सत्यमेव जयते
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पत्तन, पोत परिवहन और जलमार्ग मंत्रालय
MINISTRY OF PORTS, SHIPPING AND WATERWAYS
नौवहन महानिदेशालय, मुंबई
DIRECTORATE GENERAL OF SHIPPING, MUMBAI

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File No: 13-11014/3/2023-O/o ENGG - DGS **Date : 02.05.2023**

Merchant Shipping Notice 06 of 2023

Subject: Interim Requirements for Ships carrying Liquefied Hydrogen.

1. Noting that India has set its sight on becoming energy independent by 2047 and achieving Net Zero by 2070. To achieve this target, increasing renewable energy use across all economic spheres is central to India's Energy Transition. Green Hydrogen is considered a promising alternative for enabling this transition.
2. Recognizing that the National Green Hydrogen Mission was approved by the Union Cabinet on 4 January 2022, with an aim of making India a hub for the production and export of green hydrogen.
3. Noting that one of the key sub-components of this Mission is to support pilot projects in emerging end-use sectors and production pathways.
4. Also Noting "Niti Aayog" report "Harnessing Green Hydrogen" that India's distinct advantage in low-cost renewable energy generation makes green hydrogen the most competitive form of hydrogen in the long run and it enables India to potentially be one of the most competitive producers of green hydrogen in the world. Green hydrogen can achieve cost parity with natural gas-based hydrogen (grey hydrogen) by 2030, if not before.
5. Noting also that "Getting to Zero Coalition" has recognized that the use of zero emission fuels in shipping will be built, in part, on the back of new global hydrogen supply chains and for this to happen, the right infrastructure would need to be in place.

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6. Recognizing that above necessitates building ships to move liquid hydrogen in large volume over large distances and thus there is need to pilot such projects.
7. Noting that IMO has issued "Interim Recommendations for Hydrogen carriers vide MSC 420(97) for application to pilot projects" and Cargo Carriage and Container sub-committee of IMO is working on developing this further with the experience gained from pilot projects.
8. Taking all the above the guidelines for building Hydrogen Carrier is now attached as an Annexure to this Notice and the work of CCC Sub-committee shall be followed to make necessary changes in these requirements as and when required and rules shall be prepared once the regulations are formulated at IMO.
9. **General Requirements**

9.1. The SOLAS Convention and the International Code for the Construction and Equipment of Ships carrying Liquefied gases in bulk (IGC Code) currently do not provide specific requirements for carriage of Liquefied Hydrogen.

9.2. Paragraph 5 of Preamble of the IGC Code states that requirements for new products and their conditions of carriage will be circulated as recommendations, on an interim basis, prior to the entry into force of the appropriate amendments.

9.3. Paragraph 1.1.6.1 of the IGC Code specifies that for carriage of such new products, the Administration and the Port Administrations involved should establish a Tripartite Agreement based on a provisional assessment and lay down conditions of carriage. The Interim recommendations of the IMO are intended to facilitate establishment of a tripartite agreement for a pilot ship.

9.4. The Interim recommendations provide guidance on Chapter 19 of the IGC Code regarding general requirements for application to the carriage of Liquefied Hydrogen as well as provide special requirements, related hazards and explanations.

9.5. Indian flag ships constructed or modified to carry exclusively liquefied hydrogen in bulk are to comply with the annex to IMO interim recommendations MSC.420 (97) as appended herewith and the IGC Code.

9.6. Ship-owners intending to operate Indian flag ships for transport of liquefied hydrogen between specific ports should contact the Directorate General of Shipping and the relevant Port authorities well in advance for working out the modalities for signing a tripartite agreement as mentioned in para 9.3 above.

9.7. It is to be noted that application of these interim requirements will be considered for a specific pilot project ship which is subject to study and research and feedback from the experience gained may be submitted to IMO for development of amendments to the IGC Code.

10. This is issued with the approval of the Director General of Shipping in the rank of Secretary to the Govt. of India.

Sd/-
(Vikrant Rai)
E&SS-cum-DDG(Tech.)

To,

(i) All stakeholders through DG Shipping website.
(ii) Computer cell for placing this MS Notice at DGS website.
(iii) AD (OL) for Hindi version.

ANNEXURES TO MS Notice 06 of 2023

INTERIM RECOMMENDATIONS FOR CARRIAGE OF LIQUEFIED HYDROGEN IN BULK

1 INTRODUCTION

1.1 For the carriage of liquefied gases in bulk by ships, the ships should comply with the relevant requirements in the IGC Code, as amended by resolution MSC.370 (93) ("the Code"). The scope of the Code provided in paragraph 1.1.1 is:

"The Code applies to ships regardless of their size, including those of less than 500 gross tonnage, engaged in the carriage of liquefied gases having a vapour pressure exceeding 0.28 MPa absolute at a temperature of 37.8°C, and other products, as shown in chapter 19, when carried in bulk".

