2025

Guidelines for Ships carrying Liquefied Hydrogen in Bulk

GL-0020-E

KR

_Disclaimer :
Although all possible efforts have been made to ensure correctness and completeness of the contents contained in this guidelines, the Korean Register of Shipping is not responsible for any errors or omissions made herein, nor held liable for any actions taken by any party as a result of information retrieved from this guidelines.
This guidelines is non-mandatory, but are intended to provide practical technical materials to ship owners, ship operators, shipyards, designers and manufacturers. It might be amended periodically or upgraded to rules and guidances as future technology develops and matures.

(서식번호 : FI-03-05) (01.04.2018)

CONTENTS

Chatper 1 INTRODUCTION ····· 1
Section 1 General ····· 1

Chatper 2 GENERAL (APPLICABLE TO SHIPS WITH ANY TYPE OF CARGO CONTAINMENT SYSTEM) ····· 3
Section 1 Definitions ····· 3
Section 2 Requirements for carriage of liquefied hydrogen in bulk ····· 3
Section 3 Explanation on General Requirements ····· 7
Section 4 Special Requirements against Hazards of Liquefied Hydrogen ····· 9

Chatper 3 CARGO CONTAINMENT SYSTEMS OF INDEPENDENT CARGO TANKS USING VACUUM INSULATION ····· 15
Section 1 Additional Requirements ····· 15

Chatper 4 CARGO CONTAINMENT SYSTEMS OF INDEPENDENT CARGO TANKS USING INSULATION MATERIALS AND HYDROGEN GAS IN THE INNER INSULATION SPACES ····· 17
Section 1 Application of the Requirements in this Chapter ····· 17
Section 2 Additional requirements ····· 18
Section 3 Explanation of special requirements ····· 20

Chatper 1 INTRODUCTION

Section 1 General

101. Application

1. A ship carrying liquefied hydrogen in bulk (hereinafter called "liquefied hydrogen carrier") should comply with **Pt 7, Ch 5** of **Rules for the Classification of Steel Ships**. A gas carrier should comply with the minimum requirements for the cargo listed in **Pt 7, Ch 5, Sec 19** of **Rules for the Classification of Steel Ships**. However, the requirements for liquefied hydrogen are not specified. This Guidelines provides the interim recommendations, as referred to in paragraph 5 of the preamble of IGC 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. The Revised Interim Recommendations are intended to facilitate the establishment of a tripartite agreement among the relevant Administrations for the carriage of liquefied hydrogen in bulk. However, they are not intended to prohibit the adoption of designs and arrangements other than those specified in the Code or in these Recommendations, at the discretion of the Administrations.

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

3. This Guidelines provide the requirements to be satisfied for liquefied hydrogen carrier to be registered by the Society. In addition, in accordance with IGC Code 1.1.6.1, preliminary suitable conditions of carriage laid down under a Tripartite Agreement between the Administration and the port Administrations involved in such carriage are to be compiled with.

4. These Interim Recommendations consist of the following chapters. Chapter 2 is applicable to ships with any type of cargo containment system. Chapter 3 and subsequent part(s) prescribe additional special requirements for cargo containment systems of specific types.
   (1) Chapter 2: General (applicable to ships with any type of cargo containment system);
   (2) Chapter 3: Cargo containment systems of independent cargo tanks using vacuum insulation; and
   (3) Chapter 4: Cargo containment systems of independent cargo tanks using insulation materials and hydrogen gas in the inner insulation spaces.

5. Chapter 2 of this document was developed based on the design of Chapter 3 and 4. If subsequent part(s) are added, the special requirements prescribed in Chapter 2 may be reviewed.

Chatper 2 GENERAL (APPLICABLE TO SHIPS WITH ANY TYPE OF CARGO CONTAINMENT SYSTEM)

Section 1 Definitions

101. Definitions

The definitions of terms in this Guideline are to comply with **Pt 7, Ch 5** of **Rules for the Classification of Steel Ships**, unless otherwise specified in the followings.

