulation

1.5.1 Thermal insulation is to be provided as required to protect the hull from temperatures below those allowable and limit the heat flux into the tank to the levels that can be maintained by the pressure and temperature control system applied in [5.3].

1.6 Portable hydrogen tanks

1.6.1 Hydrogen portable tanks not dedicated to the concerned ship will be specially considered and evidences that they meet the applicable technical requirements for dedicated tanks are to be submitted to the Society..

1.6.2 Hydrogen portable tanks dedicated to the concerned ship are to be of a type approved by the Society.

1.6.3 Portable tanks, while connected to the ship system, are to be secured to the ship's structure. The arrangement for supporting and fixing the tanks is to be designed for the maximum expected static and dynamic inclinations, as well as for the maximum expected values of acceleration, taking into account the ship's characteristics and the position of the tanks.

Supporting and fixing arrangements are to be designed with a ship's safety factor of 2,5 with respect to the Maximum Securing Load (MSL). . See NI429 "Guidelines for the preparation of the cargo securing manual" for lashing calculations.

When storage consists of stacked-up tank-containers, the fixation or lashing arrangements are to be such as to avoid detrimental displacement of such containers (or other adjacent containers) in particular in case of rough sea. Standard lashing arrangement may not provide sufficient fixation.

1.6.4 Portable compressed hydrogen cylinders are to be fitted with devices (skids, rings, straps) ensuring that they can be safely handled by mechanical means and so arranged as not to impair the strength of, nor cause undue stresses in, the cylinder.

1.6.5 Portable hydrogen fuel tanks effect on ship's stability is to be taken into consideration.

1.6.6 Connections to the ship's hydrogen fuel piping systems are to be made by means of type-approved flexible hoses suitable for the fuel or other suitable means designed to provide sufficient flexibility. See Sec 9, [10].

1.6.7 Breakaway couplings or other arrangements are to be provided to limit the quantity of released hydrogen in case of inadvertent disconnection or rupture of the non-permanent connections.

1.6.8 The pressure relief system of portable hydrogen fuel tanks is to be connected to the ship fixed venting system. See Sec 8.

1.6.9 Control and monitoring systems for portable hydrogen fuel tanks are to be integrated in the ship's control and monitoring system. Safety systems for portable hydrogen fuel tanks are to be integrated in the ship's safety system (e.g. shutdown systems for tank valves, leak/vapour detection systems). See Sec 11.

1.6.10 When connected to the ship's hydrogen fuel piping system:

- Each portable hydrogen fuel tank, or group of elements for MEGC, is to be capable of being isolated at any time, and
- Isolation of one tank, or group of elements for MEGC, is not to impair the availability of the remaining portable hydrogen fuel tanks or groups of elements.

Note 1: For MEGC, isolation of all the sections may however be accepted after special consideration by the Society.

2 Compressed hydrogen cylinders

2.1 General

2.1.1 Compressed hydrogen cylinders are to be designed and constructed in line with one of the following options, depending on their type (See Sec 1, [1.4.23]):

- Type 1 cylinders: in accordance with the requirements of NR467, Pt C, Ch 1, Sec 3 for class 1 pressure vessels.
- Type 2 cylinders in accordance with a recognized standard accepted by the Society, e.g. ISO 11119-1:2020
- Type 3 cylinders in accordance with a recognized standard accepted by the Society, e.g. ISO 11119-2:2020
- Type 4 cylinders in accordance with a recognized standard accepted by the Society, e.g. ISO 11119-3:2020

2.1.2 Compressed hydrogen cylinders are to be of a type approved by the Society in accordance with Sec 13, [8] Sec 13, [9].

2.2 Equipment

2.2.1 Cylinder valves are to be designed and constructed in such a way that they are inherently able to withstand damage without release of the contents or are to be protected from damage which could cause inadvertent release of the contents of the cylinder. For portable hydrogen fuel tanks, potential damage during handling operations is to be taken into account.

2.2.2 Cylinders assembled in bundles are to be structurally supported and held together as a unit. Cylinders are to be secured in a manner that prevents movement in relation to the structural assembly and movement that would result in the concentration of harmful local stresses. Manifold assemblies (e.g. manifold, valves, and pressure gauges) are to be designed and constructed such that they are protected from impact damage and forces normally encountered.

2.2.3 Valves, piping and other fittings subjected to pressure, excluding pressure relief devices, are to be designed and constructed so that the burst pressure is at least 1,5 times the test pressure of the cylinder.

2.2.4 Service equipment is to be configured or designed to prevent damage that could result in the release of hydrogen under normal conditions. Manifold piping leading to shut-off valves is to be sufficiently flexible to protect the valves and the piping from shearing or releasing hydrogen. The filling and discharge valves and any protective caps are to be capable of being secured against unintended opening.

2.3 Installation and marking

2.3.1 Compressed hydrogen cylinders are to be clearly marked in accordance with ISO 13769:2018 or other recognized standard accepted by the Society.

2.3.2 Compressed hydrogen cylinders intended to be located on open decks are to be efficiently protected against ultraviolet, particularly in their most exposed parts by an appropriate coating or treatment or other means of shielding.

3 Multiple element gas containers (MEGC)

3.1 General

3.1.1 Elements of an MEGC are to be constructed and tested according to the requirements for compressed hydrogen cylinders defined in Article [2]. All of the elements in an MEGC are to be of the same design type.

3.1.2 MEGC are to be of a type approved by the Society in accordance with Sec 13, [10].

3.2 Equipment

3.2.1 The elements are to be divided into groups of not more than 3000 litres of water capacity. Each group is to be isolated by a valve according to Sec 9, [1.1.8].

3.2.2 Piping is to be designed, constructed and installed so as to avoid damage due to expansion and contraction, mechanical shock and vibration. Joints in tubing are to be butt-welded. The design pressure of the service equipment and of the manifold is to be not less than the design pressure of the elements.

3.2.3 For filling and discharge openings of the MEGC, two valves in series are to be placed in an accessible position on each discharge and filling pipe. One of the valves may be a non-return valve. The filling and discharge devices may be fitted to a manifold. The main valves on an MEGC are to be clearly marked to indicate their directions of closure.

Each stop-valve or other means of closure is to be designed and constructed to withstand a pressure equal to or greater than 1,5 times the test pressure of the MEGC. All stop valves with screwed spindles are to close by a clockwise motion of the handwheel. For other stop valves, the positions (open and closed) and direction of closure are to be clearly indicated. All stop valves are to be designed and positioned to prevent unintentional opening.

3.2.4 Service equipment is to be configured or designed to prevent damage that could result in the release of the pressure receptacle contents during normal conditions of handling, operation and transport. When the connection between the frame and the elements allows relative movement between the sub-assemblies, the equipment is to be so fastened as to permit such movement without damage to working parts. The manifolds, the discharge fittings (pipe sockets, shut-off devices), and the stop valves are to be protected from being wrenched off by external forces. Manifold piping leading to shut-off valves is to be sufficiently flexible to protect the valves and the piping from shearing, or releasing the pressure receptacle contents. The filling and discharge devices (including flanges or threaded plugs) and any protective caps are to be capable of being secured against unintended opening.

3.2.5 For cylinders protected by PRV, the combined delivery capacity of the pressure relief valves is to be sufficient so that, in the event of complete fire engulfment of the MEGC, the pressure (including accumulation) inside the elements does not exceed 120% of the set pressure of the pressure relief device.

3.2.6 Arrangements are to be made to prevent access to the pressure relief devices by unauthorized persons and to protect the devices from damage caused by the MEGC overturning.

3.3 Structure

3.3.1 MEGCs are to be designed, manufactured and equipped in such a way as to withstand the conditions expected on board the ship. The design is to take into account the effects of dynamic loading and fatigue. As a minimum, design loads defined as per NR467, Part B, Chapter 5 are to be considered and may be complemented depending on the specific configuration.

3.3.2 MEGCs are to be designed to withstand, without loss of contents, at least the internal pressure due to the contents, and the static, dynamic and thermal loads expected on board. The design is to demonstrate that the effects of fatigue, caused by repeated application of these loads through the expected life of the multiple-element gas container, have been taken into account.

3.3.3 The MEGC is to be capable of being filled and discharged without the removal of its structural equipment.

3.3.4 MEGC is to be provided with stabilizing members external to the elements to provide structural integrity for handling, operation and transport. MEGCs are to be designed and constructed with permanent lifting and tie-down attachments which are adequate for lifting the MEGC, including when loaded to its maximum permissible gross mass (MPGM). Mountings or attachments are not to be welded onto the elements. The combined stresses caused by element mountings (e.g. cradles, frameworks, etc.) and MEGC lifting and tie-down attachments are not to cause excessive stress in any element.

3.3.5 MEGCs are to be designed and constructed with a support structure to provide a secure base considering the forces specified in [3.3.6].

3.3.6 MEGCs and their fastenings are to be capable of withstanding the acceleration collisions loads defined in [1.2.13] and the applicable acceleration loads as per NR467, Part B, Chapter 5. Such requirement may be complemented depending on the specific configuration.

3.3.7 Under the forces defined above, the stress at the most severely stressed point of the elements is not to exceed the allowable stress defined by the manufacturer.

3.3.8 In the design of supports and frameworks, the effects of environmental corrosion is to be taken into account.

3.3.9 The elements are to be secured in a manner that prevents undesired movement in relation to the structure and the concentration of harmful localized stresses.

3.3.10 The elements and service equipment are to be protected against damage resulting from lateral or longitudinal impact or overturning except if they are so constructed as to withstand such impact or overturning. External fittings are to be protected so as to preclude the release of the elements' contents upon impact or overturning of the MEGC on its fittings. Particular attention is to be paid to the protection of the manifold. Examples of protection include:

- protection against lateral impact, which may consist of longitudinal bars
- protection against overturning, which may consist of reinforcement rings or bars fixed across the frame
- protection against rear impact, which may consist of a bumper or frame
- protection of the elements and service equipment against damage from impact or overturning by use of an ISO frame in accordance with the relevant provisions of ISO 1496-3:2019.

3.3.11 MEGCs are to be efficiently protected against corrosion, particularly in their most exposed parts, either by selection of their constituent materials, or by an appropriate coating or treatment. Contact between dissimilar metals which could result in damage by galvanic action is to be avoided.

4 Compressed hydrogen tanks other than cylinders

4.1 General

4.1.1 Compressed hydrogen tanks other than cylinders are to be designed and constructed in line with the requirements of NR467, Pt C, Ch 1, Sec 3 for Class 1 pressure vessels.

4.1.2 Compressed hydrogen tanks other than cylinders are to be certified and approved by the Society.

4.1.3 Means are to be provided to depressurize the tank in case of a fire which can affect the tank. Compressed hydrogen tanks other than cylinders are to be fitted with pressure relief valves with a set point below the design pressure of the tank and with outlet located as required in Sec 8.

5 Cryogenic tanks

5.1 General

5.1.1 Cryogenic tanks are to comply with the applicable requirements given for type C tanks in NR529, [6.4.15.3].

For the purposes of determining the minimum design vapour pressure according to NR529, [6.4.15.3.1.2], the allowable dynamic membrane stress $\Delta\sigma_A$ is to be assessed taking into account the crack propagation properties of the tank shell material considering the design temperature and the intended use.

5.1.2 If piping is connected below the liquid level of the tank, it is to be protected by a secondary barrier consisting of an external piping continuously enclosing the inner liquid pipe from the tank inner wall to the first valve body. The external pipe is to comply with the provisions of Sec 5 and Sec 9 and is to be provided with a venting line having gas detection arrangement.

5.1.3 Piping between the tank and the first valve which release liquid in case of pipe failure is to have equivalent safety as cryogenic tank itself, with dynamic stress not exceeding the values specified in [5.1.1]. In addition, the piping between the tank and the first valve is to be contained in a pipe arranged in accordance with [5.1.2].

5.1.4 The allowable filling limit for cryogenic tanks is not to exceed a volume equivalent to 95% full at the temperature corresponding to the vapour pressure of the fuel at the set pressure of the relief valves.

A loading limit curve for actual fuel loading temperatures is to be prepared from the following formula:

$$LL = FL\frac{\rho_R}{\rho_L}$$

where:

LL	:	Loading limit as defined in Sec 1, [1.4.15], expressed in per cent
FL	:	Filling limit as defined in Sec 1, [1.4.5] expressed in per cent, here 95%
ρ_R	:	Relative density of liquefied hydrogen fuel at the reference temperature
ρ_L	:	Relative density of liquefied hydrogen fuel at the loading temperature.

5.2 Vacuum insulated tanks

5.2.1 Supporting structures and adjacent hull structures are to be designed taking into account the cooling owing to loss of vacuum insulation.

5.2.2 Pipes led through the vacuum space are to be protected by a secondary barrier complying with [5.1.2] and the vacuum space is to be protected by a pressure relief device fitted with a re-closable lift plate. In addition, this pressure relief device is to be connected to the vent mast except where allowed by the Society. See Sec 8, [1.1.5].

5.2.3 For vacuum insulated tanks, the design of the outer shell is to be in accordance with a recognized standard accepted by the Society such as EN 13530-2:2003.

5.2.4 For vacuum insulated tanks special attention is to be given to the fatigue strength of the support design and special considerations are also to be made to the limited inspection possibilities between the inside and outer shell.

5.2.5 When vacuum insulation is used for a fuel containment system, the insulation performance is to be evaluated to the satisfaction of the Society based on experiments, as necessary.

5.3 Control of tank pressure and temperature

5.3.1 Cryogenic tank's pressure and temperature are to be capable of being maintained at all time within their design range by means acceptable by the Society, e.g. by one of the following methods:

- reliquefaction of vapours
- thermal oxidation of vapours
- pressure accumulation
- liquefied hydrogen fuel cooling.

The method chosen is to be capable of maintaining tank pressure below the set pressure of the tank pressure relief valves for a period of 15 days assuming full tank at normal service pressure and the ship in idle condition, i.e. only power for domestic load is generated.