1.2 A ship carrying liquefied hydrogen in bulk (hereinafter called "liquefied hydrogen carrier") should comply with the Code.

1.3 The Code requires that a gas carrier should comply with the minimum requirements for the cargo listed in chapter 19. However, the requirements for liquefied hydrogen are not specified in the Code.

1.4 This annex provides the interim recommendations, as referred to in paragraph 5 of the preamble of the Code, for the carriage of liquefied hydrogen in bulk, which are intended to provide the basis for the future minimum requirements for the carriage of this cargo.

1.5 These recommendations have been developed under the assumption that a liquefied hydrogen carrier does not carry liquefied gases other than liquefied hydrogen. These recommendations, therefore, are not applicable to liquefied hydrogen carriers carrying gases other than liquefied hydrogen.

1.6 In the Code, reference is made to paragraph 5 of the Preamble; paragraph 1.1.6.1; and Note No.8 on completion of certificate in "model form of international certificate of fitness for the carriage of liquefied gases in bulk" in appendix 2 to the Code.

2 INTERIM RECOMMENDATIONS FOR CARRIAGE OF LIQUEFIED HYDROGEN IN BULK

2.1 The Interim Recommendations for the carriage of liquefied hydrogen in bulk have been developed based on the results of a comparison study of similar cargoes listed in chapter 19 of the Code, e.g. liquefied natural gas.

2.2 In the Code, chapter 19 governs the application of general requirements for respective cargoes. Selections of the general requirements for respective cargoes are expressed in columns 'c' to 'g'. In addition to general requirements, special requirements may apply to specific cargoes depending on the properties/hazards of the cargoes.

2.3 Tables 1 and 2 specify the proposed selection of the general requirements and the special requirements, respectively, for liquefied hydrogen.

Table 1: Interim Recommendations for carriage of liquefied hydrogen in bulk

a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*
Product name		**Ship type**	**Independent tank type C required**	**Control of vapour space within cargo tanks**	**Vapour detection**	**Gauging**		**Special requirements**
Hydrogen		2G	-	-	F	C		See table 2

Table 2: Special Requirements for carriage of liquefied hydrogen in bulk

No.	Special Requirement	Related hazard
1	Requirements for materials whose design temperature is lower than -165°C should be agreed with the Administration, paying attention to appropriate standards. Where minimum design temperature is lower than -196°C, property testing for insulation materials should be carried out with the appropriate medium, over a range of temperatures expected in service.	Low temperature (see 4.2.1)
2	Materials of construction and ancillary equipment such as insulation should be resistant to the effects of high oxygen concentrations caused by condensation and enrichment at the low temperatures attained in parts of the cargo system (refer to the requirement for nitrogen).	Low temperature (see 4.2.2)

3	For cargo pipes containing liquid hydrogen and cold hydrogen vapour, measures should 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 cargo 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. Insulation on liquid hydrogen piping systems exposing to air should be of non-combustible material and should be designed to have a seal in the outer covering to prevent the condensation of air and subsequent oxygen enrichment within the insulation.	Low temperature (see 4.2.2)
4	Appropriate means, e.g. filtering, should be provided in cargo piping systems to remove impure substances condensed at low temperature.	Low temperature (see 4.2.3)
5	Pressure relief systems should be suitably designed and constructed to prevent blockage due to formation of water or ice.	Low temperature (see 4.2.4)
6	At places where contact with hydrogen is anticipated, suitable materials should be used to prevent any deterioration owing to hydrogen embrittlement, as necessary.	Hydrogen embrittlement (see 4.3)
7	All welded joints of the shells of cargo tanks should be of the in-plane butt weld full penetration type. For dome-to-shell connections only, tee welds of the full penetration type may be used depending on the results of the tests carried out at the approval of the welding procedure.	Permeability (see 4.4.1)
8	Double tube structures ensuring no leakage, or fixed hydrogen detectors being capable of detecting a hydrogen leak, should be provided for places where leakage of hydrogen may occur, such as cargo valves, flanges, and seals.	Permeability (see 4.4.2)
9	Helium or a mixture of 5% hydrogen and 95% nitrogen should be used as the tightness test medium for cargo tank and cargo piping.	Permeability (see 4.4.3)
10	The amount of carbon dioxide carried for a carbon dioxide fire-extinguishing system should be sufficient to provide a quantity of free gas equal to 75% or more of the gross volume of the cargo compressor and pump rooms in all cases.	Fire by Hydrogen (see 4.7.3) Wide range of flammability limits (see 4.10)
11	When deterioration of insulation capability by single damage is possible, appropriate safety measures should be adopted taking into account the deterioration.	High pressure (see 4.8)
12	When vacuum insulation is used for a cargo containment system, the insulation performance should be evaluated to the satisfaction of the Administration based on experiments, as necessary.	General (see 4.1)