1. **Ortho hydrogen** means a state that two proton nuclear spins are aligned parallel as one of the two isomers of hydrogen molecule.
2. **Para hydrogen** means a state that two proton nuclear spins are aligned anti-parallel as one of the two isomers of hydrogen molecule.
3. **Isomer** means molecules that have the same molecular formula but different atomic arrangements or conformation.
4. **Nuclear spin** means that atomic nucleus having odd number of masses or part of atomic nucleus having even number of masses have unique angular momentum. In simple terms, the atomic nucleus can be thought of as rotating.
5. **Detonation** means a violent explosion that the propagation velocity of the explosion exceeds the supersonic velocity.
6. **Permeation** means flow of a fluid through another material by diffusion without a defect or opening of the latter. See paragraph 3.79 of ISO/TR 15916:2015.

Section 2 Requirements for carriage of liquefied hydrogen in bulk

201. Requirements for carriage of liquefied hydrogen in bulk

1. The requirements for the carriage of liquefied hydrogen in bulk have been developed based on the results of a comparison study of similar cargoes listed in **Pt 7, Ch 5, Sec 19** of **Rules for the Classification of Steel Ships**, e.g. liquefied natural gas.
2. **Pt 7, Ch 5, Sec 19** of **Rules for the Classification of Steel Ships** 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.
3. **Tables 1** and **Table 2** specify the proposed selection of the general requirements and the special requirements, respectively, for liquefied hydrogen. In addition to table 2, special requirements for cargo containment systems of specific types are prescribed in Chapter 3 or subsequent part(s).

Table 1 Requirements for carriage of liquefied hydrogen in bulk

a	b	c	d	e	f	g	h	i
Product name		Ship type	Independent tank type C require	Control of vapour space within cargo tanks	Vapour detection	Gauging		Special requirements
Hydrogen		2G	-	-	F	C		See table 2 and, either corresponding table 4 or table 5, as appropriate for the type of cargo containment systems

Table 2 Special Requirements for carriage of liquefied hydrogen in bulk

No.	Special Requirements	Related Hazard
A-1	Requirements for materials whose design temperature is lower than -165°C should be agreed with the Society, 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 402. 1)
A-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 in **Pt 7, Ch 5 1717.** of **Rules for the Classification of Steel Ships**). This special requirement is applied to all locations where contact with condensed oxygen is anticipated under normal conditions and foreseeable single failure scenarios.	Low temperature (see 402. 2)
A-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 402. 2)
A-4	Appropriate means, e.g. filtering, should be provided in cargo piping systems to remove impure substances condensed at low temperature.	Low temperature (see 402. 3)
A-5	Pressure relief systems should be suitably designed and constructed to prevent blockage due to formation of water or ice.	Low temperature (see 402. 4)
A-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.	Hydrogen embrittlement (see 403.)
A-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.	Susceptibility to leakage (see 404. 2)
A-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.	Susceptibility to leakage (see 404. 3)
A-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.	Fire by Hydrogen (see 407. 3) Wide range of flammability limits (see 410.)
A-10	When deterioration of insulation capability by single damage is possible, appropriate safety measures should be adopted taking into account the deterioration.	High pressure (see 408.)
A-11	Appropriate measures should be provided to prevent vents becoming blocked by accumulations of ice formed from moisture in the air.	Low temperature (see 402. 2)
A-12	Due consideration should be given to means for handling boil-off gas.	High pressure (see 408.)

Table 2 Special Requirements for carriage of liquefied hydrogen in bulk (continued)

No.	Special Requirements	Related Hazard
A-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 **Pt 7, Ch 5 507. 4** of **Rules for the Classification of Steel Ships**. Antistatic clothing and footwear, and a portable hydrogen detector should be provided for each crew member working in the cargo area.	Static electricity (see **409. 2**)
A-14	The cargo operation manuals required in **Pt 7, Ch 5 1802.** of **Rules for the Classification of Steel Ships** for a liquefied hydrogen carrier should include limitations of various operations in relation to environmental conditions.	Wide range of flammability limits (see **410.**)
A-15	An appropriate procedure should be established for warm-up, inert gas purge, gasfree, 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.	Prevention of dangerous purging operation (see **411.**)
A-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.	General (see **401.**)
A-17	Fire detectors for detecting hydrogen fire should be selected, taking into account the features of hydrogen fire, to the satisfaction of the Society.	Features of hydrogen fire and fire hazards (see **407. 4**)
A-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.	Low density and high diffusivity (see **405.**)
A-19	Due consideration should be given to appropriate safety measures to prevent formation of explosive mixture in the 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)".	General (see **401.**)
A-20	In the case that fusible elements are used as a means of fire detection required by **Pt 7, Ch 5, 1810. 3** (2) of **Rules for the Classification of Steel Ships**, 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 **407. 4**)
A-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 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 **405.**)