5.3.2 Venting of hydrogen fuel vapour is not an acceptable means for control of the tank pressure except in emergency situations.

5.3.3 For worldwide service, the upper ambient design temperature is to be a sea temperature of 32°C and air temperature of 45°C. For service in particularly hot or cold zones, these design temperatures may be increased or decreased, with relevant explanations submitted to the Society.

5.3.4 The overall capacity of the system is to be such that it can control the pressure within the design conditions without venting to atmosphere.

5.3.5 Refrigerants or auxiliary agents used for refrigeration or cooling of the hydrogen fuel are to be compatible with the fuel they may come in contact with (not causing any hazardous reaction or generating excessively corrosive products). In addition, when several refrigerants or agents are used, these are to be compatible with each other.

5.3.6 The availability of the system and its supporting auxiliary services is to be such that in case of a single failure (of mechanical non-static component or a component of the control systems) the hydrogen fuel tank pressure and temperature can be maintained by another service/system. An FMEA analysis is to be submitted accordingly.

5.3.7 Coolers used in vapour reliquefaction systems and in liquefied hydrogen cooling systems and heaters used for thermal oxidation systems solely necessary to maintain the pressure and temperature of the fuel tanks within their design ranges are to have a standby heat exchanger. Alternatively, a standby heat exchanger is not required if they have a capacity in excess of 25% of the largest required capacity for pressure control and they can be repaired on board without external sources. When there is no standby unit installed, an analysis is to be submitted containing the following information:

- list of failure modes of the heat exchanger
- repair procedure for each failure mode, including downtime.

Failure of a heat exchanger within the boil-off hydrogen management system is not to result in a reduction of the capacity thereof.

5.3.8 Gas combustion units (GCU) are to comply with the relevant provisions of NR467, Pt C, Ch 1, Sec 3. Where high pressure vapours are intended to be consumed in a suitable consumer or in a dedicated GCU, and direct consumption of vapours is not possible, a buffer tank is to be installed.

Section 8 Venting and Pressure Relief System

1 General

1.1

1.1.1 Each pressure relief device on the hydrogen system and each hydrogen vent outlet is to be connected to a venting system complying with the requirements of [3.1].

1.1.2 Fuel storage hold spaces, tank connection spaces and tank cofferdams, which may be subject to pressures beyond their design capabilities, are also to be provided with a pressure relief system connected to the ship fixed venting system.

1.1.3 For cryogenic hydrogen, measures are to be taken to prevent vents from becoming blocked by accumulations of ice formed from moisture in the air.

1.1.4 Pressure control systems are to be independent of the pressure relief systems.

1.1.5 On open deck a direct release of small quantities of hydrogen into the atmosphere may be accepted, provided the released hydrogen cannot enter safe areas. Demonstration by a gas dispersion analysis is required.

2 Hydrogen fuel tanks pressure relief system

2.1

2.1.1 Hydrogen fuel tanks are to be provided with a pressure relief system appropriate to the design of the fuel containment system and the fuel being carried, and connected to a venting system complying with the requirements of [3.1].

2.1.2 Pressure relief devices fitted to hydrogen fuel tanks are to be type approved through design assessment and prototype testing in accordance with Sec 13, [6] and Sec 13, [7].

2.1.3 Relief valve sizing is to be undertaken for the most onerous scenario due to fire or due to loss of insulation.

2.1.4 Compressed hydrogen cylinders

Individual cylinders are to be equipped with pressure relief devices designed to prevent the entry of foreign matter, the leakage of hydrogen and the development of any dangerous excess pressure. Pressure relief devices are to be connected to the ship fixed venting system.

Composite cylinders are to be fitted with a TPRD.

Note 1: Pressure relief devices may be fitted for a group of cylinders subject to the satisfaction of the Society. See also [2.1.5].

2.1.5 Multiple-element gas containers (MEGC)

Every element or group of elements of an MEGC that can be isolated is to be fitted with one or more pressure relief devices connected to the ship fixed venting system. Pressure relief devices are to be of a type that will resist dynamic forces and are to be designed to prevent the entry of foreign matter, the leakage of hydrogen and the development of any dangerous overpressure.

Composite elements or groups of elements are to be fitted with TPRD.

2.1.6 Liquefied hydrogen tanks

Liquefied hydrogen tanks are to be equipped with at least two independent pressure relief valves allowing for disconnection of one PRV in case of malfunction or leakage.

The setting of the PRVs is not to be higher than the vapour pressure that has been used in the design of the tank.

Valves comprising not more than 50% of the total relieving capacity may be set at a pressure up to 5% above MARVS to allow sequential lifting, minimizing unnecessary release of vapour.

2.1.7 PRVs are to be connected to the highest part of the liquefied hydrogen tank. PRVs are to be positioned on the hydrogen fuel tank so that they will remain in the vapour phase at the filling limit (FL), under conditions of 15° list and 0,015 L trim.

2.1.8 No stop-valve is to be installed between the tank and the pressure relief devices, except when duplicate devices are provided for maintenance or other reasons, and the stop-valves serving the devices actually in use are locked open, or the stop-valves are interlocked so that at least one of the duplicate devices is always operable and capable of meeting the discharge requirements.

3 Venting systems

3.1

3.1.1 Venting systems are to be so constructed that the discharge will be unimpeded and be directed vertically upwards at the exit. The outlets are also to be arranged to minimize the possibility of water or snow entering the vent system. Distance from vent exits to non-hazardous areas and to openings to non-hazardous spaces is to be determined by a gas dispersion analysis.

3.1.2 The venting system is to be designed to withstand the consequences of an ignition inside the vent line unless ignition within the vent is prevented for example by means of a inert gas purge or flame arrester. The use of flame arrester is to be considered in the risk assessment depending on the configuration as it prevents the free release of hydrogen.

3.1.3 Where vents are grouped together, the design of the arrangement is to take into account potential for mis-directed flow, dead-ends and multiple vents operating simultaneously. Different vent stacks are recommended when the operating conditions are different (e.g. difference of pressure or temperature)

3.1.4 All vent piping is to be designed and arranged so that they are not damaged by the possible exposure to temperature variations, forces due to flow or the ship's motions.

3.1.5 For liquefied hydrogen, vent lines and their supporting arrangements are to be designed to withstand extremely cold temperature and oxygen-rich liquid air and ice formation. Drip trays are to be installed below vent lines for condensed liquid air.

3.1.6 In the venting system piping, means are to be provided for draining liquid, including water from condensation, from places where it may accumulate. The pressure relief devices and piping are to be arranged so that liquid can, under no circumstances, accumulate in or near the pressure relief devices. Draining pipe discharging to the deck may be accepted provided it is fitted with a self-closing valve and a manual shutoff valve.

4 Sizing of the venting systems

4.1

4.1.1 The venting systems are to be sized based on the maximum flow rate defined as the sum of the flow rates of hydrogen collected in the vent stack coming from all devices that could open simultaneously.

4.1.2 Openings leading to or leaving from a vent or pressure relief device are not to be obstructed in a way which could restrict or cut off the flow from the element to that device. The opening through all piping and fittings is to have at least the same flow area as the inlet of the pressure relief device to which it is connected. The nominal size of the discharge piping is to be at least as large as that of the pressure relief device outlet.

4.1.3 Pressure losses upstream and downstream of the PRVs, are to be taken into account when determining their size to ensure the flow capacity.

4.1.4 For liquefied hydrogen tanks, the venting systems are to be sized to ensure that the pressure does not increase beyond the hydrogen critical point.

4.1.5 Upstream pressure losses

The pressure drop in the vent line from the tank to the PRV inlet is not to exceed 3% of the valve set pressure at the calculated flow rate.

Pilot-operated PRVs are to be unaffected by inlet pipe pressure losses when the pilot senses directly from the tank dome, and pressure losses in remotely sensed pilot lines are to be considered for flowing type pilots.

4.1.6 Downstream pressure losses

Where common vent headers and vent masts are fitted, calculations are to include flow from all attached PRVs that can open simultaneously.

This maximum pressure drop from the PRV outlet to the location of discharge to the atmosphere, and including any vent pipe interconnections is generally not to exceed 10% of the lowest set pressure of all the relief valves which can open at the same time, and is not to exceed the maximum back pressure specified for any of these relief valves.

Alternative values provided by the PRV manufacturer may be accepted.

4.1.7 To ensure stable PRV operation, the blow-down is not to be less than the sum of the inlet pressure loss and 0,02 MARVS at the rated capacity.

Section 9 Hydrogen Piping and Equipment System

1 General

1.1

1.1.1 The arrangement and installation of hydrogen fuel piping are to provide the necessary flexibility to maintain the integrity of the piping system in the actual service situations, taking potential for fatigue into account.

1.1.2 Any piping that may contain liquefied or gaseous hydrogen, including venting system, is not to be located less than 800 mm from the shell plating or aft terminal of the ship. For double-walled pipes, the distance to be considered is the distance between the inner pipe and the ship's side.

1.1.3 Where pipes pass through enclosed spaces in the ship, they are to be protected by a secondary enclosure, designed according to [2.1.3] to [2.1.6], equipped with mechanical under pressure ventilation sufficient to dilute the average gas/vapour concentration below 25% of the LEL in all maximum probable leakage scenarios due to technical failures and provided with gas detection. Other solutions providing an equivalent safety level may also be accepted by the Society.

1.1.4 Hydrogen piping is not to be led directly through any accommodation space, service space, electrical equipment room, control station or through a machinery space other than a hydrogen consumer machinery space, except if it is arranged in accordance with [3.1.2] for gaseous piping or [4.1.2] for liquid piping.

1.1.5 Hydrogen piping is not to be routed through individual accommodation spaces (such as cabins).

1.1.6 Where tanks or piping are separated from the ship's structure by thermal insulation, provision are to be made for electrical bonding of both the piping and the tanks to the ship's structure. All gasketed pipe joints and hose connections are to be electrically bonded.

1.1.7 All hydrogen piping is to:

- be butt-welded as far as practicable
- be arranged to minimize the number of connections
- be provided with fixed detectors capable of detecting a leak in places where leakage of hydrogen may occur, such as valves, flanges and seals. Detectors are to be selected depending on the piping arrangement and environment (e.g. hydrogen, acoustic, pressure sensors…).

Gaskets are to be protected against blow-out.

1.1.8 Hydrogen fuel tank, or group of elements for MEGC, inlets and outlets are to be provided with isolation valves located as close to the tank as possible, except for pressure relief devices and liquid level gauging devices. Valves required to be operated during normal operation which are not accessible are to be remotely operated. Isolation valves whether accessible or not are to be automatically operated when the safety system is activated.

Note 1: Normal operation in this context is when hydrogen is supplied to consumers and during bunkering operations.

1.1.9 All hydrogen fuel piping system is to be arranged for gas freeing and inerting.

2 Design of piping components

2.1 General

2.1.1 Hydrogen piping components are to be designed in accordance with ASME B31.12-2019 Part IP: Industrial Piping standard or other recognized standard accepted by the Society.

2.1.2 The design pressure of piping, piping system and components is to be taken as the greater of the following values, as appropriate:

a) the minimum design pressure required by NR467 Pt C, Ch 1, Sec 10 [1.3.2]

b) for systems or components which may be separated from their relief valves and which contain only vapour at all times, the superheated vapour pressure at 45°C or higher or lower if agreed upon by the Society, assuming an initial condition of saturated vapour in the system at the system operating pressure and temperature; or

c) the MARVS of the hydrogen tanks and hydrogen processing systems; or

d) the pressure setting of the associated pump or compressor discharge relief valve if the latter is of sufficient discharge capacity to ensure that the pressure in the piping will drop; or

e) the maximum total discharge or loading head of the hydrogen piping system; or

f) the pressure relief valve setting on a pipeline system if of sufficient capacity; or

g) a pressure of 10 bar except for open ended lines where it is not to be lower than 5 bar.

2.1.3 The design pressure of the outer pipe or duct of hydrogen fuel systems is not to be lower than the maximum working pressure of the inner pipe. Alternatively for hydrogen fuel piping systems with a working pressure greater than 10 bars, the design pressure of the outer pipe or duct is not to be lower than the maximum built-up pressure arising in the annular space considering the local instantaneous peak pressure in way of any rupture and the ventilation arrangements.

2.1.4 For high-pressure hydrogen fuel piping the design pressure of the ducting is to be taken as the higher of the following:

- the maximum built-up pressure: static pressure in way of the rupture resulting from the gas flowing in the annular space
- local instantaneous peak pressure in way of the rupture: this pressure is to be taken as the critical pressure given by the following expression:

$$p = p_0\left(\frac{k}{k+1}\right)^{\frac{k}{k-1}}$$

where:

p_0 : Maximum working pressure of the inner pipe

k : Cp / Cv constant pressure specific heat divided by the constant volume specific heat. k is taken equal to 1,41 for hydrogen.

The tangential membrane stress of a straight pipe is not to exceed the tensile strength divided by 1,5 (Rm / 1,5) when subjected to the above pressures. The pressure ratings of all other piping components is to reflect the same level of strength as straight pipes.

As an alternative to using the peak pressure from the above formula, the peak pressure found from representative tests can be used. Test reports are then to be submitted.

2.1.5 Verification of the strength is to be based on calculations demonstrating the duct or pipe integrity. As an alternative to calculations, the strength can be verified by representative tests.

2.1.6 For low pressure hydrogen fuel piping the duct is to be dimensioned for a design pressure not less than the maximum working pressure of the fuel pipes.

2.1.7 High pressure hydrogen fuel piping systems are to have sufficient constructive strength. This is to be confirmed by carrying out stress analysis and taking into account:

- stresses due to the weight of the piping system
- acceleration loads when significant, and
- internal pressure and loads induced by hog and sag of the ship.

2.1.8 When the design temperature is minus 110°C or colder, a complete stress analysis, taking into account all the stresses due to weight of pipes, including acceleration loads if significant, internal pressure, thermal contraction and loads induced by hog and sag of the ship is to be carried out for each branch of the piping system.