13	Appropriate measures should be provided to prevent vents becoming blocked by accumulations of ice formed from moisture in the air.	Low temperature (see 4.2.2)
14	Due consideration should be given to means for handling boil-off gas.	High pressure (see 4.8)
15	Due consideration should be given to static electricity associated with rotating or reciprocating machinery including the installation of conductive machinery belts and precautionary measures incorporated in operating and maintenance procedures. Anti-static clothing and footwear, and a portable hydrogen detector should be provided for each crew member working in the cargo area.	Static electricity (see 4.9.2)
16	An operation manual for a liquefied hydrogen carrier should include limitations of various operations in relation to environmental conditions.	Wide range of flammability limits (see 4.10)
17	An appropriate procedure should be established for warm-up, inert gas purge, gas-free, hydrogen purge and pre-cooling. The procedure should include: a) Selection of inert gas in relation to temperature limit; b) Measurement of gas concentration; c) Measurement of temperature; d) Rates of supply of gases; e) Conditions for commencement, suspension, f) resuming and termination of each operation; g) Treatment of return gases; and h) Discharge of gases.	Prevention of dangerous purging operation (see 4.11)
18	Only almost pure para-hydrogen (i.e. more than 95%) should beloaded in order to avoid excessive heating by ortho- to para-hydrogen conversion.	General (see 4.1)
19	Fire detectors for detecting hydrogen fire should be selected after due deliberation, taking into account the features of hydrogen fire, to the satisfaction of the Administration.	Features of hydrogen fire (see 4.7.4)
20	At the design stage, dispersion of hydrogen from vent outlets should 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 should be considered based on the results of the analysis.	Low density and high diffusivity (see 4.5)
21	Due consideration should be given to appropriate safety measures to prevent formation of explosive mixture in the case of a leakage of hydrogen, including: a) Installation of hydrogen detectors in order to detect a possible ground-level travel of low temperature	General (see 4.1)

	hydrogen gas, and at high points in spaces where warm hydrogen gas can be trapped; and b) Application of "best practice" for land-based liquid hydrogen storage taking into account appropriate guidance such as "Cryogenics Safety Manual – Fourth Edition (1998)"8).	
22	In the case that fusible elements are used as a means of fire detection required by paragraph 18.10.3.2 of the Code, flame detectors suitable for hydrogen flames should be provided in addition at the same locations. Appropriate means should be adopted to prevent the activation of ESD system owing to false alarm of flame detectors, e.g. avoiding activation of ESD system by single sensor (voting method).	Fire hazard (see 4.7.4)
23	Consideration should be given to enhance the ventilation capacity of the enclosed spaces subject to liquefied hydrogen leakage, taking into account the latent heat of vapourization, specific heat and the volume of hydrogen gas in relation to temperature and heat capacity of adjacent spaces.	Low density and high diffusivity (see 4.5)
24	Liquid and gas hydrogen pipes should not pass through enclosed spaces other than those referred to in paragraph 5.2.2.1.2 of the Code, unless: a) The spaces are equipped with gas detection systems which activate the alarm at not more than 30% LFL and shut down the isolation valves, as appropriate, at not more than 60% LFL (see sections 16.4.2 and 16.4.8 of the Code); and b) The spaces are adequately ventilated; or c) The spaces are maintained in an inert condition. This requirement is not applicable to spaces constituting a part of a cargo containment system using vacuum insulation where the degree of vacuum is monitored.	Permeability (see 4.4)
25	A risk assessment should be conducted to ensure that risks arising from liquefied hydrogen cargo affecting persons on board, the environment, the structural strength or the integrity of the ship are addressed. Consideration should be given to the hazards associated with properties of liquefied hydrogen and hydrogen gas, physical layout, operation and maintenance, following any reasonably foreseeable failure. For the risk assessment, appropriate methods, e.g. HAZID, HAZOP, FMEA/FMECA, what-if analysis, etc., should be adopted taking into account	General (see 4.1)

