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GUIDELINES ON
CARRIAGE OF LIQUEFIED HYDROGEN IN BULK

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Guidelines

Carriage of Liquefied Hydrogen in Bulk

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Introduction

Hydrogen is anticipated to contribute to the reduction of direct greenhouse gas emissions vide its use in various energy related applications globally. In this regard, it is anticipated that there will be a rise in global transportation of liquefied hydrogen in bulk especially through maritime.

The IGC Code (MSC.370(93)) as amended is the principal instrument for Ships involved in carriage of liquefied gases in bulk. However, this code at present does not address Hydrogen in the list of cargoes in Chapter 19. In this regard, it should be noted that Paragraph 1.1.6.1 of the IGC Code applies to products presently not designated in Chapter 19.

The IMO published the Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk in 2016 vide resolution MSC.420(97). Based on experience gained, the IMO revised these recommendations by adopting resolution MSC.565(108) in 2024.

It is recognized that the carriage of liquefied hydrogen is yet in it's infancy and there will be further technological innovations in the future. The present experience of maritime is yet growing but there are other industries (for e.g. space, chemicals etc.) which have significant experience in the handling of liquefied hydrogen. These Guidelines also aim to take this experience into account while keeping in mind the unique challenges posed by carriage of liquefied hydrogen.

This document is intended to complement the Interim Recommendations from IMO on Safe Carriage of Liquefied Hydrogen Cargo in Bulk.

Section 1

General

1.1 Scope and Objective

1.1.1 These Guidelines are applicable to ships which carry liquefied hydrogen cargo in bulk.

1.1.2 These Guidelines should be applied in conjunction with the IGC Code and MSC.565(108) (as may be amended).

1.1.3 In addition, liquefied hydrogen carriers should also comply with the conditions laid down in the tripartite agreement between the flag Administration and the port authorities (see paragraph 1.1.6.1 of the IGC Code)

1.1.4 These Guidelines cover the carriage of Liquefied Hydrogen within Independent Type C tanks. For other tank types, IRS will specially consider the design evaluation on a case-to-case basis.

1.2 Categorization

1.2.1 In regard to Chapter 19 of the IGC Code, Liquefied Hydrogen Cargo is considered to be categorized as shown in the Table below

a	b	c	d	e	f	g	h	i
Product Name		Ship Type	Independent Type C tank required	Control of vapour space within cargo tanks	Vapour detection	Gauging		Special Requirements
Hydrogen		2G	-	-	F	C		

1.3 Classification

1.3.1 Ships carrying liquefied hydrogen in bulk will be assigned a class notation in accordance with Part 5, Chapter 4, Section IR2.0 of the *Rules and Regulations for Construction and Classification of Steel Ships* (hereinafter referred to as the Main Rules).

1.4 Drawings, Plans and Reports

1.4.1 The following documentation should be submitted to IRS for review in addition to those required by Part 5, Chapter 4, Section 1, IR1.5 of the Main Rules:

- Risk assessment report (refer Section 2)
- Specification for materials exposed to temperatures below -196^{o}C (this may also include material test reports where available)
- Vacuum insulation system details
- Gas detection systems for hydrogen
- Gas dispersion analyses

1.5 Properties of liquefied hydrogen

1.5.1 For reference, table 1.5.1 shows the comparison of physical properties of hydrogen and methane, the major component of LNG.