3 Gaseous hydrogen piping system

3.1 General

3.1.1 Gaseous hydrogen piping may be routed on open decks without protective enclosure against leakage, subject to risk assessment.

Note 1: For cold gaseous hydrogen piping, relevant prescription of [5.1] may apply.

3.1.2 Gaseous fuel piping may be routed through the spaces mentioned in [1.1.4] provided the piping is placed in a structural trunk or casing designed to A-60 class standard towards high fire risk spaces or A-0 class standard toward other spaces and:

- the piping is protected by a secondary enclosure arranged in accordance with Sec 10, [1.8.1] and [2.1.3] to [2.1.6]; or
- the trunk or casing is designed for a pressure not less than the maximum working pressure of the hydrogen piping, equipped with mechanical under pressure ventilation sufficient to dilute the average gas/vapour concentration below 25% of the LEL in all maximum probable leakage scenarios due to technical failures and provided with gas detection.

3.1.3 Single wall hydrogen piping without casing may be accepted in one of the following cases:

- for hydrogen pipes located in gastight GVU spaces / enclosures
- for fully welded venting pipes led through mechanically ventilated spaces
- in spaces too small to be entered when the space comply with the requirement for GVU spaces. See Sec 3, [1.8].

4 Liquefied hydrogen piping system

4.1 General

4.1.1 Secondary enclosure

Liquefied hydrogen pipes are to be fitted with a vacuum-insulated secondary enclosure.

The enclosure is to be arranged with a pressure relief system that prevents the enclosure from being subjected to pressure above their design pressure.

The maximum built-up pressure in the enclosure is to take into account the local instantaneous peak pressure in way of any rupture and the ventilation arrangements.

The enclosure is to be made of a material that can withstand cryogenic temperatures.

4.1.2 Liquefied hydrogen piping may be routed through the spaces mentioned in [1.1.4] provided the piping is protected by a secondary enclosure complying with [4.1.1]and placed in a structural trunk or casing designed to A-60 class standard towards high fire risk spaces or A-0 class standard toward other spaces.

4.1.3 Bunkering liquefied hydrogen piping located on open decks or in enclosed or semi-enclosed bunkering stations need not be fitted with a protective enclosure against leakage.

4.1.4 For pipes containing liquefied hydrogen and cold hydrogen vapour, measures are to be taken to prevent the exposed surfaces from reaching –183°C. For places where preventive measures against low temperature are not sufficiently effective, such as manifolds, other appropriate measures such as ventilation which avoids the formation of highly enriched oxygen and the installation of trays recovering liquid air may be permitted in lieu of the preventive measures.

4.1.5 Liquefied hydrogen and cold hydrogen vapours piping systems are to be provided with a thermal insulation system as required to minimize heat leak during bunkering and transfer operations and to protect personnel from direct contact with cold surfaces.

Note 1: The thermal insulation may be omitted in the following cases:

- surfaces of hydrogen fuel piping systems which are protected by physical screening measures to prevent direct contact with personnel
- surfaces of manual valves, having extended spindles that protect the operator from the hydrogen fuel temperature
- surfaces of hydrogen fuel piping systems whose design temperature (to be determined from inner fluid temperature) is above minus 10°C.

4.1.6 Appropriate means, e.g. filtering, are to be provided in hydrogen fuel piping systems to remove impure substances condensed at low temperature.

4.1.7 Use of materials reactive to contact with liquefied air or liquid oxygen (e.g. lubricants, grease) is to be avoided.

4.1.8 All pipelines or components which may be isolated in a liquid hydrogen full condition are to be provided with relief valves, the outlet of which is to be led to a venting system complying with Sec 8.

5 Valves

5.1 General

5.1.1 All valves used in hydrogen systems are to be of an approved type. See Sec 13, [4].

6 Filters

6.1 General

6.1.1 Where filters are fitted, means are to be provided to indicate that they are becoming blocked and to isolate, depressurise and clean the filters safely.

7 Compressor

7.1 General

7.1.1 If closed circuit water-cooling is used, coolers are to be protected against overpressure on the water side.

8 Pressure regulator

8.1 General

8.1.1 Means are to be provided to isolate pressure regulator.

8.1.2 A relief device downstream of the pressure regulator is to be provided to protect the supply line in case of failure. The set pressure of the relief device is to be lower than or equal to the piping maximum allowable working pressure.

9 Vaporizer

9.1 General

9.1.1 Vaporizers are to be adequately sized for the maximum flow requirement. If a cryogenic pump is used to feed the vaporizer, the vaporizer capacity is to match the pump capacity.

9.1.2 Vaporizers and the associated piping are to be protected with a thermal relief valve.

9.1.3 Piping and its associated equipment downstream of the vaporizer is to be suitable for cryogenic temperature on a sufficient length to protect the equipment before the safety system described in Sec 11, [11.2.1] is actuated.

9.1.4 Heat for the vaporization of the liquefied hydrogen is to be supplied by indirect means through heating medium (e.g. water)

10 Flexible hoses

10.1 General

10.1.1 Except where otherwise stated in the present note, flexible hoses are to comply with the provisions of NR467, Pt C, Ch 1, Sec 10.

10.1.2 Flexible hoses used for hydrogen are to be of a type-approved by the Society. See Sec 13, [3].

10.1.3 Flexible hoses are to be routed in order to minimise exposure to accidental damage.

10.1.4 Means are to be provided to prevent injury from failed high-pressure flexible hose, e.g. restraining wire or protective cage.

11 Hydrogen fuel supply to consumer

11.1 General

11.1.1 The main supply line to each hydrogen consumer or set of consumers is to be equipped with a manually operated stop valve and an automatically operated “master valve” coupled in series or a combined manually and automatically operated valve. The valves are to be situated in the part of the piping that is outside the machinery space containing hydrogen consumers. They are to be placed as close as possible and downstream to the installation for heating the hydrogen, if fitted. The master valve is to automatically cut off the hydrogen supply when activated by the safety system as required in Sec 13, Tab 1.

11.1.2 The manually operated stop valves (or combined manually and automatically operated valves) are to be readily accessible.

Such valves may be located inside the tank connection space (TCS):

- only for low pressure hydrogen supply systems for cryogenic tanks, or
- for compressed hydrogen tanks

in the following cases:

- when the access to the TCS is through a door provided with an airlock, or
- when the valves can be manually closed from outside the TCS.

11.1.3 The master valve is to be operable from safe locations on escape routes inside the machinery space containing the hydrogen consumer or group of consumers, the engine control room, if applicable, outside the machinery space, and from the navigation bridge.

11.1.4 Each hydrogen consumer is to be provided with “double block and bleed” valves arrangement. These valves are to be arranged as outlined in a) or b) so that when the safety system is activated this will cause the shut off valves that are in series to close automatically and the bleed valve to open automatically and:

a) the two shut-off valves are to be in series in the hydrogen fuel pipe to the hydrogen consuming equipment. The bleed valve is to be in a pipe that vents to a safe location in the open air that portion of the hydrogen fuel piping that is between the two valves in series, or

b) the function of one of the shut-off valves in series and the bleed valve can be incorporated into one valve body, so arranged that the flow to the hydrogen utilization unit will be blocked and the ventilation opened.

11.1.5 The two shut-off valves are to be of the fail-to-close type, while the ventilation valve is to be fail-to-open.

11.1.6 The double block and bleed valves are also to be used for normal stop of the hydrogen consumer.

11.1.7 In cases where the master gas fuel valve is automatically shut-down, the complete hydrogen supply branch downstream of the double block and bleed valve is to be automatically vented assuming reverse flow from the hydrogen consumer to the pipe.

11.1.8 There is to be one readily accessible manually operated shutdown valve in the supply line to each hydrogen consumer upstream of the double block and bleed valves to allow safe isolation during maintenance. Where located inside the tank connection space (TCS) or GVU enclosure arranged with bolted access hatch, the valve is to be arranged for manual closing from outside the TCS or GVU enclosure.

11.1.9 For single engine installations and multi-engine installations, where a separate master valve is provided for each engine, the master valve and the double block and bleed valve functions may be combined.

11.1.10 For each hydrogen supply line to high pressure installations, means are to be provided for rapid detection of a rupture of the hydrogen line in the machinery space. When rupture is detected a valve is to be automatically shut off. This valve is to be located in the hydrogen supply line before it enters the machinery space or as close as possible to the point of entry inside the machinery space. It may be a separate valve or combined with other functions, e.g. the master valve.

Note 1: The shutdown may be time delayed to prevent shutdown due to transient load variations.

12 Redundancy of fuel supply for essential services

12.1 General

12.1.1 The provisions of the present sub-article apply to single fuel installations intended as the only source of power for ship propulsion or for other essential services as defined in NR467, Pt A, Ch 1, Sec 1, [1.2.1] and NR467, Pt C, Ch 2, Sec 1, [3.2].

12.1.2 For single fuel installations the fuel supply system is to be arranged with full redundancy and segregation all the way from the hydrogen fuel tanks to the consumer, so that a leakage in one system does not lead to an unacceptable loss of power.

12.1.3 For single fuel installations, the hydrogen fuel storage is to be divided between two or more tanks. The tanks are to be located in separate compartments. One tank may be accepted if two completely separate tank connection spaces are installed for the tank.

12.1.4 Filters that could impair the proper functioning of the system, fitted on hydrogen or air supply lines are to be arranged so that they can be cleaned without interrupting the supply. For that purpose, two filters or strainers fitted in parallel, or one duplex type with a change over facility, may be accepted.

Section 10 Machinery, Electricity and Fire Protection

1 Power generation

1.1 Machinery spaces containing hydrogen-fuelled internal combustion engines

1.1.1 In order to minimize the probability of a hydrogen explosion in a machinery space the gas safe machinery space concept is to be applied: Arrangements in machinery spaces are to be such that the spaces are considered gas safe under all conditions, normal as well as abnormal conditions, i.e. inherently gas safe.

In a gas safe machinery space a single failure is not to lead to release of hydrogen into the machinery space.

Other concepts, like the ventilated/inerted concepts for fuel cell spaces, may be considered on a case-by-case basis by the Society.

Machinery spaces containing hydrogen-fuelled and non-hydrogen-fuelled engines are to be covered by the risk assessment as per Sec 2, [1.1.10].

1.2 Internal combustion engine

1.2.1 Hydrogen engines are to be type approved on the basis of the following general and specific provisions for dualfuel and single-fuel engines, in addition to those required in NR467, Pt C, Ch 1, Sec 2, for standard diesel engines.

1.2.2 All engine components and engine-related systems are to be designed in such a way that fire and explosion risks are minimized.

1.2.3 Engine components containing hydrogen are to be effectively sealed to prevent leakage of fuel into the machinery space.

1.2.4 The capability of engines driving generators to accept sudden load variations is to be verified.

1.2.5 A risk assessment of the engine is to be carried out using an HAZID analysis or other acceptable methods and reflected in the safety concept of the engine. The risk assessment is to cover at least the following hazards:

- presence and possible accumulation of hydrogen in the charge air system or in the crankcase
- leakage of high pressure hydrogen
- presence of unburnt hydrogen in the exhaust system
- failure of a hydrogen admission valve or injection valve
- failure of the ignition system (sparking plug or pilot injection)
- failure of the oil system (cooling and sealing)
- failure of the purging system.

1.3 Single fuel engines

1.3.1 In case of a normal stop or an emergency shutdown, the hydrogen supply is to be shut off not later than the ignition source. It is not to be possible to shut off the ignition source without first or simultaneously closing the fuel supply to each cylinder or to the complete engine.

1.4 Dual fuel engines

1.4.1 The lowest specified speed is to be verified in diesel mode and hydrogen mode.

1.4.2 In case of shut-off of the hydrogen supply, the engines are to be capable of continuous operation by oil fuel only without interruption.

1.4.3 An automatic system is to be fitted to change over from hydrogen fuel operation to oil fuel operation with minimum fluctuation of the engine power. Acceptable reliability is to be demonstrated through testing. In the case of unstable operation on engines when hydrogen firing, the engine is to automatically change to oil fuel mode. There is to also be the possibility for manual changeover.

1.4.4 In case of an emergency stop or a normal stop, the hydrogen supply is to be automatically shut off not later than the pilot oil fuel. It is not to be possible to shut off the pilot oil fuel without first or simultaneously closing the fuel supply to each cylinder or to the complete engine.

1.5 Auxiliary systems

1.5.1 Auxiliary systems where hydrogen may leak directly into the system medium (lubricating oil, cooling water) are to be equipped with appropriate detection and extraction means fitted directly after the medium outlet from the system in order to prevent dispersion.

Hydrogen extracted from auxiliary systems media is to be vented to a safe location in the open air.

1.6 Exhaust system of internal combustion engines

1.6.1 The exhaust system is to be designed to prevent any accumulation of unburnt fuel.

1.6.2 The exhaust system is to be designed to withstand combustion of any fuel-air leak mixture by means of:

- explosion relief venting to prevent excessive pressure build-up. Where explosion relief venting is installed, the combustion products are to be vented to a safe location, or
- having sufficient strength to contain a worst-case explosion, in which case, evidences are to be submitted.

1.6.3 Each fuel consumer is to have a separate exhaust system.

1.7 Fuel cell

1.7.1 Fuel cell systems using hydrogen are to comply with the relevant requirements given in NR547.

1.8 Piping arrangements in machinery spaces

1.8.1 Hydrogen fuel piping in machinery spaces is to be completely enclosed by a double pipe or duct fulfilling one of the following conditions:

a) The hydrogen piping is to be a double wall piping system with the fuel contained in the inner pipe. The space between the concentric pipes is to be pressurized with inert gas at a pressure greater than the fuel pressure. Suitable alarms are to be provided to indicate a loss of inert gas pressure between the pipes. When the inner pipe contains high pressure hydrogen, the system is to be so arranged that the pipe between the master valve and the engine is automatically purged with inert gas when the master valve is closed, or

b) The hydrogen fuel piping is to be installed within a ventilated pipe or duct. The air space between the hydrogen fuel piping and the wall of the outer pipe or duct is to be equipped with mechanical under pressure ventilation sufficient to dilute the average gas/vapour concentration below 25% of the LEL in all maximum probable leakage scenarios due to technical failures. The fan motors is to comply with the required explosion protection in the installation area. The ventilation outlet is to be covered by a protection screen and placed in a position where no flammable gas-air mixture may be ignited on the open deck, or

Other solutions providing an equivalent safety level may also be accepted by the Society.