	IEC/ISO 31010:2009 "Risk management – Risk assessment techniques"7) and SAE ARP 5580-2001 "Recommended failure modes and effects analysis (FMEA) practices for non-automobile applications"9).	
26	Relief valve sizing should be undertaken for the most onerous scenario. Whether this scenario is brought into existence due to fire or by loss of vacuum from the overall insulation system should be assessed and the resulting magnitude of the heat flux on the containment system considered in each case.	High pressure hazard (see 4.8)
27	A filling limit exceeding 98% at reference temperature should not be permitted.	High pressure hazard (see 4.8)
28	Bolted flange connections of hydrogen piping should be avoided where welded connections are feasible.	Permeability (see 4.4.2)
29	Due consideration should be given to the invisible nature of hydrogen fire.	Fire hazard (see 4.7.1)

3 EXPLANATIONS ON GENERAL REQUIREMENTS

3.1 Properties of liquefied hydrogen

The application of general requirements in the Code for liquefied hydrogen has been considered based on a comparison study on the physical properties of liquefied hydrogen and LNG. LNG and liquefied hydrogen are cryogenic liquids, non-toxic, and generate flammable high pressure gas. For reference, table 3 shows the comparison of physical properties of hydrogen and methane, the major component of LNG.

Table 3: Comparison of physical properties of Hydrogen and Methane

	Hydrogen	Methane	References
Boiling temperature(K)*	20.3	111.6	ISO[1)],AnnexA,TableA.3
Liquid density(kg/m^3)*	70.8	422.5	ISO[1)],AnnexA,TableA.3
Gas density(kg/m^3)**(Air:1.198)	0.084	0.668	NISTRefProp[10)]
Viscosity(g/cm•sx10^{-6}) Gas Liquid	8.8 13.49	10.91 116.79	NISTRefProp[10)] NISTRefProp[10)]
Flame temperature in air(°C)	2396	2230	Calculated using Cantera and GRI 3.0 mechanism
Maximum burning velocity(m/s)	3.15	0.385	Calculated using Cantera and GRI 3.0 mechanism
Heat of vapourization (J/g)*	448.7	510.4	ISO[1)],AnnexA,TableA.3
Lower flammability limit (%vol. fraction)***	4.0	5.3	ISO[1)],AnnexB,TableB.2

Upper flammability limit (% vol. fraction)***	75.0	17.0	ISO[1),AnnexB,TableB.2
Lower detonation limit (%vol. fraction)***	18.3	6.3	ISO[1),AnnexB,TableB.2
Upper detonation limit(%vol. fraction)***	59.0	13.5	ISO[1),AnnexB,TableB.2
Minimum ignition energy(mJ)***	0.017	0.274	ISO[1),AnnexB,TableB.2
Auto-ignition temp.(°C)***	585	537	ISO[1),AnnexB,TableB.2
Toxicity	Non	Non	Orangebook[5)
Temperature at critical point(K)	33.19****	190.55	Hydrogen:ISO[1), Annex A, Table A.1 Methane: The Japan Society of Mechanical Engineers, Data Book, Thermo physical Properties of Fluids(1983)
Pressure at critical point(kPaA)	1297****	4595	Hydrogen:ISO[1),Annex A, Table A.1 Methane: The Japan Society of Mechanical Engineers, Data Book, Thermo physical Properties of Fluids(1983)

Remarks:
- * At their normal boiling points for comparison purpose.
- ** At normal temperature and pressure.
- *** Ignition and combustion properties for air mixtures at 25°C and 101.3 kPaA.
- **** Normal Hydrogen.

3.2 Explanation on respective requirements

3.2.1 Ship type (column 'c')

As a result of the studies, the following points were noted in relation to ship type allocated in the Code:

Type 1G is allocated only to dangerous goods of class 2.3* in the International Maritime Dangerous Goods Code, but not to class 2.2 and class 2.1;

Type 2G and type 2PG are allocated mainly to non-toxic flammable gases of class 2.1; and

3.2.2 Type 3G is allocated only to non-flammable and non-toxic gases of class 2.2.

"Type 2PG" is not applicable to liquefied hydrogen for the reason that the design temperature is lower than -55°C. Taking into account that liquefied hydrogen is a class 2.1 dangerous good, it is appropriate to allocate "type 2G" to liquefied hydrogen.

3.2.3 Independent tank type C required (column 'd')

Independent tank type C is allocated only to dangerous goods of class 2.3 whose vapour density is heavier than air. Independent tank type C is considered not to be required for liquefied hydrogen.