Table 1.5.1: Comparison of physical properties of Hydrogen and Methane

Property	**Hydrogen**	**Methane**	**References**
Boiling temperature *	20.3 K / -253 °C	111.6 K / -161.55 °C	ISO 15916:2015, Annex A, Table A.3
Liquid density (kg/m³)*	70.8	422.5	ISO 15916:2015, Annex A, Table A.3
Gas density (kg/m³)* (Air: 1.198)	0.084	0.668	NIST RefProp database
Viscosity (g/cm•s × 10⁶) Gas Liquid	 8.8 13.49	 10.91 116.79	NIST RefProp database
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 vaporization (J/g)*	454.6	510.4	ISO 15916:2015, Annex A, Table A.3
Lower flammability limit (% vol. fraction)***	4	5.3	ISO 15916:2015, Annex B, Table B.2
Upper flammability limit (% vol. fraction)***	77	17.0	ISO 15916:2015, Annex B, Table B.2
Minimum ignition energy (mJ)***	0.017	0.274	ISO 15916:2015, Annex B, Table B.2
Auto-ignition temperature(°C)***	858	810	ISO 15916:2015, Annex B, Table B.2
Toxicity	Non	Non	Orange book – UN Recommendations on the Transport of Dangerous Goods – Model Regulations, Rev.22
Temperature at critical point ****	33.19 K / -239.96 °C	190.55 K / -82.6 °C	Hydrogen: ISO 15916:2015, Annex A, Table A.1 Methane: The Japan Society of Mechanical Engineers, Data Book, Thermophysical Properties of Fluids (1983)
Pressure at critical point (kPaA) ****	1315	4595	Hydrogen: ISO 15916:2015, Annex A, Table A.1 Methane: The Japan Society of Mechanical Engineers, Data Book, Thermophysical 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.

Section 2

Risk Assessment

2.1 **Objective**

2.1.1 Risk assessment of the hydrogen cargo system should be performed so as to ensure that the hazards from storage and cargo handling of liquefied hydrogen are prevented and/or mitigated such that the risk to persons, property and environment is eliminated or minimized to the extent practicable.

2.1.2 For the purpose of these Guidelines, the hydrogen cargo system is considered to be composed of all items which could be exposed to hydrogen either continuously or intermittently. These include the following components, but not limited to:

- Cargo manifold
- Cargo hoses and vapour return lines
- Cargo piping and supports including insulation
- Cargo tank including insulation
- Equipment (pumps, compressors, level gauges, gas detection equipment, electrical equipment and wiring etc.)
- Cargo tank pressure relief system including vent mast

2.2 **Risk Assessment**

2.2.1 The risk assessment should consider the following hazards/scenarios but not be limited to:

- Material embrittlement hazards for cryogenic storage and cargo handling of liquefied hydrogen at -253°C
- Deterioration and/or failure of insulation of the cargo tank and associated piping (for vacuum insulated systems, a failure modes effects analysis should be conducted)
- Structural failure of cargo tank and/or associated piping
- Leakage of hydrogen liquid and/or vapour from equipment, piping and components
- Fire in the space containing the cargo tanks
- Fire in the space adjacent to the space containing the cargo tanks
- Accidental spill of hydrogen owing to failure during cargo loading/unloading operation
    - Failure of the loading arms
    - Excessive vessel movement
    - Impurities in the liquefied hydrogen (e.g. frozen gases)
- Failure of cargo equipment (e.g. pumps, compressors etc.)
- Ignition and fire at the cargo tank vent system outlet due to release of hydrogen
- Failure of control and monitoring system
- Failure of safety systems including ESD system
- Operations such as gas freeing, inerting and purging of cargo tanks
- Boiling liquid expanding vapour explosion (BLEVE)
- Rapid phase transition (RPT)
- Personnel hazards from exposure to liquefied hydrogen or cold hydrogen vapours
- Hazards from oxygen condensation and/or enrichment
- Hazards from other external events such as
    - Collision
    - Grounding
    - Mechanical damage due to dropped object on the cargo tank and/or piping
    - Lightning strikes

2.3 It is recommended that a team of experts perform the risk assessment using acceptable methods/techniques.

2.4 The Risk assessment is to be adequately documented and the report should include the following but not be limited to:

- Design philosophy of the hydrogen cargo system including the associated ancillary systems.
- Composition of the team of experts performing the risk assessment along with brief CVs outlining their professional background and experience
- Details of hazard identification sessions (HAZID).
- Details of simulations or studies performed to address specific scenarios (e.g. gas dispersion analysis)
- Close-out actions identified from the HAZID and Risk Assessment and information on how these are envisaged to be addressed (or aim to be implemented) in the design and construction

2.5 It is recommended to involve IRS at an early stage through the risk assessment process. The final report of the risk assessment should be submitted to IRS for review.