1.9 Availability of power for propulsion or essential services

1.9.1 When hydrogen is intended to be used for propulsion or essential services, a combination of separated sources of power distributed in several spaces is required. This requirement may be waived upon consideration by the Society when hydrogen is not essential to the proper functioning (e.g.: dual-fuel engines).

2 Fire and explosion prevention

2.1 General

2.1.1 In order to facilitate the selection of appropriate electrical apparatus and the design of electrical installations, hazardous areas are divided into zones 0, 1 and 2, and the different spaces are to be classified according to [2.2]. Alternatively, area classification according to IEC 60079-10-1:2020 may be applied with special consideration by the Society.

2.1.2 Electrical equipment and wiring are not in general to be installed in hazardous areas unless essential for operational purposes or safety enhancement. Where electrical equipment is installed in hazardous areas, it is to comply with NR467, Pt C, Ch 2, Sec 2, [6] according to the hazardous area classification.

2.1.3 Electrical equipment is to be selected and installed in accordance with a recognized standard (e.g. IEC 60079 and IEC 60092-502:1999) and certified-safe for installation in the relevant hazardous area (See NR467, Pt C, Ch 2, Sec 3, [10]).

2.1.4 The temperature class T1 and equipment group IIC are to be used for potential flammable atmosphere for certified safe equipment.

2.2 Area classification

2.2.1 Hazardous area Zone 0

This zone includes, but is not limited to, the interiors of fuel tanks, any pipework for pressure relief or other venting systems for fuel tanks, pipes and equipment containing fuel.

2.2.2 Hazardous area Zone 1

This zone includes, but is not limited to:

- tank connection spaces, fuel storage hold spaces containing pressure vessels or cryogenic tanks including potential leakage sources, e.g. tank connections
- fuel preparation room arranged with ventilation according to Sec 4, [1.5]
- enclosed or semi-enclosed spaces in which pipes containing fuel are located, e.g. ducts around hydrogen pipes whatever their arrangement (ventilated duct, duct pressurized with inert gas, vacuum-insulated pipes), semi-enclosed bunkering stations, GVU spaces and GVU enclosures
- a space protected by an airlock is considered as non-hazardous area during normal operation, but equipment required to operate following loss of differential pressure between the protected space and the hazardous area is to be certified safe for use in hazardous area zone 1.

Following areas are to be considered as Zone 1 hazardous areas with an extent based on hydrogen dispersion analysis:

- areas on open deck, or semi-enclosed spaces on deck, close to any fuel tank outlet, gas or vapour outlet, bunker manifold valve, other fuel valve, fuel pipe flange, fuel preparation room ventilation outlets
- areas on open deck or semi-enclosed spaces on deck, close to fuel preparation room entrances, fuel preparation room ventilation inlets and other openings into zone 1 spaces
- areas on the open deck within spillage coamings surrounding gas bunker manifold valves.

The hydrogen dispersion analysis scenarios and conditions are to be justified.

Areas within at least 3 m of high pressure sources of release are to be considered as Zone 1.

2.2.3 Hazardous area Zone 2

This zone includes, but is not limited to, airlocks and space containing bolted hatch to tank connection space e.g. fuel storage hold space.

Areas surrounding open or semi-enclosed spaces of zone 1 are to be considered as Zone 2 hazardous areas with an extent based on hydrogen dispersion analysis.

The hydrogen dispersion analysis scenarios and conditions are to be justified.

2.3 Ventilation

2.3.1 Ventilation ducts are to have the same area classification as the ventilated space.

2.3.2 At the design stage, dispersion of hydrogen from vent outlets is to be analysed in order to minimize risk of ingress of flammable gas into accommodation spaces, service spaces, machinery spaces and control stations. Extension of hazardous areas is to be considered based on the results of the analysis.

3 Fire safety and explosion protection

3.1 General provisions

3.1.1 The requirements of this chapter are additional to those of NR467, Part C, Chapter 4.

3.1.2 Fuel preparation rooms are to be regarded as machinery spaces of category A for fire protection purposes as addressed in NR467, Pt C, Ch 4, Sec 5.

3.1.3 Anti-static clothing and footwear, and a portable hydrogen detector are to be provided for each crew member working in the fuel area. That equipment is to be indicated in the Fire Control Plan.

3.2 Fire and explosion protection

3.2.1 The fire and mechanical protection of gas pipes led on open deck or through ro-ro spaces is to be subject to special consideration by the Society depending on the use and expected pressure in the pipes.

3.2.2 The bunkering station is to be separated by:

- A-60 class divisions towards machinery spaces of category A, accommodation spaces, control stations and high fire risk spaces.
- A-0 class divisions towards spaces such as tanks, voids, auxiliary machinery spaces of little or no fire risk, sanitary and similar spaces of low fire risk.

3.2.3 Any boundary of accommodation spaces, service spaces, control stations, escape routes or machinery spaces, facing fuel tanks on open deck, is to be shielded by A-60 class divisions. The A-60 class division is to extend up to the underside of the deck of the navigation bridge. The Society may accept relaxation concerning the insulation provided that a minimum safe distance between the above spaces and the hydrogen fuel tank has been determined. When the fuel containment system is located on open deck directly above a space with high fire risk, the separation is to be done by a cofferdam of at least 900 mm with insulation of A-60 class.

3.2.4 The fuel storage hold space and the tank connection space are to be separated from the machinery spaces of category A or other rooms with high fire risks by a cofferdam of at least 900 mm with insulation of A-60 class fitted on the bulkhead adjacent to the machinery space or high fire risk room. When determining the insulation of the space containing fuel containment system from other spaces with lower fire risks, the fuel containment system is to be considered as a machinery space of category A, in accordance with NR467 Pt C, Ch 4, Sec 5.

For cryogenic tanks, the fuel storage hold space may be considered as a cofferdam provided that:

- the tank is not located directly above machinery spaces of category A or other rooms with high fire risk; and
- the minimum distance to the A-60 boundary from the outer shell of the tank or the boundary of the tank connection space, if any, is not less than 900 mm.

3.3 Explosion protection

3.3.1 Explosion relief devices are to be designed so that if an explosion occurs the pressure will be relieved without creating projectiles.

3.4 Fire detection

3.4.1 A fixed fire detection and fire alarm system complying with NR467, Pt C, Ch 4, Sec 15, [8] is to be provided in the fuel storage hold spaces and the ventilation trunk to the tank connection space and in the tank connection space, fuel preparation rooms, enclosed and semi enclosed bunkering stations and in all other rooms of the fuel gas system where fire cannot be excluded.

3.4.2 The fire detection system is to allow the remote identification of each individual detector; alternatively, the detectors are to be arranged in small separate loops.

3.4.3 Smoke detectors alone are not considered sufficient for rapid detection of a fire. In the case where fusible elements are used as a means of fire detection, flame detectors suitable for hydrogen flames are to be provided in addition at the same locations.

3.5 Fire main

3.5.1 When the fuel storage tank is located on the open deck, isolating valves are to be fitted in the fire main to isolate damaged sections of the fire main. Isolation of a section of fire main is not to deprive the fire line ahead of the isolated section from the supply of water.

3.6 Water spray system

3.6.1 A water spray system is to be installed for cooling and fire prevention to cover exposed parts of fuel storage tank(s) located on open deck. For tankers, special attention is to be paid to the interaction between fixed foam fire extinguishing system and water spray system.

3.6.2 The water spray system may be part of the fire main system provided that the required fire pump capacity and working pressure are sufficient for the simultaneous operation of both the required number of hydrants and hoses and the water spray system.

3.6.3 The water spray system is also to provide coverage for boundaries of the superstructures, fuel preparation rooms, cargo control rooms, bunkering control stations, bunkering stations and any other normally occupied deck houses that face the storage tank on open decks. If the tank is located 10 metres or more from the boundaries, this requirement may be waived provided it is demonstrated to the satisfaction of the Society that the boundaries will not be affected by a fire. Water spray systems are to cover also bunkering connections and fuel preparation equipment located on open decks.

Note 1: Normally occupied deckhouse means deckhouse containing essential equipment or normally manned or accessible to passengers.

3.6.4 The system is to be designed to cover all areas as specified in [3.6.1] and [3.6.3] with an application rate of 10 $l/min/m^2$ for the largest horizontal projected surfaces and 4 $l/min/m^2$ for vertical surfaces.

3.6.5 Stop valves are to be fitted in the water spray application main supply line(s), at intervals not exceeding 40 metres, for the purpose of isolating damaged sections. Alternatively, the system may be divided into two or more sections that may be operated independently, provided the necessary controls are located together in a readily accessible position not likely to be inaccessible in case of fire in the areas protected.

3.6.6 The capacity of the water spray pump is to be sufficient to deliver the required amount of water to the hydraulically most demanding area among the areas protected as specified in [3.6.1] and [3.6.3].

3.6.7 If the water spray system is not part of the fire main system, a connection to the ship's fire main through a stop valve is to be provided.

3.6.8 Remote start of pumps supplying the water spray system and remote operation of any normally closed valves to the system is to be located in a readily accessible position which is not likely to be inaccessible in case of fire in the areas protected.

3.6.9 The nozzles are to be of an approved full bore type and they are to be arranged to ensure an effective distribution of water throughout the area being protected.

3.6.10 The system is not to spray water directly on the valves of the hydrogen safety systems (e.g. valves associated to the pressure relief system). Alternatively, such valves are to be equipped with protection from water spray system.

3.7 Fire extinguishing

3.7.1 Before actuation of the fixed fire-extinguishing system in any hydrogen-related space, the fuel supply is to be shut off automatically.

3.7.2 Fuel preparation rooms containing pumps, compressors or other potential ignition sources are to be provided with a carbon dioxide fixed fire extinguishing system complying with NR467, Pt C, Ch 4, Sec 15, [4] except that the amount of carbon dioxide is to be sufficient to provide a quantity of free gas equal to 75% or more of the gross volume of the protected space. Alternatively, a fixed dry chemical powder fixed fire extinguishing system complying with IMO MSC.1/Circ.1315 may be considered.

4 Electrical systems

4.1 General

4.1.1 The provisions of this chapter are to be applied in conjunction with applicable requirements of NR467, Part C, Chapter 2.

4.1.2 Electrical generation and distribution systems, and associated control systems, are to be designed such that a single fault will not result in the loss of ability to maintain fuel tank pressure and hull structure temperature within normal operating limits. See Sec 2, [1.1.5].

4.1.3 The onboard installation of the electrical equipment units is to be such as to ensure the safe bonding to the hull of the units themselves.

4.1.4 Cable penetrations are to be sealed against the passage of gas or vapour.

4.1.5 Due consideration is to be given to static electricity associated with rotating or reciprocating machinery including the installation of conductive machinery belts.

4.1.6 Electrical continuity is to be maintained throughout the hydrogen system.

4.1.7 All systems are to be earth bonded. Means are to be provided to ensure that all non-permanent components are earthed at all times when connected to a permanent hydrogen system.

4.1.8 Power systems (systems exceeding 24V) are to be provided with purged or explosion-proof enclosures.

Section 11 Control, Monitoring and Safety Systems

1 General

1.1

1.1.1 The requirements given in the following paragraphs may be adapted on the basis of the risk analysis required in Sec 2, [1]. In particular, monitoring and control options are to be defined for systems not covered in the following paragraphs but for which the risk analysis would show significant risks.

1.1.2 Monitoring and alarm sensors intended for hydrogen fuel bunkering, storage, preparation and supply systems are to be of a type approved by the Society.

1.1.3 In case of emergency shutdown, the safety system is to be reset manually before the hydrogen consumer or equivalent can be restarted.

2 Gas or vapour detection

2.1 Monitoring and control

2.1.1 Permanently installed gas detectors are to be fitted in:

- the tank connection spaces
- all ducts around fuel pipes
- machinery spaces containing hydrogen piping, hydrogen equipment or hydrogen consumers
- fuel preparation rooms
- other enclosed spaces containing fuel piping or other fuel equipment without ducting
- other enclosed or semi-enclosed spaces where fuel vapours may accumulate
- airlocks
- gas heating circuit expansion tanks
- motor rooms associated with the fuel systems
- at ventilation inlets to accommodation and machinery spaces if required based on the risk assessment
- in GVU spaces and enclosures
- at ventilation inlets to ro-ro spaces or special category spaces
- in space containing bolted hatch to tank connection space, if any
- in enclosed and semi-enclosed bunkering stations.

2.1.2 The number of detectors in each space is to be determined taking into account the size, layout and ventilation of the space. The detectors are to be located where gas may accumulate and/or in the ventilation outlets. Detectors on ground-level are to be considered in case of low temperature hydrogen. Gas dispersal analysis or equivalent is to be used to find the best arrangement for the following spaces:

- machinery spaces containing hydrogen piping, hydrogen equipment or hydrogen consumers
- fuel preparation rooms
- tank connection spaces
- enclosed and semi-enclosed bunkering stations.

2.1.3 Two independent gas detectors located close to each other are required for redundancy reasons. If the gas detector is of the self-monitoring type, the installation of a single gas detector may be accepted.

2.1.4 Gas/vapour detection equipment is to be designed, installed and tested in accordance with a recognized standard accepted by the Society (e.g. ISO 26142:2010 for hydrogen detectors). The gas detection equipment is to be of a type approved by the Society and suitable for all expected ambient conditions including air flow velocities.