3.2.4 Control of vapour space within cargo tank (column 'e')

Special environment controls such as drying and inserting are generally required for liquid chemical products in consideration of the reactivity of cargo vapour and air. As is the case for LNG, I t is considered not to be necessary to apply such requirements for liquefied hydrogen.

3.2.5 Vapour detection (column'f')

Because hydrogen is flammable and non-toxic, it is appropriate to require Flammable (F) as vapour detection for liquefied hydrogen.

3.2.6 Gauging (column'g')

On the grounds that Closed (C) gauging is required, in principle, for flammable or toxic cargoes, such as methane, it is considered to be appropriate to require Closed(C) gauging for hydrogen, taking into account that hydrogen has high ignitability and a wide flammable range in air and that closed gauging is effective to prevent leakage of gases into air.

4. Special requirements against hazards of liquefied hydrogen

4.1 Hazards of liquefied hydrogen to be considered

4.1.1 The hazards related to liquefied hydrogen are low ignition energy, a wide range of flammability limits, low visibility of flames in case of fire, high flame velocity which may lead to the detonation with shockwave, low temperature and liquefaction/solidification of inert gas and constituents of air which may result in an oxygen-enriched atmosphere, high permeability, low viscosity, and hydrogen embrittlement including weld metals. Where vacuum insulation is adopted, due consideration should be given to the possibility of untimely deterioration of insulation properties at the envisaged carriage temperatures of liquid hydrogen. The vacuum insulation evaluation should be specified for the normal range or upper limit of cold vacuum pressure (CVP), and loss of vacuum should be defined with respect to this value. Accordingly, effect of vacuum pressure should be taken into account at the time of design and testing of cargo containment systems and piping. Supporting structure and adjacent hull structure should be designed taking into account the cooling owing to loss of vacuum insulation.

*Toxic and flammable gases are classified as class 2.3 with subsidiary class 2.1.

4.1.2 Hydrogen is essentially a mixture of ortho- and para-hydrogen, with an equilibrium concentration of 75% ortho-hydrogen and 25% para-hydrogen at ambient temperature. When liquefied at 20K, there is a slow but continuous transformation of ortho-hydrogen to para-hydrogen. The exothermic conversion of the nuclear spin isomers of hydrogen (ortho- to para-hydrogen) may take place and the effect of the conversion may have an impact on the cooling capacity and relief valve capacity of the vessel's equipment.

4.1.3 For consideration on the special requirements for liquefied hydrogen carriers, bibliographic studies were conducted using the references at the end of this document, in particular, ISO/TR 15916, "High Pressure Gas Safety Act"1) (Japanese law), "Safety standard for hydrogen and hydrogen system" by AIAA2) and NFPA 2 "Hydrogen Technologies Code"6).The majority of special requirements for liquefied hydrogen carriers are provided based on ISO/TR 15916. This standard refers to liquefied hydrogen tank storage facilities on shore, tank trucks and so on, and includes basic viewpoints when discussing the properties of liquefied hydrogen.

4.1.4 Trace amounts of air will condense or solidify in an environment with liquid hydrogen possibly resulting in an unstable and explosive mixture. Precautions should be taken to assure that the possibility of condensed air is accounted within properly secured hazard areas.

4.2 Low temperature hazard

4.2.1 Selection of appropriate material

4.2.1.1 Tables 6.3 and 6.4 in the Code prescribe material selection for piping or cargo tanks whose design temperature is -165°C or higher. According to Note 2 of table 6.3 and Note 3 of table 6.4 of the Code, the requirements for materials whose design temperatures are lower than -165°C should be specially agreed with the Administration. In this regard, the publication by AIAA2) introduces some appropriate materials corresponding to the design temperature and the Administration should take into account such references for the material selection.

4.2.1.2 Although paragraph 4.19.3 in the Code requires testing of materials used for thermal insulation for various properties adequate for the intended service temperature, the minimum test temperature is -196°C. The requirements in the Code do not refer to the normal boiling point of hydrogen, being -253°C. In case of carriage of liquefied hydrogen, special requirements should be provided to consider the lower design temperature.

4.2.2 Measures for condensed air

4.2.2.1 In the case of nitrogen whose normal boiling point is -196°C, for which air condensation and oxygen enrichment are concerns, the following special requirement has already been included in paragraph 17.17 in the Code: "Material of construction and ancillary equipment such as insulation shall be resistant to the effect of high oxygen concentrations caused by condensation and enrichment at the low temperatures attained in parts of the cargo system. Due consideration shall be given to ventilation in such areas where condensation might occur to avoid the stratification of oxygen-enriched atmosphere."