Section 3

Special Requirements

3.1 **General**

3.1.1 This section incorporates the contents of IMO resolution MSC.565(108). Additional guidance from IRS is included and prefixed by the initials IR.

3.1.2 The guidance in section 3.2 is applicable in general for all types of containment systems. Specific guidance for vacuum insulated independent tanks and independent cargo tanks using insulation as well as hydrogen gas in inner insulation spaces are indicated in sections 3.3 and 3.4.

3.1.3 These Guidelines addess the carriage of liquefied hydrogen only within independent Type C tanks. Use of other tank types (e.g. membrane tanks/ Type B independent tank) will be subject to special consideration by IRS, if the hazards of liquefied hydrogen as provided in Section 4 of the Annex to MSC.565(108) are adequately addressed. The IRS *Guidelines for Alternative Design and Risk based Design Evaluation* are to be complied with in this regard as applicable.

3.2 **General Guidelines for Carriage of Liquefied Hydrogen in Bulk**

3.2.1 Requirements for materials for cargo tanks or piping whose design temperature is lower than -165°C should be agreed with IRS, 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.
(Special Requirement A-1 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

IR3.2.1 Austenitic Stainless Steel Grades 316, 316L, 304 and 304L are deemed to be acceptable materials. For other metallic materials, a material testing programme has to be submitted and agreed with IRS.

3.2.2 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). This special requirement is applied to all locations where contact with condensed oxygen is anticipated under normal conditions and foreseeable single failure scenarios.
(Special Requirement A-2 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

IR3.2.2 The recommendations from the Risk assessment in Section 2 should be taken into account.

3.2.3 For cargo pipes containing liquid hydrogen and cold hydrogen vapour, measures should be taken to prevent the exposed surfaces from reaching -183°C(Boiling point of Oxygen). 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.
(Special Requirement A-3 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

IR3.2.3.1 Pipes carrying Liquid hydrogen and cold hydrogen vapour should be vacuum insulated.

IR3.2.3.2 Trays to recover liquid air should be constructed from materials which are appropriate for the temperature of -196ºC(Boiling point of Nitrogen). Means should be provided to safely dispose the liquid air which is recovered in such trays. The capacity of the trays should be determined and be adequate so as to ensure no spillage of liquid air.

IR3.2.3.3 Trays to recover liquid air should be fitted with means to detect presence of liquid hydrogen and liquid air.

IR3.2.3.4 The use of ventilation as a measure to prevent formation of enriched oxygen should be evaluated in the risk assessment in Section 2.

3.2.4 Appropriate means, e.g. filtering, should be provided in cargo piping systems to remove impure substances condensed at low temperature.
(Special Requirement A-4 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

IR3.2.4 Filters provided in cargo piping systems to remove impure substances should be constructed of a material which is appropriate for liquid hydrogen. Refer Section 4.

3.2.5 Pressure relief systems should be suitably designed and constructed to prevent blockage due to formation of water or ice.
(Special Requirement A-5 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

IR3.2.5 Pressure relief systems for liquefied hydrogen should be designed in accordance with a recognized standard such as CGA 5.5 (for sizing of the pressure relief valve, also see IR 3.2.24).

3.2.6 At places where contact with hydrogen is anticipated, suitable materials should be used to prevent any structural deterioration owing to hydrogen embrittlement and degradation of strength and fatigue properties due to continual exposure to hydrogen, as necessary.
(Special Requirement A-6 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

IR3.2.6 Refer Section 4 for requirements regarding materials in hydrogen service.