2.1.5 Gas/vapour detection is to be continuous without delay.

2.2 Actions of the alarm system and safety system

2.2.1 Gas/vapour detection above a gas or vapour concentration of 20% LEL is to cause an alarm.

Gas/vapour detection above a gas or vapour concentration of 40% LEL is to activate the safety systems.

3 Ventilation performance

3.1 Monitoring and control

3.1.1 In order to verify the performance of the ventilation system, a detection system of the ventilation flow and of the pressure is to be installed. A running signal from the ventilation fan motor is not sufficient to verify performance.

3.1.2 Operation of the overpressure ventilation required in Sec 4, [1.2.6] is to be monitored.

3.1.3 Operation of the extraction ventilation required in Sec 4, [1.2.7] in the hazardous space is to be monitored.

3.2 Actions of the alarm system and safety system

3.2.1 Ventilation reduced below the required capacity is to trigger an alarm.

a) In the event of failure of the overpressure ventilation required in Sec 4, [1.2.6]:
   - an audible and visual alarm is to be given at a continuously manned location, and
   - if overpressure cannot be immediately restored, automatic or programmed, disconnection of electrical installations according to IEC 60092-502:1999 Electrical Installations in Ships - Tankers - Special Features, table 5 is required.

b) In the event of failure of the extraction ventilation required in Sec 4, [1.2.7]:
   - an audible and visual alarm is to be given at a continuously manned location, and
   - if under pressure cannot be immediately restored, automatic or programmed, disconnection of electrical installations according to a recognized standard in the non-hazardous space is required. Immediate restoration of the under pressure is deemed satisfied if the extraction ventilation is served by redundant fans arranged with automatic change-over to the standby fan in case of loss of under pressure.

c) Loss of ventilation in secondary enclosure of pipes for gaseous hydrogen is to trigger the closing of the related fuel valves by the normal process control.

4 Inerting performance

4.1 Monitoring and control

4.1.1 A detection system showing a proper value of the pressure of inert gas or any selected alternative method accepted by the Society is to be provided in inerted spaces.

4.2 Actions of the alarm system and safety system

4.2.1 Loss of pressure in an inerted secondary enclosure of pipes for gaseous hydrogen is to trigger the closing of the related fuel valves by the normal process control.

5 Control of a safe atmosphere

5.1 Monitoring and control

5.1.1 In order to prevent the risk of anoxia, where stratification of air is possible (See Sec 4, [1.1.1]):
- in spaces normally accessible, oxygen concentration is to be monitored
- in spaces not normally accessible, means are to be provided to ensure a sufficient oxygen concentration before entry

Alternative means to prevent the risk of anoxia may be considered on a case-by-case basis.

5.2 Actions of the alarm system and safety system

5.2.1 Alarm is to be activated at an oxygen concentration below 19%.

6 Bilge wells

6.1 Monitoring and control

6.1.1 A bilge well in each space where liquid hydrogen can be present is to be provided with both a level indicator and a temperature sensor.

6.2 Actions of the alarm system and safety system

6.2.1 Alarm is to be activated at high liquid levels in bilge wells.

Low temperature indication is to lead to automatic closing of tank valve.

7 Drip trays

7.1 Monitoring and control

7.1.1 Drip trays are to be fitted with a temperature sensor located in a small well to detect a possible leakage.

7.2 Actions of the alarm system and safety system

7.2.1 Alarm is to be activated at low temperature indication and lead to the automatic shutdown of the concerned valves.

8 Hydrogen Bunkering

8.1 Monitoring and control

8.1.1 Monitoring and control of the hydrogen bunkering is to be possible from a safe location remote from the bunkering station. At this location:

- Tank pressure, tank level and tank temperature (if required by [9.1.3]) are to be monitored.
- Remote control valves required by Sec 6, [3.1.4] and Sec 10, [3.6.8] are to be capable of being operated. Emergency shutdown is to be also possible from the navigation bridge.
- Overfill alarm and automatic shutdown are to be indicated.

8.2 Actions of the alarm system and safety system

8.2.1 Audible and visual alarm is to be provided and emergency shutdown is to be activated if:

- Ventilation in the ducts enclosing the bunkering lines or serving enclosed or semi-enclosed bunkering stations stops
- Hydrogen is detected in the ducts around the bunkering lines or in the bunkering station

9 Hydrogen Fuel tank

9.1 Monitoring and control

9.1.1 Tanks not permanently installed in the vessel

For tanks not permanently installed in the vessel a monitoring system is to be provided as for permanently installed tanks.

9.1.2 Compressed hydrogen tanks

Tanks, individual cylinders, or group of elements for a MEGC, are to be provided with a pressure gauge.

9.1.3 Cryogenic tank

Each tank is to be fitted with appropriate level gauging devices, arranged to ensure a level reading whenever the tank is operational. The devices are to be designed to operate throughout the design pressure range of the tank and at temperatures within the fuel operating temperature range. Unless maintenance can be carried out while the fuel tank is in service, at least two level gauging devices are to be installed.

Except for cryogenic tanks supplied with vacuum insulation system and pressure build-up fuel discharge unit, each cryogenic tank is to be provided with devices to measure and indicate the temperature of the fuel in at least three locations; at the bottom and middle of the tank as well as the top of the tank below the highest allowable liquid level.

10 Liquefied hydrogen pipes

10.1 Actions of the alarm system and safety system

10.1.1 Alarms are to be provided to indicate a loss of vacuum between the inner and outer pipes.

10.2 Monitoring and control

10.2.1 The vacuum-insulated secondary enclosure is to be provided with a pressure sensor to detect a loss of vacuum. Alternatively, temperature sensors on the enclosure may be accepted provided that the time for detection is deemed acceptable.

11 Vaporizers

11.1 Monitoring and control

11.1.1 Low temperature detectors are to be fitted at the outlet of the vaporizers.

11.2 Actions of the alarm system and safety system

11.2.1 Alarm is to be activated at low temperature indication at the outlet of the vaporizer and lead to the automatic shut off of the concerned supply line.

12 Filters

12.1 Monitoring and control

12.1.1 Filters on hydrogen supply lines are to be fitted with differential pressure monitoring.

13 Fuel preparation room

13.1 Monitoring and control

13.1.1 Pressure and operation monitoring of compressors is to be provided and is to include the following elements:

- low pressure detectors and/or oxygen analysers at the inlet of compressors
- oxygen analysers at the inlet of compressors where the risk assessment shows that the compressors could operate below atmospheric pressure
- high temperature and pressure detectors at the outlet of the compressors
- low water pressure or flow detectors in the cooling water system
- low pressure detectors where motors and auxiliary equipment are pressurized by an inert gas
- low pressure detectors where compressor crankcase are pressurized by hydrogen or inert gas.

13.1.2 Where bulkhead penetrations are used to separate the drive from a hazardous space, temperature monitoring for bulkhead shaft glands and bearings is to be provided.

13.2 Actions of the alarm system and safety system

13.2.1 Compressors are to be fitted with audible and visual alarms both on the navigation bridge, in the engine room and in the fuel preparation room.

Alarm is to be activated:

- at low pressure indication at the compressor inlet and lead to the compressor shut down before reaching the atmospheric pressure.
- at an oxygen content of 1% at the compressor inlet and lead to the compressor shut down.
- at high temperature or high pressure at the compressor outlet and lead to the compressor shut down before reaching the maximum allowable value.
- at low water pressure in the cooling water system and lead to the compressor shut down.
- at low pressure where motors and auxiliary equipment are pressurized by an inert gas and lead to the motor and auxiliaries shut down
- at low pressure where compressor crankcase are pressurized by hydrogen or inert gas and lead to the compressor shut down.

Alarms are to include low gas input pressure, low gas output pressure, high gas output pressure and compressor operation. An alarm is to be initiated at high temperature for bulkhead shaft glands and bearings.

14 Internal combustion engine

14.1 Monitoring and control

14.1.1 Means are to be provided to monitor and detect poor combustion or misfiring. In the event that it is detected, continued operation may be allowed, provided that the fuel supply to the concerned cylinder is shut off and provided that the operation of the engine with one cylinder cut-off is acceptable with respect to torsional vibrations.

14.2 Actions of the alarm system and safety system

14.2.1 In the event that poor combustion or misfiring is detected, alarm is to be activated and lead to the engine shut down. Continued operation may be allowed, provided that the fuel supply to the concerned cylinder is shut off and provided that the operation of the engine with one cylinder cut-off is acceptable with respect to torsional vibrations.

15 Emergency shutdown push buttons

15.1 General

15.1.1 Emergency shutdown of the bunkering is to be possible from the bunkering control location and from the navigation bridge.

15.1.2 Compressors, pumps and fuel supply are to be arranged for manual remote emergency stop from the following locations as applicable:

- navigation bridge
- cargo control room
- onboard safety centre
- engine control room
- fire control station, and
- adjacent to the exit of fuel preparation rooms.

The hydrogen compressor is also to be arranged for manual local emergency stop.

16 Required alarms and safety actions

16.1 Monitoring and alarms functions

16.1.1 The required monitoring and alarms functions to be provided are listed in:

- Tab 1 for general monitoring and alarm functions
- Tab 2 for bunkering and hydrogen fuel storage.

Additional alarms may be required for unconventional or complex installations.

16.1.2 Gas and liquid detection alarms are to be given both at the navigation bridge, at the continuously manned central control station and locally.

16.2 Safety actions

16.2.1 The required safety actions to be implemented on board are listed in:

- Tab 1 for general monitoring and alarm functions
- Tab 2 for bunkering and hydrogen fuel storage.

Additional safety actions may be required for unconventional or complex installations.

16.2.2 Safety functions required to be activated in case of a cryogenic leakage are to remain available in case of low temperatures

Table 1 : Alarm and safety actions

Symbol convention: H = high; HH = high high; L = low X = Function is required	Monitoring		Shutdown			
Identification of system parameter	Alarm	Criteria	Tank isolation valve **(1)**	Hydrogen supply to machinery / fuel cell space	Ignition sources	Compressor
GAS DETECTION						
Tank connection space	H	20% LEL				
	HH	40% LEL	X			
Fuel preparation room	H	20% LEL				
	HH	40% LEL	X		X	
Secondary enclosure of piping and equipment outside of machinery/ fuel cell space	H	20% LEL				
	HH	40% LEL	X **(2)**			
Secondary enclosure of piping and equipment inside machinery/ fuel cell space	H	20% LEL				
	HH	40% LEL	X	X **(3)**	X	
In other areas	H	20% LEL				
	HH	40% LEL	**(4)**	**(4)**	**(4)**	
LIQUID DETECTION						
Cryogenic tank connection space bilge well	H					
Drip trays **(4)**	L	Low temperature				
VENTILATION						
Ventilated spaces	L	Reduced ventilation **(5)**				
Secondary enclosure of piping and equipment outside of machinery/ fuel cell space	X	Loss ventilation **(5)**	X **(2)**			

Symbol convention: H = high; HH = high high; L = low X = Function is required	Monitoring		Shutdown			
Identification of system parameter	Alarm	Criteria	Tank isolation valve **(1)**	Hydrogen supply to machinery / fuel cell space	Ignition sources	Compressor
Secondary enclosure of piping and equipment inside of machinery/ fuel cell space	X	Loss ventilation **(5)**		X **(3)**		
Tank connection space	X	Loss of ventilation **(5)**	X			
Fuel preparation room	X	Loss of ventilation **(5)**	X			
Airlock and space protected by airlock	X	Loss of ventilation **(5)**			X	
INERTING						
Secondary enclosure of pipes	X	Loss of overpressure	X	X		
Inerted space	X	Loss of overpressure				
Inert gas supply	H	Oxygen content > 1%				
	H	Abnormal quantity delivered **(6)**				
COMPRESSOR						
Compressor inlet	L	Low pressure				X
	H	Oxygen content > 1%				X
Compressor outlet	H	Temperature				X
	H	Pressure				X
Compressor water cooling system	L	Low pressure				X
Compressor motor and auxiliary equipment pressurization	L	Low pressure				**(7)**
Compressor crankcase pressurization	L	Low pressure				X
OTHER						
Spaces with anoxia risk including inert gas generator or storage facilities	L	Oxygen content < 19%				
Cryogenic tank connection space bilge well	L	Low temperature	X			
Vaporizer outlet	L	Low temperature	X	X		
Vacuum in liquid hydrogen pipes	H	High pressure				
Differential pressure across filters	H **(8)**					
Internal combustion engine	X	Poor combustion or misfiring		X **(9)**		

(1) See Sec 9, [1.1.8]
(2) If the tank is supplying hydrogen to more than one consumer and the supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct, only the upstream master valve on the supply pipe leading into the duct where hydrogen or loss of ventilation is detected may close.
(3) If hydrogen is supplied to more than one engine and the supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct and outside of the machinery space containing hydrogen-fuelled consumers, only the master valve on the supply pipe leading into the duct where hydrogen or loss of ventilation is detected is to close.
(4) Safety action to be determined depending on the concerned area
(5) Monitoring of pressure and ventilation flow. See [3.1.1]
(6) See Sec 4, [2.1.4]
(7) Shutdown of compressor motor and auxiliaries
(8) Local alarm
(9) May be limited to the concerned cylinder. See [14.2.1]

Table 2 : Bunkering and storage alarms and safety action

Symbol convention: H = high; HH = high high; L = low X = Function is required	Monitoring		Shutdown			
Identification of system parameter	Alarm	Criteria	Bunkering valves	Bunkering facility	Tank inlet valve	Hydrogen pump
BUNKERING SYSTEM						
Emergency shutdown manually actuated	X					
Ducting of bunkering lines	X	Loss of ventilation	X	X		
	X	Hydrogen detection	X	X		
Bunkering station	X	Hydrogen detection	X	X		
HYDROGEN FUEL TANK						
Liquefied hydrogen tank level	H					
	HH				X	
	L					
	LL					X
Tank pressure	H				X	
	L					

Section 12 Onboard Testing

1 General

1.1 Hydrogen piping system

1.1.1 The testing requirements in this Section apply to fuel piping inside and outside the hydrogen fuel tanks. However, relaxation from these requirements for piping inside fuel tanks and open ended piping may be considered by the Society.