A similar special requirement is applicable to hydrogen.

4.2.2.2 A vent may be blocked by accumulation of ice formed from moisture in the air, which may result in excessive pressure leading to rupture of the vent and relevant piping (see paragraph 4.2.4).

4.2.3 Removal of impure substances condensed

The removal of impure substances, such as those contained in condensate in pipes, should be separately considered. Installation of filters can be an appropriate measure and should be stipulated as a special requirement.

4.2.4 Prevention of blockage due to formation of water or ice

Pressure relief systems may become blocked due to formation of water or ice, depending on the temperature and humidity of air, resulting from the low temperature of the cargo and its vapour (see paragraph 4.2.2). Appropriate means should be provided to prevent such phenomena.

4.3 Hydrogen embrittlement

4.3.1 Selection of appropriate materials should be required to prevent failures owing to hydrogen embrittlement. The publication by AIAA2) introduces some appropriate materials resistant to hydrogen embrittlement, and concludes that aluminium is the material least affected.

4.3.2 International or national standards should be followed for the selection of materials for the design of liquefied and gaseous hydrogen installations in a marine environment.

4.4 Permeability

4.4.1 Prevention of leakage from cargo tanks

To mitigate leakage of hydrogen, it is deemed appropriate to require "butt weld full penetration" type welds, regardless of tank types, taking into account the high permeability of hydrogen. Furthermore, dome-to-shell connections welds and nozzle welds should be designed with full penetration regardless of tank types, taking into account paragraphs 4.20.1.1 and 4.20.1.2 of the Code.

4.4.2 Prevention of leakage from pipes

To mitigate undetected accumulation of hydrogen in a confined space, effective measures should be employed to reduce the possibility of leakage of hydrogen, taking its high permeability into account. Effective measures can be double tube structures, or fixed hydrogen leak detectors in areas assessed as being highly hazardous with regard to hydrogen leakage. Hydrogen leakage through welds, joints and seals is an important consideration for the design of hydrogen systems and an important operational issue.

4.4.3 Implementation of effective tightness test

4.4.3.1 Tightness tests for cargo tanks and cargo pipes/valves are required by paragraphs 4.20.3.2, 5.13.1 and 5.13.2.3 in the Code respectively. Helium or a mixture of 5% hydrogen and 95% nitrogen should be used as the medium for tightness tests, instead of air, because the permeability of hydrogen is high.

4.4.3.2 For a hydrogen installation, the pipe work should be pressure-tested at its design pressure. Consideration should be given to using oxygen-free nitrogen with a small molecule tracer gas, such as helium as the test medium and an electronic leak detector for identifying leaks.

4.4.4 Confirmation of appropriate operating procedure

Instructions/manuals containing the operating procedures for the prevention of leakage during transport, methods for early detection in case of leakage, and appropriate measures after such events, should be provided. For this, paragraph 18.3 of the Code requires that the information shall be on board and available to all concerned, giving the necessary data for the safe carriage of cargo. In detail, the Code requires such information on action to be taken in the event of spills or leak, countermeasures against accidental personal contact, procedures for cargo transfer, and emergency procedures to be on board. With regard to the manuals on procedures for liquefied hydrogen during carriage and transfer operations, the requirements in the Code are applicable and no special requirement is necessary.

4.5 Low density and high diffusivity

Though low density and high diffusivity of hydrogen may reduce the possibility of formation of a flammable atmosphere in open spaces, adequate ventilation is necessary for enclosed spaces in cargo areas where formation of hydrogen-oxygen/air mixture may occur. Paragraph 12.2 of the Code requires fixed ventilation systems or portable mechanical ventilation for such enclosed spaces. These requirements in the Code are applicable to liquefied hydrogen carriers and no special requirement is necessary in this regard.

4.6 Ignitability

4.6.1 The Code requires electrical bonds of the piping and the cargo tanks in paragraph 5.7.4, exclusion of all sources of ignition in paragraph 11.1.2, electrical installations to minimize the risk of fire and explosion from flammable products in paragraph 10.2.1 and so on, in order to prevent ignition of flammable cargoes.

4.6.2 The Code requires compliance with the relevant standards issued by the International Electro technical Commission (IEC) and the IEC standards specify the details of such safety measures depending on the respective properties of flammable gases including hydrogen. No special requirement is necessary with regard to ignitability of hydrogen*.