3.2.7 Double tube structures ensuring no leakage, or fixed hydrogen detectors being capable of detecting a hydrogen leak, should be provided for confined places where leakage of hydrogen may occur, such as cargo valves, flanges and seals.
(Special Requirement A-7 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.2.8 Helium or a mixture of 5% hydrogen and 95% nitrogen should be used as the tightness test medium for cargo tank and cargo piping.
(Special Requirement A-8 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.2.9 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.
(Special Requirement A-9 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.2.10 When deterioration of insulation capability by single damage is possible, appropriate safety measures should be adopted taking into account the deterioration.
(Special Requirement A-10 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

IR3.2.10 The risk of deterioration of insulation capability due to single damage should be evaluated in the risk assessment (refer Section 2). Suitable prevention and mitigation measures should be identified.

3.2.11 Appropriate measures should be provided to prevent vents becoming blocked by accumulations of ice formed from moisture in the air.
(Special Requirement A-11 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

IR3.2.11 Pressure relief systems for liquefied hydrogen should be designed in accordance with a recognized standard such as CGA 5.5

3.2.12 Due consideration should be given to means for handling boil-off gas.
(Special Requirement A-12 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.2.13 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, in addition to the bonding of tanks, piping and equipment required by Part 5, Chapter 4, 5.7.4 of the Main Rules (paragraph 5.7.4 of the IGC Code). Anti-static clothing and footwear should be provided for each crew member working in the cargo area. Additionally, atleast two portable hydrogen detectors should be available onboard.
(Special Requirement A-13 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.2.14 The cargo operation manuals required in Part 5, Chapter 4, 18.2 of the Main Rules (paragraph18.2 of the IGC Code) should include limitations of various operations in relation to environmental conditions.
(Special Requirement A-14 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.2.15 An appropriate procedure should be established for warm-up, inert gas purge, gas-free, hydrogen purge and pre-cooling. The procedure should include:

.1 selection of inert gas in relation to temperature limit;
.2 measurement of gas concentration;
.3 measurement of temperature;
.4 rates of supply of gases;
.5 conditions for commencement, suspension, resuming and termination of each operation;
.6 treatment of return gases; and
.7 discharge of gases.

(Special Requirement A-15 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.2.16 Only almost pure para-hydrogen (i.e. more than 95%) should be loaded in order to avoid excessive heating by ortho- to para-hydrogen conversion.
(Special Requirement A-16 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.2.17 Fire detectors for detecting hydrogen fire should be selected, taking into account the features of hydrogen fire, to the satisfaction of the Administration.
(Special Requirement A-17 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

IR3.2.17 The suitability of fire detectors proposed to be installed should be taken into consideration within the risk assessment (refer Section 2)

3.2.18 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.
(Special Requirement A-18 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

IR3.2.18 A gas dispersion analysis should be performed considering reasonably foreseeable scenarios. Also refer IEC 60079-10-1:2020 for the methodology to be followed.

3.2.19 Due consideration should be given to appropriate safety measures to prevent formation of explosive mixture in case of a leakage and permeation of hydrogen, including:

.1 installation of hydrogen detectors in order to detect a possible ground-level travel of low temperature hydrogen gas, and at high points in spaces where warm hydrogen gas can be trapped; and

.2 application of "best practice" for land-based liquid hydrogen storage taking into account appropriate guidance such as "Cryogenics Safety Manual – Fourth Edition (1998)"8) .
(Special Requirement A-19 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.2.20 In case that fusible elements are used as a means of fire detection required by Part 5, Chapter 4, Cl. 18.10.3.2 of the Main Rules (paragraph 18.10.3.2 of the IGC 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).
(Special Requirement A-20 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.2.21 Consideration should be given to enhance the ventilation capacity of the enclosed spaces subject to liquefied hydrogen leakage and permeation, taking into account the latent heat of vaporization, specific heat and the volume of hydrogen gas in relation to temperature and heat capacity of adjacent spaces.
(Special Requirement A-21 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

IR3.2.21 Leakage of liquefied hydrogen in enclosed spaces should be addressed based upon measures identified from the risk assessment in section 2.