1.1.2 After assembly, all fuel piping is to be subjected to a strength test. The test pressure is to be at least 1,5 times the design pressure for liquid lines and 1,5 times the maximum system working pressure for vapour lines.

When piping systems or parts of systems are completely manufactured and equipped with all fittings, the test may be conducted prior to installation on board the ship. Joints welded on board are to be tested to at least 1,5 times the design pressure.

Manifolds assemblies mentioned in Sec 7, [2.2.2] are to have at least the same test pressure as the cylinders.

1.1.3 After assembly on board, the fuel piping system is to be subjected to a leak test at design pressure. Two options are available:

- leak test with helium (typically nitrogen / helium mixture) combined with helium leak detection or
- test with hydrogen after leak test with nitrogen, initially test at low pressure and then at increasing pressures, observing for leaks at each point.

Alternative protocols allowing to safely detect hydrogen leakages may however be accepted after special consideration by the Society.

The measured leakage rate is not to exceed the rate determined by the analysis required in Sec 4, [1.1.2].

1.1.4 In double wall fuel piping systems the outer pipe or duct is to also be pressure tested to show that it can withstand the expected maximum pressure at pipe rupture. In case of gas fuel piping arranged in accordance with Sec 10, [1.8.1], item b), the test pressure of the outer pipe or duct is not to be less than 1.5 times the maximum built-up pressure calculated in accordance with Sec 9, [2.1.4]. This also applies to GVU enclosures.

1.1.5 All piping systems, including valves, fittings and associated equipment for handling fuel or vapours, is to be tested under normal operating conditions not later than at the first bunkering operation, in accordance with the requirements of the Society.

1.1.6 Non-destructive testing

All welded joints, including the inside wherever possible, are to be visually examined over their full length.

Radiographic or ultrasonic examination of all butt-welded joints over their full length is to be carried out for piping systems with:

- design temperatures lower than -10°C, or
- design pressure greater than 1,0 MPa, or
- hydrogen supply pipes in machinery spaces, or
- inside diameters of more than 75 mm, or
- wall thicknesses greater than 10 mm.

For other butt-welded joints, spot radiographic or ultrasonic examination or other non-destructive tests is to be carried out depending upon service, position and materials. In general, at least 10% of butt-welded joints of pipes is to be subjected to radiographic or ultrasonic examination.

For other types of welded joints which cannot be examined by radiographic or ultrasonic examination, liquid penetrant examination is to be carried out on every weld over their full length.

1.2 Hydrogen containment system

1.2.1 All hydrogen tanks and process pressure vessels are to be subjected to hydrostatic or hydro-pneumatic pressure testing in accordance with [1.2.6].

1.2.2 After assembly, all tanks, pressure vessels and their related fittings are to be subject to a tightness test which may be performed in combination with the pressure test referred to in [1.2.1].

1.2.3 The gas tightness of the fuel containment system spaces with reference to Sec 7, [1.1.4] is to be tested.

1.2.4 The overall performance of the fuel containment system is to be verified for compliance with the design parameters during the first LH2 bunkering, when steady thermal conditions of the liquefied hydrogen are reached, to the satisfaction of the surveyor. Records of the performance of the components and equipment, essential to verify the design parameters, are to be maintained on board and be available to the Society.

1.2.5 The fuel containment system is to be inspected for cold spots during or immediately following the first LH2 bunkering, when steady thermal conditions are reached. Inspection of the integrity of thermal insulation surfaces that cannot be visually checked is to be carried out to the satisfaction of the surveyor.

1.2.6 Testing procedure

a) Each pressure vessel is to be subjected to a hydrostatic test at a pressure measured at the top of the tanks, of not less than 1,5 the design vapour pressure. In no case during the pressure test the calculated primary membrane stress at any point is to exceed 90% of the yield strength of the material at the test temperature. To ensure that this condition is satisfied where calculations indicate that this stress will exceed 0,75 times the yield strength, the test of the first of a series of identical tanks is to be monitored by the use of strain gauges or other suitable equipment in pressure vessels other than simple cylindrical and spherical pressure vessels.

b) The temperature of the water used for the test is to be at least 30°C above the nil-ductility transition temperature of the material, as fabricated.

c) The pressure is to be held for 2 hours per 25 mm of thickness, but in no case less than 2 hours.

d) Where necessary for liquefied hydrogen fuel pressure vessels, a hydro-pneumatic test may be carried out under the conditions prescribed in items a) to c).

e) Special consideration may be given to the testing of tanks in which higher allowable stresses are used, depending on service temperature. However, regulation in item a) is to be fully complied with.

Section 13 Survey at Work and Certification

1 General

1.1

1.1.1 The manufacture, testing, and survey is to be in accordance with the applicable Rules for Classification, recognized standards accepted by the Society and the specific requirements given in this Rule Note.

The general requirements for certification of machinery, equipment and systems using hydrogen as fuel are listed in Article [12]. Additional requirements for specific items regarding type approval and production testing are provided in Article [2] to Article [11].

2 Liquefied hydrogen bunkering hoses

2.1 Production testing

2.1.1 All hose assemblies are to be subject to a hydraulic pressure test, at a pressure equal to 1,5 times the design pressure.

3 Gaseous hydrogen flexible hoses

3.1 Type approval

3.1.1 Each type of flexible hose is to be type tested.

Each size of hose assembly is to be type tested. However, for ranges with more than 3 different diameters, the prototype tests are to be carried out for at least:

- the smallest diameter
- the largest diameter
- intermediate diameters selected based on the principle that prototype tests carried out for a hose assembly with a diameter D are considered valid only for the diameters ranging between 0,5 D and 2 D.

The scope of tests is to include at least the tests specified in Tab 1.

All flexible hose assemblies for gaseous hydrogen are to be satisfactorily prototype burst tested to demonstrate that they are able to withstand a pressure not less than:

- 4 times the design pressure when the design pressure is below 40 MPa
- 3 times the design pressure + 40 Mpa when the design pressure is above 40 Mpa.

Table 1 : Type tests of flexible hoses for gaseous hydrogen

No.	Test	Applicable testing standard	Other information
1	Hydraulic pressure test (permanent deformation check)	ISO 16964:2019	
2	Burst pressure test		See [3.1.1]
3	Pressure cycle test	ISO 16964:2019	
4	Pneumatic leak test (including permeability measuring)	ISO 16964:2019	
5	Bend radius test (pliability + cycle test)		See NR467, Pt C, Ch 1, Sec 10, Tab 35 and NR467, Pt C, Ch 1, Sec 10, Tab 36
6	Material compatibility test	ISO 11114-4:2017	
7	Integrity of restraining wire arrangement	ISO 16964:2019	If any
8	Vibration	IEC 60068-2-6 Test Fc	See NR467, Pt C, Ch 3, Sec 6, Tab 1
9	Fire resistance **(1)**		See NR467, Pt C, Ch 1, Sec 10, Tab 35 and NR467, Pt C, Ch 1, Sec 10, Tab 36
10	Impulse		See NR467, Pt C, Ch 1, Sec 10, Tab 35 and NR467, Pt C, Ch 1, Sec 10, Tab 36
(1) For non-metallic hoses			

3.2 Production testing

3.2.1 The following production tests are to be performed on all hose assemblies:

- a hydraulic pressure test, at a pressure equal to 1,5 times the design pressure.
- a pneumatic leak test.
- a visual inspection, especially concerning the end fitting.

4 Valves

4.1 Type approval

4.1.1 Each type of valve is to be type tested. The scope of tests is to include at least the tests specified in Tab 2.

4.2 Production testing

4.2.1 Each valve is to be tested in the presence of the Surveyor unless an alternative survey scheme (BV Mode I) has been agreed. Testing is to include hydrostatic test of the valve body at a pressure equal to 1,5 times the design pressure for all valves, seat and stem leakage test at a pressure equal to 1,1 times the design pressure for valves other than pressure relief valves. In addition, cryogenic testing consisting of valve operation and leakage verification for a minimum of 10% of each type and size of valve for valves other than safety valves intended to be used at a working temperature below -55°C. The set pressure of safety valves is to be tested at ambient temperature.

For valves used for isolation of instrumentation in piping not greater than 25mm, unit production testing need not be witnessed by the Surveyor. Records of testing are to be available for review.

Table 2 : Type tests of valves

No.	Test	Applicable testing standard
1	Hydraulic pressure test	
2	Burst test **(1)**	
3	Pneumatic leak test (internal and external, including permeability measuring)	
4	Insulation test **(2)**	
5	Material compatibility test	ISO 11114-4:2017
6	Fire resistance test **(3)**	ISO 19921:2005 ISO 19922:2005

(1) All valves, piping and fittings mentioned in Sec 7, [3.2.3] are to be burst tested to ensure that the burst pressure is at least 1,5 times the cylinder test pressure.
(2) Applicable to automatic valves
(3) For emergency shutdown valves, with materials having melting temperatures lower than 925°C.

5 Expansion joints/bellows

5.1 Type approval

5.1.1 Expansion bellows intended for use in hydrogen systems are to be type tested and approved by the Society as given in NR529 [16.7.2].

5.2 Production testing

5.2.1 All bellows are to be tested in the presence of the Surveyor unless an alternative survey scheme (BV Mode I) has been agreed. Testing is to include hydrostatic test of the bellow at a pressure equal to 1,5 times the design pressure.

6 Pressure relief valves for tanks

6.1 Type approval

6.1.1 Each type of PRV is to be type tested in accordance with recognized standards. The scope of tests is to include at least:

- verification of relieving capacity
- seat tightness testing, and
- pressure test to at least 1,5 times the design pressure for pressure containing parts.

6.2 Production testing

6.2.1 Each PRV is to be tested in the presence of the Surveyor , unless an alternative survey scheme (BV Mode I) has been agreed, to ensure that:

- it opens at the prescribed pressure setting, with an allowance not exceeding:
  - ±10% for 0 to 0,15 MPa
  - ±6% for 0,15 to 0,3 MPa
  - ± 3% for 0,3 MPa and above
- seat tightness is acceptable; and
- pressure containing parts will withstand at least 1,5 times the design pressure.

7 Thermally activated pressure relief devices (TPRD)

7.1 Type approval

7.1.1 Each type of TPRD is to be type tested in accordance with recognized standards. The scope of tests is to include at least the tests specified in Table 11.

Table 3 : Type tests of Thermally activated pressure relief devices (TPRD)

No.	Test	Applicable testing standard
1	Pressure cycling	
2	Accelerated life	
3	Temperature cycling	
5	Leak	
6	Bench top activation	
7	Flow rate	
8	Material compatibility test	ISO 11114-4:2017

8 Type 1 cylinders and other metallic compressed hydrogen tanks

8.1 Type approval

8.1.1 Type 1 cylinders are to be of a type approved according to a recognized standard (e.g. ISO 9809 series).

8.2 Production testing

8.2.1 Production tests for Type 1 cylinders are to be performed according to a recognized standard (e.g. ISO 9809 series).

Production tests for metallic tanks are to be performed according to NR467, Pt C, Ch 1, Sec 3, [9]

The following tests of all tanks or cylinders are to be witnessed by the Surveyor, unless an alternative survey scheme (BV Mode I) has been agreed:

- a hydraulic pressure test. Tanks and cylinders are to meet the acceptance criteria specified in the design and construction technical standard or technical code
- a leak test as per Sec 12, [1.1.3]
- inspection and assessment of manufacturing defects and either repairing them or rendering the cylinders unserviceable. In the case of welded pressure receptacles, particular attention is to be paid to the quality of the welds
- an inspection of the marks on the pressure receptacles.

9 Type 2, 3 and 4 cylinders

9.1 Type approval

9.1.1 Each type of composite cylinder is to be type tested. The scope of tests is to include at least the tests specified in Tab 4.

9.2 Production testing

9.2.1 The following production tests are to be performed on liners:

- Verification of the compliance with the design specification
- Verification of the raw material certification
- Verification of the homogeneity of the material (non-destructive testing) for metallic liner
- Verification of the tensile strength and elongation (one per batch) for non-metallic liner.

The following production tests are to be performed on cylinders:

- Verification of the compliance with the design specification
- Verification of the raw material certification
- a hydraulic pressure test according to the standard used but not less than 1,5 times the design pressure.
- A pressure cycle test according to the standard used (one cylinder per 5 batches)
- A burst test according to the standard used (one cylinder per batch)
- A leak test for cylinders with welded or non-metallic liners.

The pressure cycle test and burst test are to be witnessed by a Surveyor unless an alternative survey scheme (BV Mode I) has been agreed.

Table 4 : Type test of type 2, 3 and 4 composite cylinders

No.	Test	Applicable testing standard **(1)**	Other information
SEMI-PRODUCTS			
1	Composite material test	• ISO 11119-1:2020 • ISO 11119-2:2020 • ISO 11119-3:2020 • EN 17339:2020	Includes tests on resin shear strength, glass transition temperature and overwrap materials. Resin content to be mentioned in the final report
2	Liner material tests		
END PRODUCTS			
3	Liner burst tests	• ISO 11119-1:2020 • ISO 11119-2:2020 • ISO 11119-3:2020 • EN 17339:2020	For load sharing liner only
4	Protection against UV	Visual inspection	Design data **(2)**
5	Proof pressure test	• ISO 11119-1:2020 • ISO 11119-2:2020 • ISO 11119-3:2020 • EN 17339:2020	
6	Cylinder burst test		
7	Resistance to pressure cycles	• ISO 11119-1:2020 • ISO 11119-2:2020 • ISO 11119-3:2020 • EN 17339:2020	Criteria for non-limited life
8	Exposure to elevated temperature	• ISO 11119-1:2020 • ISO 11119-2:2020 • ISO 11119-3:2020 • EN 17339:2020	Criteria for non-limited life (≥ 20 years)
9	Drop or impact test		
10	Flawed cylinder test	• ISO 11119-2:2020 • ISO 11119-3:2020 • EN 17339:2020	
11	Environmental cycle test	• ISO 11119-1:2020 • ISO 11119-2:2020 • ISO 11119-3:2020 • EN 17339:2020	Including vacuum test
12	Fire resistance test		
13	Leak/Permeability test	• ISO 11119-3:2020 • EN 17339:2020	
14	Torque test	• ISO 11119-1:2020 • ISO 11119-2:2020 • ISO 11119-3:2020 • EN 17339:2020	
15	Neck strength test	• EN 17339:2020	
16	Neck ring test	• EN 17339:2020	

(1) Considering the wide diversity of materials and design used for manufacturing composite cylinders, column 3 indicates examples of testing procedure to be applied. Other testing procedure may be accepted by the Society provided that what is required in the other columns is fulfilled.