4.7 Fire hazard

4.7.1 Safety of personnel in case of fire

To avoid the effects of flame and UV radiation produced by a hydrogen fire, it is effective to use fire-fighter's outfits and protective equipment. The Code already requires fire-fighter's outfits or ships carrying flammable products in paragraph 11.6.1 and safety equipment in paragraph 14.3. This issue should be considered as the matter of cargo information required by paragraph 18.3 of the Code. Due consideration should be given to the invisible nature of hydrogen fire.

* Electrical equipment used in hydrogen/air mixture should be, at least, the type of "II-C" and "T-1" as the group based on the maximum experimental safe gap for flameproof enclosures and the temperature class based on maximum surface temperature, respectively, according to IEC 60079-20-14).

4.7.2 Compatibility of fire-extinguishing systems

Dry chemical powder fire-extinguishing or carbon dioxide fire-extinguishing systems are considered to be effective in case of hydrogen fire and such fire-extinguishing systems are already required by paragraphs 11.4 and 11.5 of the Code. Special requirements for installation of other types of fire-extinguishing systems are considered unnecessary, except with regard to the increased of amount of carbon dioxide required, as mentioned in the next paragraph in this document.

4.7.3 Increase of the amount of gas for carbon dioxide fire-extinguishing systems

4.7.3.1 Paragraph 11.5.1 of the Code requires as follows:
"Enclosed spaces meeting the criteria of cargo machinery spaces in 1.2.10, and the cargo motor room within the cargo area of any ship, shall be provided with a fixed fire-extinguishing system complying with the provisions of the FSS Code and taking into account the necessary concentrations/application rate required for extinguishing gas fires."

4.7.3.2 Chapter 5 of the FSS Code, i.e. Fixed gas fire-extinguishing systems, requires that the quantity of carbon dioxide for cargo spaces, unless otherwise provided, shall be sufficient to give a minimum volume of free gas equal to 30% of the gross volume of the largest cargo space to be protected in the ship, in paragraph 2.2.1.1.

4.7.3.3 On the other hand, NFPA 123) requires that the design quantity of carbon dioxide for hydrogen fire should be 75% or more of the gross volume of the protected space. The special requirement for an increased amount of carbon dioxide should be provided for carbon dioxide fire-extinguishing systems.

4.7.4 Features of hydrogen fire

Hydrogen burns at high temperature, but generally gives off less radiant heat than propane or other hydrocarbons (e.g. only about 10% of that radiated by an equal-sized propane flame). Although the heat radiated by a hydrogen flame is also relatively low compared to hydrocarbons, it is important to take into account the differences in heats of combustion, burning rate and flame size. Hydrogen flames are colourless or nearly colourless. Both of these characteristics make it more difficult to detect a hydrogen fire. Even relatively small hydrogen fires are very difficult to extinguish. The only reliable approach to extinguish a fire is to shut off the source of hydrogen supply.

4.8 High pressure hazard

4.8.1 High pressure is a hazard common to hydrogen and other flammable gases listed in the Code. To prevent overpressure, the Code requires various measures such as pressure control and pressure design. Specifically, paragraph 8.2, in regard to the provision of pressure control of cargo tanks, requires fittings of pressure relief valves to the cargo tanks. Furthermore, paragraph 7.1.1 requires temperature control by the use of mechanical refrigeration and/or design to withstand possible increases of temperature and pressure. In addition, paragraph 15.2 specifies the filling limit of cargo tanks taking into account cargo volume increase by its thermal expansion. These requirements are applicable for hydrogen and no special requirement is considered necessary in this regard.

4.8.2 Vacuum insulation systems are likely to be used for liquefied hydrogen containment systems and the insulation capability of such systems may be adversely affected by damage to the system, depending on the design of the system. If a rapid deterioration of the insulation system took place, rapid increase of temperature in the cargo tank would occur and/or the rate of vapourization of liquefied hydrogen might exceed the capacity of pressure relief valves. To prevent such dangerous deterioration of insulation, appropriate safety measures should be taken.

4.8.3 Boil-off may be a bigger problem for hydrogen than for LNG in particular when insulation properties have deteriorated. Means of handling boil-off gas should be carefully considered taking into account the following issues:

4.8.3.1 Re-liquefaction of hydrogen involves very specific and costly equipment. Cargo cooling in order to avoid boil-off shows the same kind of issues; and

4.8.3.2 Notwithstanding the provision in paragraph 7.4.1 of the Code, thermal oxidation of hydrogen may be permitted in accordance with paragraph 1.3 of the Code.