3.2.22 Liquid and gas hydrogen pipes should not pass through enclosed spaces in addition to other than those referred to in Part 5, Chapter 4, Cl. 5.2.2.1.2 of the Main Rules (paragraph 5.2.2.1.2 of the IGC Code), unless:

1.1 the spaces are equipped with gas detection systems which activate the alarm at not more than 20% LFL and shut down the isolation valves, as appropriate, at not more than 40% LFL (see Part 5, Chapter 4, 16.4.2 and 16.4.8 of the Main Rules or sections 16.4.2 and 16.4.8 of the IGC Code); and

1.2 .1.2 the spaces are adequately ventilated; or

1.3 .2 the spaces are maintained in an inert condition.

(Special Requirement A-22 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

IR3.2.22 In situations where it becomes inevitable for the liquefied and cold hydrogen pipes to pass through enclosed spaces, risk assessment should be performed to identify suitable measures.

3.2.23 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 IEC/ISO 31010:2019 "Risk management – Risk assessment techniques"7) and SAE ARP 5580-2001 "Recommended failure modes and effects analysis (FMEA) practices for non-automobile applications"9)
(Special Requirement A-23 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

IR3.2.23 Refer Section 2 for additional guidance.

3.2.24 Relief valve sizing should be undertaken for the most onerous scenario. The evaluation should include the fire scenario and should consider the resulting magnitude of the heat flux on the cargo containment system.
(Special Requirement A-24 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

IR3.2.24 Relief valve sizing should be in accordance with ISO 21013-3:2016.

3.2.25 A filling limit exceeding 98% at reference temperature should not be permitted.
(Special Requirement A-25 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.2.26 Bolted flange connections of hydrogen piping should be avoided where welded connections are feasible.
(Special Requirement A-26 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.2.27 Due consideration should be given to the invisible nature of hydrogen fire from the viewpoint of safety of ships and especially personnel in case of fire.
(Special Requirement A-27 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

IR3.2.27 This should be taken into account during risk assessment (refer Section 2) when identifying safety measures.

IR3.2.28 The use of water spray systems as outlined in Part 5, Chapter 4 of the Main Rules should be carefully considered keeping in view that the water spray should not impinge on the pressure relief vent mast so as to freeze the water at the vent mast outlet.

IR3.2.29 For suppression of a hydrogen fire, it should be first ensured that supply of hydrogen to the fire is shutoff before undertaking the fire-suppression activities.

3.3 Carriage of Liquefied Hydrogen in Bulk in independent Type C tanks fitted with vacuum insulation systems

3.3.1 The insulation performance of vacuum insulation of cargo containment system should be evaluated to the satisfaction of the IRS/Administration based on experiments, as necessary.
(Special Requirement B-1 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

IR 3.3.1 The heat leak performance of the cargo containment system should be evaluated in accordance with ISO 21014:2019. Also refer Section 4.8.

3.3.2 Notwithstanding special requirement in 3.2.22, liquid and gas hydrogen pipes may pass through spaces constituting a part of a cargo containment system using vacuum insulation where the degree of vacuum is monitored.
(Special Requirement B-2 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.3.3 When selecting the most onerous scenario stipulated in special requirement in 3.2.24, the evaluation should include fire or loss of vacuum from the overall insulation system and should also consider the resulting magnitude of the heat flux in case of a single failure on the cargo containment system in each case.
(Special Requirement B-3 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

IR3.2.23 Fire scenario and loss of vacuum scenario can be separately evaluated. However, evaluation for the fire scenario should also consider whether a fire in the space in which the cargo tank is installed can lead to consequential failure of the vacuum insulation system.

3.4 Carriage of Liquefied Hydrogen in Bulk in independent Type C double wall tanks fitted with insulation and using hydrogen gas in the annular space

3.4.1 The outer shell of the cargo containment system should be located at the distance from the ship's outer shell, as required in Part 5, Chapter 4, Cl.2.4.1 and 2.4.2 of the Main Rules (paragraphs 2.4.1 and 2.4.2 of the IGC Code) for cargo tanks of type 2G ship.
(Special Requirement C-1 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.4.2 Strength of the outer shell should be determined by analyses and tests considering safety principles, all applicable design conditions, materials used, and construction processes in reference to chapter 4 of the Code and should be approved by the IRS/Administration.
(Special Requirement C-2 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.4.3 Notwithstanding special requirement in 3.4.2, the temperature of the outer shell should be determined by a temperature calculation, under the assumption that the inner shell is at the cargo temperature.
(Special Requirement C-3 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.4.4 Notwithstanding, the above, the following special requirements should be applied to the outer shell:

.1 All joints of the outer shell should be welded and of full penetration type. All joints of the outer shell should be of in-plane butt weld, as far as practicable. Tee welds of full penetration type may be used depending on the results of the test carried out at the approval of the welding procedure where the in-plane butt weld is not practicable due to the construction process and structure of the outer shell.

.2 If a manhole is sealed by welding using backing rings, backing rings may be left after welding without removal, provided that they do not cause any significant harmful effects.

(Special Requirement C-4 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.4.5 The outer shell should be subjected to pneumatic pressure testing to check its strength.
(Special Requirement C-5 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.4.6 Appropriate thermal insulation should be provided to keep the temperature of the outer shell and outer insulation layer above the boiling point of oxygen. The insulation performance should be evaluated to the satisfaction of the IRS/Administration based on experiments, as necessary. When applying Part 5, Chapter 4, Cl. 4.19.1.1.5 of the Main Rules (paragraph 4.19.1.1.5 of the IGC Code), the degradation of insulation performance caused by hydrogen atmosphere should be considered. Means should be provided for monitoring the condition of the insulation for detection of failures.
(Special Requirement C-6 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.4.7 The pressure of the inner insulation space should be monitored taking into account the requirement for a cargo tank in Part 5, Chapter 4, 13.4 of the Main Rules (paragraph 13.4 of the IGC Code).
(Special Requirement C-7 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.4.8 Under normal conditions, appropriate measures should be taken to maintain the pressure of the inner insulation space within the design limits.
(Special Requirement C-8 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.4.9 Pressure and vacuum relief valves should be provided for inner insulation space which may be subject to pressures beyond their design capabilities, taking into account the requirements for pressure relief systems of cargo tanks in Part 5, Chapter 4, 8.2 and 8.3 of the Main Rules (paragraphs 8.2 and 8.3 of the IGC Code). The appropriate capacity of vacuum relief valves should be provided taking into account the expected rate of pressure drop in the inner insulation space of the cargo tanks of the ship under normal cargo operations, which replaces the requirements of Part 5, Chapter 4, Cl. 8.3.1.2 of the Main Rules (paragraph 8.3.1.2 of the IGC Code). When applying Part 5, Chapter Cl. 8.3.2 of the Main Rules (8.3.2 of the IGC Code), the vacuum relief valves should not admit air to the inner insulation space. In the event that the pressure relief valve for the inner insulation space is activated, the hydrogen gas release should be vented to a safe location.
(Special Requirement C-9 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.4.10 The requirements in Part 5, Chapter 4, Section 5 other than 5.3 and 5.10 of the Main Rules, i.e. the requirements for cargo piping outside the cargo areas, should be applied for piping handling hydrogen for the inner insulation space.
(Special Requirement C-10 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.4.11 Appropriate measures should be taken for atmosphere control of the inner insulation space, e.g. inerting, gas freeing, aerating and purging, etc. (see also 3.2.15).
(Special Requirement C-11 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.4.12 The special requirement in 3.2.8 should be applied to the tightness test of outer shell.
(Special Requirement C-12 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.4.13 The special requirements in 3.2.3 and 3.2.4 should be applied to piping handling hydrogen for the inner insulation space.
(Special Requirement C-13 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.4.14 The special requirements in 3.2.8 and 3.2.26 should be applied to exposed parts of piping handling hydrogen for the inner insulation space.
(Special Requirement C-14 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.4.15 Special requirement in 3.2.7 need not be applied to piping handling hydrogen for the inner insulation space, other than piping penetrating the inner shell, located inside the inner insulation space.
(Special Requirement C-15 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.4.16 Notwithstanding special requirement in 3.2.22, piping handling hydrogen for an inner insulation space may pass through other inner insulation spaces.
(Special Requirement C-16 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.4.17 The requirements for type C independent tank should be applied to the inner shell.
(Special Requirement C-17 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.4.18 Manholes for access from or to the inner insulation space through the inner shell should not be permitted.
(Special Requirement C-18 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