(2) Protection against UV and salt mist is to be carried out for equipment installed in weather exposed area.

No.	Test	Applicable testing standard **(1)**	Other information
17	Salt mist	• ISO 21746:2019	**(2)**
18	High velocity impact test	• ISO 11119-1:2020 • ISO 11119-2:2020 • ISO 11119-3:2020 • EN 17339:2020	If deemed relevant according to the safety assessment

(1) Considering the wide diversity of materials and design used for manufacturing composite cylinders, column 3 indicates examples of testing procedure to be applied. Other testing procedure may be accepted by the Society provided that what is required in the other columns is fulfilled.
(2) Protection against UV and salt mist is to be carried out for equipment installed in weather exposed area.

10 Multiple-element gas containers (MEGC)

10.1 Type approval

10.1.1 Components of the MEGC are to be type approved as per relevant items: cylinders, piping, fittings, valves, process equipment, etc.

10.2 Production testing

10.2.1 The initial inspection and test of an MEGC is to include a check of the design characteristics, an external examination of the MEGC and its fittings, and a pressure test based on the pressure test determined in Article [8] or Article [9]. The pressure test of the manifold may be performed as a hydraulic test or by using another liquid or gas with the agreement of the Society. Before the MEGC is placed into service, a leak test and a test of the satisfactory operation of all service equipment are also to be performed. When the elements and their fittings have been pressure-tested separately, they are to be subjected together after assembly to a leak test.

11 Internal combustion engine

11.1 Type approval

11.1.1 The engine is to undergo at least the following type tests, in addition to those required in NR467, Pt C, Ch 1, Sec 2, for standard Diesel engines:

- For dual fuel engines, the lowest specified speed is to be verified in diesel mode and hydrogen mode.
- For dual-fuel engines, switch over between hydrogen and diesel modes are to be tested at different loads.
- The efficiency of the ventilation arrangement of the double walled hydrogen piping system is to be verified.
- The capability of engines driving generators to take sudden load and loss of load is to be verified.

12 Certification

12.1

12.1.1 Equipment are to be certified as listed in Tab 5. Symbols used in Tab 5 have the following meaning:

C : A BV product certificate is required with invitation of the Surveyor to attend the tests unless otherwise agreed, in addition to the manufacturer's document stating the results of the tests performed and/or compliance with the approved type as applicable

DA : Design assessment / Appraisal of the product is required; this one may be carried out as applicable either for a specific unit or using the Type Approval procedure

TA : Type Approval is required

TA (HBV): Type Approval is required with work's recognition (HBV scheme as per NR320)

W : A manufacturer's document is required, stating the results of the tests performed and/or stating compliance with the approved type (as applicable)

X : Examinations and tests are required

Where fitted, each additional index (h, ndt) indicates a specific type of test:

h : Hydraulic pressure test (or equivalent)

ndt : Non-destructive tests as per Rules.

Table 5 : Certification requirements

Item	Product certification				Remarks
	Design assessment / Approval	Raw material certificate	Examination and testing	Product certificate	
1 - Compressed hydrogen tank	DA (1)	C	X h ndt	C	(1) As per provisions of Sec 5 and Sec 7, [4]. Compressed hydrogen tanks are to be considered as Class I pressure vessels, in accordance with NR467, Pt C, Ch 1, Sec 3, [1.4.1] Note: Running tests - during trials of the ship
2 - Type 1 cylinder	TA (1)	C	X h ndt	C	(1) As per NR467, Pt C, Ch 1, Sec 3
3 - Type 2 cylinder:	TA (1)		X h ndt	C	(1) In compliance with national or international standard (e.g ISO 11119 series or equivalent). Approval includes salt mist testing (e.g. ISO 21746 or equivalent)
• resin system	TA(HBV)	W			
• reinforcement fibre	TA(HBV)	W			
• metallic liner	TA	C	X ndt		
4 - Type 3 cylinder:	TA (1)		X h ndt	C	(1) In compliance with national or international standard (e.g ISO 11119 series, EN 17339:2020 or equivalent). Approval includes salt mist testing (e.g. ISO 21746 or equivalent)
• resin system	TA(HBV)	W			
• reinforcement fibre	TA(HBV)	W			
• metallic liner	TA	C	X ndt		
5 - Type 4 cylinder:	TA (1)	W	X h ndt	C	(1) In compliance with national or international standard (e.g ISO 11119 series, EN 17339:2020 or equivalent). Approval includes salt mist testing (e.g. ISO 21746 or equivalent)
• resin system	TA(HBV)	W			
• reinforcement fibre	TA(HBV)	W			
• non metallic liner	TA(HBV)	W	X		
6 - Multiple-element gas containers (MEGC) (1)	TA (2)		X (2)	C	(1) Components of the MEGC are to be certified as per relevant items in this table: cylinders, piping, fittings, valves, process equipment, etc. (2) Structure of the container is to be reviewed and surveyed as per requirements in Sec 7, [3]
7 - Cryogenic hydrogen tank	DA (1)	C (1)	X h ndt	C	(1) As per provisions of Sec 5 and Sec 7, [5]. Note: Running tests - during trials of the ship
8 - Plates and profiles for hydrogen fuel tanks	(1)	C (1)	X	C	(1) As per provisions of Sec 5

Item	Product certification				Remarks
	Design assessment / Approval	Raw material certificate	Examination and testing	Product certificate	
9 - Flexibles hoses assembly (1)	TA (2)	W	X h (3)	C	(1) Short length of metallic or non-metallic hose with end fittings ready for installation. (2) See Sec 9, [10] for type approval and Article [3] for type tests (3) All hoses are to be tested as per Article [3]
10 - Fans for hazardous enclosed spaces, and their prime movers:					(1) For anti-sparking fans (2) As per conditions set in the Type Approval (3) For electrical motors, refer to NR266 item K
• fans	TA (1)		X	C or W (2)	
• prime movers	(3)		X (3)	C	
11 - Fire and gas detection system	TA (1)		X	C	(1) Automation systems: see relevant provisions of NR266 item N
12 - Gaseous hydrogen valve, incl. non-return valves (1):					(1) Class of piping as per provisions of Sec 5 (2) In case of welded construction. When the valves have welded elements, the welding procedures are to be examined (3) Unit production testing: all valves are to be tested as per [4.2]
• ND ≥ 50 mm	TA	C	X h ndt (2) (3)	C	
• ND < 50 mm	TA	W	X h ndt (2) (3)	C	
13 - Pressure relief valves for piping	TA or DA (1)	C	X h ndt (2) (3)	C	(1) TA, or case-by-case DA (2) Checking of the setting (3) When the valves have welded elements, the welding procedures are to be examined
14 - Pressure relief valve for tank	TA	C	X h ndt (1) (2)	C	(1) As per provisions given in [6] (2) When the valves have welded elements, the welding procedures are to be examined
15 - Thermally activated pressure relief device	TA	C	X h ndt (1) (2)	C	(1) As per provisions given in Article [7] (2) When the devices have welded elements, the welding procedures are to be examined
16 - Bursting disc	TA (HBV)				

Item	Product certification				Remarks
	Design assessment / Approval	Raw material certificate	Examination and testing	Product certificate	
17 - Fuel pipes for gaseous hydrogen fuel with design pressure equal or lower than 10 bar (Class I or Class II), including elbows, reducers and flanges					(1) As per provisions of this Rule Note and NR467, Pt C, Ch 1, Sec 10 (2) W for Seamless pipes, C for longitudinally welded steel pipes (3) Non-destructive testing to be carried out as required by Sec 12, [1.1.6]
• Class I: single wall pipes, and ND ≥ 50 mm		C	X h ndt (1) (3)	C	
• Class II: double wall pipes, and ND ≥ 100 mm		C	X h ndt (1) (3)	C	
• Class I: single wall pipes, and ND < 50 mm		W	X h ndt (1) (3)	C/W (2)	
• Class II: double wall pipes, and ND < 100 mm		W	X h ndt (1) (3)	C/W (2)	
18 Fuel pipes for gaseous hydrogen with design pressure higher than 10 bar (Class I), including elbows, reducers and flanges. (1)					(1) For both single and double wall configuration (2) As per provisions of this Rule Note and NR467, Pt C, Ch 1, Sec 10 (3) W for Seamless pipes, C for longitudinally welded steel pipes (4) Non-destructive testing to be carried out as required by Sec 12, [1.1.6]
• ND ≥ 50 mm		C	X h ndt (2) (4)	C	
• ND < 50 mm		W	X h ndt (2) (4)	C/W (3)	
19 - Outer pipe of double wall fuel pipes (Class II) (1), including elbows, reducers and flanges.					(1) As per provisions of this Rule Note and NR467, Pt C, Ch 1, Sec 10 (2) W for Seamless pipes, C for longitudinally welded steel pipes
• ND ≥ 100 mm		C	X h ndt	C	
• ND < 100 mm		W	X h ndt	C/W (2)	
20- Raw pipes for liquefied hydrogen			X h ndt	C	
21 - Pipe fittings for liquefied hydrogen	DA		X h ndt	C	
22 - Expansion bellows	TA (1)	C (2)	X h ndt	C	(1) Prototype tests to be performed on each type of expansion bellows intended for use on gas fuel piping (2) Refer to Items 11, 12 and 13, as appropriate
23 - Liquefied hydrogen bunker hose	TA		X h ndt	C	
24 - Boil-off gas handling system (1)	TA or DA		X (2)	C	(1) See Sec 7, [5.3] (2) As per agreed program, based on the requirements of this Rule Note and/or standards recognized by the Society
25 - Inert gas generation system (1)					(1) See NR 266 Item D and relevant provisions of Sec 4, [2]
26 - Fire fighting system					(1) See NR266 Item C and relevant provisions of this Rule Note

Item	Product certification				Remarks
	Design assessment / Approval	Raw material certificate	Examination and testing	Product certificate	
27 - Gas valve unit (GVU) (1)	TA or DA		X (2)	C	(1) See Sec 3, [1.8] (2) As per agreed program, based on the requirements of this Rule Note and/or standards recognized by the Society
28 - Gas combustion unit (GCU) (1)	TA or DA		X (2)	C	(1) See Sec 7, [5.3] (2) As per agreed program, based on the requirements of this Rule Note and/or standards recognized by the Society
29 - Condensers, gasifiers or vaporizers, separators, heat exchangers, receivers, process pressure vessels, or other similar apparatus of hydrogen supply system	DA (1)	C (1)	X h ndt	C	(1) As per provisions of Sec 5. Process pressure vessels handling hydrogen are to be considered as Class I pressure vessels, in accordance with NR467, Pt C, Ch 1, Sec 3, [1.4.1] Note: Running tests - during trials of the ship
30 - Pressure regulator	TA				
31 - Mechanical joints (1) and other pipes fittings	TA(HBV) (2)	W (3)	X h ndt (4)	W (5)	(1) Mechanical joints (as per NR467, application of mechanical joints and their acceptable use for each service is depending on the class of piping, pipe dimensions, working pressure and temperature) (2) See NR467, Pt C, Ch 1, Sec 10 and this Rule Note. Mechanical joints are to be approved based on type approval procedure defined in NR467, Pt C, Ch 1, App 5. Prototype tests are to be carried out in accordance with a program agreed by the Society (3) The materials used for mechanical joints are to comply with the requirements of NR467, Pt C, Ch 1, Sec 10, [2.4.5] and this Rule Note. The manufacturer has to submit evidence to substantiate that all components are adequately resistant to the media at design pressure and temperature specified. (4) If of welded construction (5) As per conditions set in the Type Approval (TA) Note: The installation of mechanical joints is to be in accordance with the manufacturer's assembly instructions. Where special tools and gauges are required for installation of the joints, they are to be supplied by the manufacturer
32 - Gaseous hydrogen process and containment sensors, transmitters, flow meters, PT100 and PLC, Circuit breakers, Electric Cables	TA (1)		X	C/W (2)	(1) For some equipment, DA is applicable on a case-by-case basis; refer to NR266 items K and items N (2) As per conditions set in the Type Approval (TA)

Item	Product certification				Remarks
	Design assessment / Approval	Raw material certificate	Examination and testing	Product certificate	
33 - Vent lines (1)	DA	C/W (3)	X h ndt (2)	C	(1) The design pressure of the vent pipe is to be in accordance with Sec 8, [3.1.2] and Sec 9 (2) In case of welded construction. When the vent lines have welded elements, the welding procedures are to be examined (3) Depending on the class of piping as per Sec 5
34 - Fire damper	TA (1)		X ndt	C/W (2)	(1) In the case of a discrepancy between the provisions of the applicable International and National statutory regulations and those of the Society's Rules, normally the former take precedence. A valid certification to MED 2014/90/EU (or MED96/98/EC as amended for its Annex A1 items) is to be recognised for classification purpose (2) As per conditions set in the Type Approval (TA)

CHAPTER 2
HYDROGENFUEL PREPARED SHIPS

Section 1 HYDROGENFUEL-PREPARED

1 General

1.1 Application

1.1.1 The additional class notation **HYDROGENFUEL-PREPARED** is assigned, in accordance with NR467, Pt A, Ch 1, Sec 2, [6] to new ships that are designed to accommodate future installation of a hydrogen fuel system, in accordance with the requirements of this Section.