4.8.4 The special requirements in these aspects are considered necessary.

4.9 Health hazard

4.9.1 Human safety concern under low temperature

With regard to the influences of cold hydrogen on persons' bodies, suitable protective equipment is effective. In this aspect, paragraph 14.1 of the Code requires suitable protective equipment taking into account the character of the products, therefore, no special requirement is considered necessary.

4.9.2 Static electricity

Hydrogen ignition energy is very low and hydrogen can be easily ignitable by static electricity and due consideration should be given to this issue, in accordance with the requirement in the Code on suitable protective equipment.

4.9.3 Oxygen depletion and asphyxiation

Leakage of hydrogen may cause low level of oxygen and associated asphyxiation.

4.10 Wide range of flammable limits

4.10.1 Extinguishing hydrogen fire

4.10.1.1 As mentioned in paragraph 4.6, for flammable products the Code already requires elimination of sources of ignition, including use of electrical installations of appropriate types in order to minimize the risk of fire and explosion. No special requirement is considered necessary with regard to ignitability of hydrogen.

4.10.1.2 Furthermore, with regard to the wide range of flammable limits of hydrogen, the increased quantities of carbon dioxide as a fire-extinguishing medium should be specified as mentioned in paragraph 4.7. No additional special requirement is considered to be necessary with regard to the wide range of flammable limits of hydrogen.

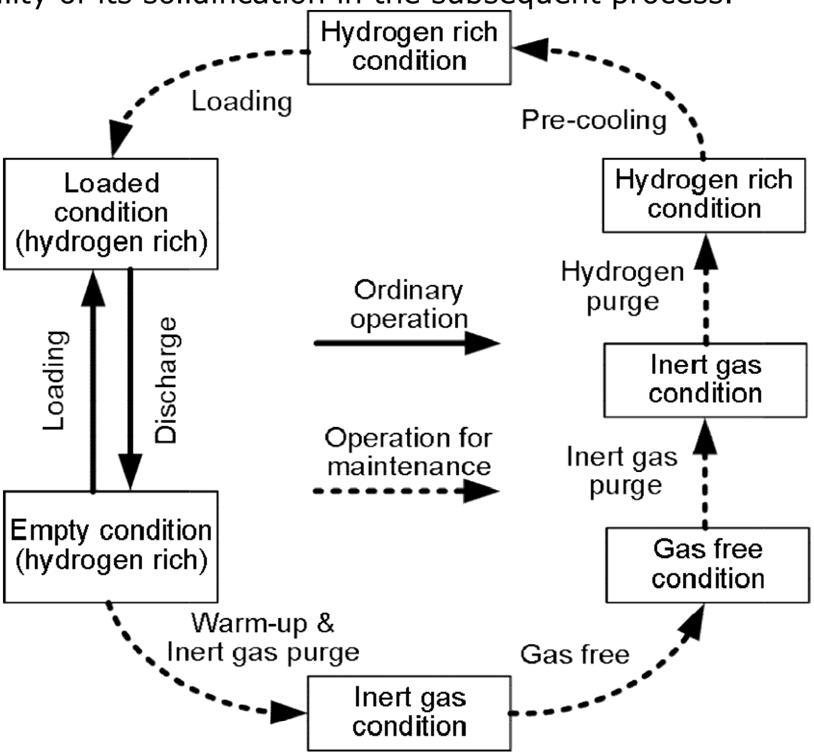
4.10.2 Disposal of cold hydrogen gas

The wide flammability range makes disposal of cold hydrogen gas a major hazard. Cold plumes downwind and inadequate dilution to below 4% provide possibilities for flash-back to the vent from distant ignition sources outside safety-controlled areas. The low ignition energy and wide flammable range may present significant challenges.

4.11 Prevention of dangerous purging operation

4.11.1 During cargo operations for maintenance, pipes and tanks should be purged with an inert gas or inert gases as illustrated in the figure below. For safety, due consideration should be given to temperature and boiling points of the inert gases. Residual pockets of hydrogen or the purge gas will remain in the enclosure if the purging rate, duration, or extent of mixing is too low. Therefore, reliable gas concentration measurements should be obtained at a number of different locations within the system for suitable purges. Temperature should also be measured at a number of locations. Oxidizing agents may exist in a hydrogen containing equipment, specifically: air, cold box atmospheres containing air diluted with nitrogen, or oxygen-enriched air that can be condensed on process pipe work within the cold box in special circumstances.

4.11.2 There are special measures that may need to be put in place in order to mitigate the hazards, e.g. air should be eliminated by nitrogen purge prior to introduction of hydrogen into cargo piping or processing equipment. Nitrogen should then be eliminated by hydrogen purge, where there is a possibility of its solidification in the subsequent process.



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