3.4.19 Cargo piping connected to the inside of the inner shell should be led directly from the weather deck. No pipe should penetrate the inner shell from or to the inner insulation space.
(Special Requirement C-19 of the Revised Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk)

Section 4

Testing

4.1 General

4.1.1 This document enumerates requirements to be applied in regard to construction and testing of liquefied hydrogen tanks, piping, valves and relevant cargo equipment.

4.1.2 The document enumerates requirements considering that Independent Type C tanks as defined in Part 5, Chapter 4, 4.23 of the Main Rules (4.23 of the IGC Code) will be utilized for carriage of liquefied hydrogen. For other types of containment systems for hydrogen, requirements for construction and testing will be specially considered.

4.2 Construction and Welding

4.2.1.1 All welded joints of the shell of independent tanks are to be of the butt-weld full penetration type. For dome to shell connections, IRS may approve fillet welds of the full penetration type. All nozzle welds including small penetrations on domes are to be designed with full penetration.

4.2.1.2 All longitudinal and circumferential joints are to be of butt welded, full penetration, double vee or single vee type. Full penetration butt welds are to be obtained by double welding or by the use of backing rings. If used, backing rings are to be removed except from very small process pressure vessels. Other edge preparations may be permitted depending on the results of the tests carried out at the approval of the welding procedure.

4.2.1.3 The bevel preparation of the joints between the pressure vessel body and domes and between domes and relevant fittings are to be designed according to a standard acceptable to IRS. All welds connecting nozzles, domes or other penetrations to the vessel and all welds connecting flanges to the vessel or nozzles, are to be full penetration welds.

4.3 Inspection and NDE

4.3.1.1 All welds are to be inspected visually.

4.3.1.2 Nondestructive examination

Radiography
Butt welds: 100%

Surface crack detection
all welds: 10%
reinforcement rings around holes, nozzles, etc: 100%

Ultrasonic testing
Ultrasonic testing may be accepted for replacing partially the radiographic examination, if so specially allowed by IRS. In addition the IRS may require a total ultrasonic examination on welding of reinforcement rings and holes, nozzles, etc.

A liquid penetrant test or a magnetic particle inspection test is to be carried out for welded joints, where it may not be possible to perform Radiography or Ultrasonic testing

4.4 **Cold Shock Test**

4.4.1 Each cargo tank is to be subjected to a cold shock test. The purpose of this test is to verify the compatibility of the tank with the liquefied hydrogen fuel for cryogenic conditions. With this test, defects or anomalies are detected which arise due to the contraction of material from exposure to cryogenic conditions. (Prior to undertaking this test, the fuel tank is to be inspected visually to ascertain that it has been properly constructed in accordance with the approved drawings as well as NDE has been performed with no defects revealed). This test is to be performed after the leak tightness (Section 4.5) and the hydrostatic test (Section 4.6)

4.4.2 Liquid Nitrogen is the practical medium which can be utilized for the cold shock testing. The difference between the densities of liquid nitrogen and hydrogen as well as the boiling points is to be considered while planning and executing the test.

4.4.3 Liquid Nitrogen is to be introduced within the fuel tank (at it's boiling point of -196^{o}C at atmospheric pressure).The fuel tank is to be exposed to the liquid nitrogen environment until the time when the temperature does not change or fluctuate in the tank (i.e. steady state). For this purpose, the temperature within the tank is to be monitored. The steady state is to be maintained for a period not less than 60 minutes.

4.4.4 The fuel tank is to be inspected for signs of any failures or cold spots. If detected, then they are to be repaired using appropriate techniques and the fuel tank is to be again subjected to the cold shock test.