1.1.2 The additional class notation **HYDROGENFUEL-PREPARED** may be completed by one or a combination of the following notations:

A : When specific arrangements for ventilation and access to hydrogen-related spaces are already on board (see Article [4]).

B : When the original boil-off gas management method can also be used with hydrogen (see Article [8]).

HL or **HG**: When the original fuel handling equipment (pumps, heat exchangers, compressors) can also be used with hydrogen respectively in its liquefied or gaseous form (see Article [6]).

PL or **PG**: When the original piping system can also be used with hydrogen respectively in its liquefied or gaseous form (see Article [7]).

Note 1: The notations **PL** and **PG** are assigned for the whole piping system meaning that **PL** and **PG** are mutually exclusive.

S : When specific arrangements are implemented for the ship structure at the original design stage with the aim of preventing the need for specific structural modifications at the conversion stage (see [3]).

TL or **TG**: When at least one original fuel storage tank can also be used with hydrogen fuel respectively in its liquefied or gaseous form, possibly with modifications of the operational conditions of the tank at the ship conversion stage (see [5].

Example:

HYDROGENFUEL-PREPARED

HYDROGENFUEL-PREPARED (S)

HYDROGENFUEL-PREPARED (TL, HL, PL, B).

1.1.3 When the ship is effectively converted to operate on hydrogen fuel, the additional class notation **HYDROGENFUEL-PREPARED** will be replaced by the additional service feature **hydrogenfuel**, provided that all the applicable requirements of Chapter 1are complied with.

1.2 Documentation and information to be submitted

1.2.1 The plans and documents to be submitted are listed in Tab 1.

Table 1 : Documentation to be submitted

No.	I/A **(1)**	Documents
		General
1	I	General arrangement drawing of the ship showing the areas and spaces where hydrogen may be present and the associated installations, either fitted at the new construction stage or planned at a later stage, in particular: • the hydrogen bunkering station(s) • the hydrogen tank(s) • the hydrogen consumer(s), e.g. fuel cell, engine • the hydrogen boil-off management system(s) where fitted • the hydrogen fuel handling system • the hydrogen valve units • the vent mast(s) • the inert gas system. The equipment and systems installed at the new construction stage and those intended to be installed at a later stage are to be clearly identified on the drawing.

(1) A = to be submitted for approval; I = to be submitted for information

No.	I/A (1)	Documents
2	I	General specification of the contemplated hydrogen fuel installation including: • bunkering method (from terminal, bunker ship or barge, truck…) • type and capacity of the hydrogen fuel tanks, range of pressure and temperature anticipated under operational conditions • fuel cell/engine type and nominal power • boil-off management principle where relevant.
3	A	Drawing showing the hazardous areas and their classification, assuming that all hydrogen installations are fitted on board
5	A	Drawing showing the structural fire protection and cofferdams provided in connection with hydrogen installations
6	I	Longitudinal strength calculations and stability calculations covering the loading conditions assuming the hydrogen installation in ready-for-use condition
9	I	Report of HAZID analysis
10	A	Electrical balance and heat balance anticipated with the use of hydrogen as fuel
Notation **S**		
11	A	Structural drawings for the following spaces: • hydrogen bunkering station • hydrogen tank holds • hydrogen fuel preparation room • hydrogen valve unit room (where fitted).
12	I	Calculations of the local structural reinforcements in way of machinery, piping components and supports of tanks associated with the use of hydrogen as fuel
Notation **A**		
13	A	Arrangement of accesses to hydrogen-related spaces
14	A	Arrangement of the ventilation systems serving hydrogen-related spaces
Notation **TL** or **TG**		
15	I	Manufacturer's document describing the hydrogen readiness of the original tank and the modifications foreseen at a later stage
16	A	Tank material specification
17	I	Structural analysis for the tank(s) and supports as applicable
18	I	Sloshing calculation covering the full range of intended filling levels (for liquid hydrogen, if applicable)
Notation **HL** or **HG**		
19	I	Manufacturer's document describing the hydrogen readiness of the original fuel handling system and the modifications foreseen at a later stage
20	A	Justifications regarding the suitability of the concerned equipment (pumps, heat exchangers, compressors) for use with hydrogen, in particular with respect to operating characteristics, capacity and materials
Notation **PL** or **PG**		
21	I	Manufacturer's document describing the hydrogen readiness of the original fuel piping system and the modifications foreseen at a later stage
22	A	Schematic diagram and arrangement of the hydrogen (liquid and gaseous) piping systems, including venting systems
23	A	Arrangement of the venting and gas freeing system
Notation **B**		
24	I	Manufacturer's document describing the hydrogen readiness of the original boil-off vapour management system(s), in particular its capability to control the tank pressure and temperature, and the modifications foreseen at a later stage
25	I	Calculations of the boil-off rate of the tank when containing hydrogen, for the different operating conditions (maximum ambient temperature, filling rates, pressure and temperature in the tank after bunkering)
(1) A = to be submitted for approval; I = to be submitted for information		

2 General requirements

2.1 Design principles

2.1.1 The initial design of the ship is to take into account the specific characteristics of hydrogen.

2.1.2 The design of spaces intended to accommodate the hydrogen fuel tanks is to take into account the required fuel capacity to cover the operating range of the ship.

2.1.3 The additional electrical and thermal power that may be necessary to supply the hydrogen systems is to be taken into account.

2.1.4 All parts of the ship that may be in contact with hydrogen are to be made of materials compatible with hydrogen.

2.1.5 An HAZID analysis is to be conducted to ensure that the risks arising from the use of hydrogen fuel are addressed. Loss of function, system damage, spillage of liquid hydrogen or release of hydrogen vapours, fire and explosion are, as a minimum, to be considered. The results of the HAZID are to be implemented in the design of the hydrogen systems.

2.2 General arrangement

2.2.1 The initial design of the ship is to take into account the necessary spaces or zones to accommodate the future installation of the following hydrogen installations:

a) Bunkering station

b) Hydrogen fuel tanks

c) Fuel handling and supply system

d) Boil-off management system, where required

e) Ventilation systems (independent systems)

f) Valve units

g) Venting and gas freeing system

h) Inert gas system.

2.2.2 The arrangement and location of hydrogen-related spaces are to comply with the provisions of Chapter 1.

2.2.3 The space below deck or the area above deck where the hydrogen storage tanks will be installed are to comply with the requirements for protective location of the tank given in Ch 1, Sec 3.

2.2.4 The hazardous / non-hazardous area classification of hydrogen-related spaces and areas is to be defined in accordance with the provisions of Ch 1, Sec 10, [2.2].

2.3 Ship structure and stability

2.3.1 The ship stability is to be assessed for preliminary loading conditions, assuming the hydrogen installation in ready-for-use condition, and to comply with the relevant provisions of Chapter 1. The relevant loads are to be stated.

2.3.2 The longitudinal strength of the ship is to be assessed, assuming the hydrogen installation in ready-for-use condition, and to comply with the relevant provisions of Chapter 1.

2.4 Machinery

2.4.1 All installations and equipment necessary for the ship to operate on hydrogen and that are fitted to the ship at the new construction stage are to comply with the relevant provisions of this Chapter 1.

3 Additional requirements for notation S

3.1 General

3.1.1 In addition to complying with the provisions of Article [2], ships having the notation S are to comply with the requirements of this Article.

3.1.2 The structural arrangements and reinforcements in way of machinery, piping components and supports of tanks associated with the use of hydrogen as fuel are to be implemented at the new construction stage with the aim of preventing the need for specific structural modifications at a later stage.

4 Additional requirements for notation A

4.1 Application

4.1.1 In addition to complying with the provisions of Article [2], ships having the notation **A** are to comply with the requirements of this Article.

4.2 Access

4.2.1 The access to hydrogen-related spaces is to comply with the provisions of Ch 1, Sec 3. Where required, airlocks are to be provided.

4.3 Ventilation

4.3.1 The ship ventilation is to be arranged in accordance with the provisions of Ch 1, Sec 4, [1] in particular regarding the separation between the ventilation systems serving hydrogen-related spaces and those serving other spaces.

4.3.2 Ventilation systems are to be fitted with all necessary locations sized for ventilators compatible with the requirements of [4]. Such ventilators need not be installed at new construction stage.

5 Additional requirements fro notation TL and TG

5.1 General

5.1.1 In addition to complying with the provisions of Article [2], ships having the notation **TL** or **TG** are to be provided with tanks suitable for liquid, or gaseous, hydrogen, as per [5.2] or [5.3]. The operational conditions of the tank (e.g. operating pressure or maximum filling level) may however be modified at a later stage.

5.2 Design of the liquefied hydrogen fuel tank

5.2.1 Material compatibility

The original tank is to be made of a material complying with the provisions of Ch 1, Sec 5.

5.2.2 Scantlings

The scantlings of the original tank is to take into account the static and dynamic loads on the tank structure due to liquid hydrogen, the maximum expected service pressure and, where applicable, the sloshing loads for the full range of intended filling levels.

5.2.3 Tank connections

The diameter of the tank connections is to be sufficient to allow the required flow rates, taking into account the energy density of hydrogen and the permissible velocity.

The tank is to be fitted, at the new construction stage, with all the connections necessary for operation with hydrogen. In particular, where deemed necessary, a vapour return connection is to be fitted.

5.2.4 Pumps

Where original submerged pumps need to be replaced at a later stage, the corresponding parts of the tank (such as tank opening and pump supporting arrangements) are to be designed for the expected size of the hydrogen pump.

5.2.5 Instrumentation

The tank is to be fitted, at the new construction stage, with all the necessary penetrations for the instrumentation relevant to hydrogen operation.

5.3 Design of the gaseous hydrogen fuel tank

5.3.1 Material compatibility

The original tank is to be made of a material complying with the provisions of Ch 1, Sec 5.

5.3.2 Scantlings

The scantlings of the original tank is to take into account the load on the tank structure due to hydrogen, including the maximum expected service pressure.

5.3.3 Tank connections

The diameter of the tank connections is to be sufficient to allow the required flow rates, taking into account the energy density of hydrogen and the permissible velocity.

The tank is to be fitted, at the new construction stage, with all the connections necessary for operation with hydrogen.

5.3.4 Instrumentation

The tank is to be fitted, at the new construction stage, with all the necessary penetrations for the instrumentation relevant to hydrogen operation.

6 Additional requirements for notation HL or HG

6.1 General

6.1.1 In addition to complying with the provisions of [2], ships having the notation **HL** or **HG** are to be provided with a fuel handling system that is also suitable for use with liquid, or gaseous, hydrogen, as per [6.2] or [6.3].

6.2 Design of the liquefied hydrogen fuel handling system

6.2.1 Design parameters

The fuel handling system intended for hydrogen is to be designed for the pressure and temperature conditions and the required flow rate at the consumer inlet.

The capacity of the fuel handling system is to take into account the characteristics of hydrogen, in particular its volumetric energy density, heat of vaporization and heat capacity.

6.2.2 Material compatibility

The components of the fuel handling system are to be made of materials complying with the provisions of Ch 1, Sec 5.

6.3 Design of the gaseous hydrogen fuel handling system

6.3.1 Design parameters

The fuel handling system intended for hydrogen is to be designed for the pressure and temperature conditions and the required flow rate at the consumer inlet.

The capacity of the fuel handling system is to take into account the characteristics of hydrogen, in particular its volumetric energy density and heat capacity.

6.3.2 Material compatibility

The components of the fuel handling system are to be made of materials complying with the provisions of Ch 1, Sec 5.

7 Additional requirements for notation PL or PG

7.1 General

7.1.1 In addition to complying with the provisions of Article [2], ships having the notation **PL** are to be provided with a fuel piping system also suitable for use with liquefied hydrogen and gaseous hydrogen downstream of the vaporization stage as per [7.2].

7.1.2 In addition to complying with the provisions of Article [2], ships having the notation **PG** are to be provided with a fuel piping system also suitable for use with gaseous hydrogen, as per [7.2].

7.2 Design of the hydrogen piping system

7.2.1 The piping system intended for hydrogen is to be designed for the pressure and temperature conditions expected in the different parts of the system.

7.2.2 Pipe diameters are to be suitable for the maximum expected flow rates, taking into account the energy density of hydrogen and the maximum allowable velocity.

7.2.3 The piping system is to be comply with the provisions of Ch 1, Sec 9 as relevant.

7.2.4 Material compatibility

Materials used for pipes (including the enclosing duct or pipe), valves and fittings are to comply with the provisions of Ch 1, Sec 5.

8 Additional requirements for notation B

8.1 General

8.1.1 In addition to complying with the provisions of Article [2], ships having the notation **B** are to be provided with a boil-off gas management system suitable for use with hydrogen, as per [8.2] to [8.4].

8.2 Design of the pressure accumulation method

8.2.1 The capability of the pressure accumulation method to maintain tank pressure below the set pressure of the tank pressure relief valves for a period of 15 days is to be justified considering the characteristics of hydrogen.

8.3 Design of the hydrogen combustion unit (thermal oxidizer)

8.3.1 The combustion unit (thermal oxidizer) is to be designed to ensure complete burning of hydrogen for the full ranges of pressures, temperatures and flow rates of the hydrogen boil-off vapours.

8.3.2 Some components such as the burner, combustion fans, igniters, pilot burner or flame scanning system may be modified or replaced at a later stage.

8.3.3 Materials used for the different parts of the combustion unit or boiler, including piping, valves and fittings are to comply with the provisions of Ch 1, Sec 5.

8.4 Design of the refrigerating system

8.4.1 The refrigerating system is to be designed so that it will provide adequate refrigerating capacity for the hydrogen liquid or vapours in the storage tanks to control its pressure.

8.4.2 Materials used for the different parts of the refrigerating unit, including piping, valves and fittings are to comply with the provisions of Ch 1, Sec 5.

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