4.5 **Leak Tightness Test**

4.5.1 For each tank A leak tightness test is to be undertaken prior to the hydrostatic test. The objective of this test is to confirm the integrity of the welds (cracks, porosity etc.) as well as tightness of the seals, gaskets etc. This test is to be performed using Helium or a mixture of 95% Nitrogen and 5% Hydrogen.

4.6 **Hydrostatic Test**

4.6.1 The fuel tank or process vessel is to be subjected to a hydrostatic test according to the Rules ofIRS, at a pressure, measured at the top of the tanks, of not less than 1.5P_0, In no case during the pressure test is the calculated primary membrane stress at any point to exceed 90% of the yield stress of material (for definition of vapour pressure P_0, see 4.1.2 of the IGC Code). To ensure that this condition is satisfied where calculations indicate that this stress will exceed 0.75 times the yield strength, the prototype test is to be monitored by the use of strain gauges or other suitable equipment in pressure vessels except simple cylindrical and spherical pressure vessels.

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

4.6.3 The pressure is to be held for not less than two hours per 25 mm of thickness but in no case less than two hours.

4.6.4 If the cargo tank is constructed from austenitic stainless steel, then the chloride content of the water used for the test and time of exposure is to be controlled so as to avoid stress corrosion cracking.

4.6.5 Where necessary for cargo tanks (e.g. they are so designed or supported that they cannot be filled safely with water or cannot be readily dried), a hydropneumatic test may be carried out with specific approval of IRS in the conditions prescribed under 4.6.1, 4.6.2 and 4.6.3.

4.6.6 Upon completion of the hydrostatic test, the internal surface of the tank is to be dried and cleaned.

4.7 **Pressure Test of Outer Vessel (for vacuum insulated tanks)**

4.7.1 The outer vessel of vacuum insulated tanks will be subject to internal pressure testing. The test pressure used for testing is not to be less than 1.5 times the difference between normal atmospheric pressure and the minimum design internal absolute pressure of the outer vessel.

4.8 **Performance of vacuum insulation (for vacuum insulated fuel tanks)**

4.8.1 The performance of vacuum insulation is to be measured in accordance with a recognized standard. Vacuum retention rate (or rate of decay of vacuum) is to be measured over a period no less than 24 hours.

4.9 **Hydrogen Equipment and Fittings prior to installation onboard**

4.9.1 **Valves**

4.9.1.1 Refer Part 5, Chapter 4, Section 5.13.1.1 of the Main Rules

4.9.2 **Bellows**

4.9.2.1 Refer Part 5, Chapter 4, Section 5.13.1.2 Of the Main Rules.

4.9.3 **Cargo Pumps and Compressors**

4.9.3.1 Refer Part 5, Chapter 4, Section 5.13.1.3 of the Main Rules

4.9.4 **Insulation for Cargo Piping**

4.9.4.1 Requirements are applicable as provided in Part 5, Chapter 4 of the Main Rules.

Normative List of References and Standards

The following standards can be used as guidance:

[1] ANSI/AIAA G-095A-2017, Guide to Safety of Hydrogen and Hydrogen Systems

[2] ASME Boiler and Pressure Vessel Code, 2023

[3] ASME B31.12-2019, Hydrogen piping and Pipelines

[4] ISO 11114 series

[5] ISO 21011:2008, Cryogenic vessels. Valves for cryogenic service

[6] ISO 21014:2009, Cryogenic vessels. Cryogenic insulation performance

[7] ISO 20421-1:2019, Cryogenic vessels. Large transportable vacuum-insulated vessels. Part 1: Design, fabrication, inspection and testing

[8] ISO 20421-1:2019/Amd.1:2022, Cryogenic vessels — Large transportable vacuum-insulated vessels. Part 1: Design, fabrication, inspection and testing. Amendment 1

[9] ISO 23208:2017, Cryogenic vessels. Cleanliness for cryogenic service

[10] ISO 24490:2016, Cryogenic vessels. Pumps for cryogenic service

[11] NFPA 2, Hydrogen Technologies code

[12] Resolution MSC.565(108).

End of Guidelines