Table 2 Special Requirements for carriage of liquefied hydrogen in bulk (continued)

No.	Special Requirements	Related Hazard
A-22	Liquid and gas hydrogen pipes should not pass through enclosed spaces in addition to other than those referred to in Pt 7, Ch 5, Sec 16 of Rules for the Classification of Steel Ships. However if comply the following, it may pass through enclosed spaces. 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 Pt 7, Ch 5, 1604. 2 and 8 of Rules for the Classification of Steel Ships) and the spaces are adequately ventilated; or 2. The spaces are maintained in an inert condition.	Susceptibility to leakage (see 404.)
A-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" and SAE ARP 5580-2001 "Recommended failure modes and effects analysis (FMEA) practices for non-automobile applications".	General (see 401.)
A-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.	High pressure hazard (see 408.)
A-25	A filling limit exceeding 98% at reference temperature should not be permitted.	High pressure hazard (see 408.)
A-26	Bolted flange connections of hydrogen piping should be avoided where welded connections are feasible.	Permeability (see 404. 2)
A-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.	Fire hazard (see 407. 1)

Section 3 Explanation on General Requirements

301. Properties of liquefied hydrogen

The application of general requirements in the **Pt 7, Ch 5** of **Rules for the Classification of Steel Ships** 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
Boiling temperature (K)*	20.3	111.6
Liquid density (kg/m^3)*	70.8	422.5
Gas density (kg/m^3)**	0.084 (Air: 1.198)	0.716 (Air: 1.198)
Viscosity ($g/cm{\cdot}s \times 10^{-6}$)	Gas 8.8 Liquid 13.49	Gas 10.91 Liquid 116.79
Flame temperature in air (℃)	2396	2230
Maximum burning velocity (m/s)	3.15	0.385
Heat of vaporization (J/g)*	454.6	510.4
Lower flammability limit (%vol.fraction)***	4	5.3
Upper flammability limit (%vol.fraction)***	77	17.0
Minimum ignition energy (mJ)***	0.017	0.274
Auto-ignition temperature (℃)***	858	810
Toxicity	No	No
Temperature at critical point (K)	33.19****	190.55
Pressure at critical point (kPaA)	1315****	4595

(Note)
* 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.

302. Explanation on respective requirements

1. Ship type (column 'c')

(1) As the hazard associated with hydrogen cargo is flammability but not toxicity, the ship type is considered 2G.

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

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

4. Vapour detection (column 'f')

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

5. 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.

Section 4 Special Requirements against Hazards of Liquefied Hydrogen

401. Hazards of liquefied hydrogen to be considered

1. The hazards related to liquefied hydrogen are

(1) Low ignition energy,
(2) A wide range of flammability limits,
(3) Low visibility of flames in case of fire,
(4) High flame velocity which may lead to the detonation with shockwave,
(5) Low temperature and liquefaction/solidification of inert gas and constituents of air which may result in an oxygen-enriched atmosphere,
(6) High permeation,
(7) Low viscosity, and
(8) 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 piping with vacuum insulation. Supporting structure and adjacent hull structure should be designed taking into account the cooling owing to loss of vacuum insulation.

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 20 K, 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.

3. 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.

402. Low temperature hazard

1. Selection of appropriate material

(1) **Tables 7.5.6** and **Table 7.5.7** in **Pt 7, Ch 5, 604.** of **Rules for the Classification of Steel Ships** prescribe material selection for piping or cargo tanks whose design temperature is −165°C or higher. According to Note 2 of table **Tables 7.5.6** and Note 3 of **Tables 7.5.7**, the requirements for materials whose design temperatures are lower than −165°C should be specially agreed with the Society. In this regard, the publication by AIAA introduces some appropriate materials corresponding to the design temperature.

(2) Although **Pt 7, Ch 5, 419. 3** of **Rules for the Classification of Steel Ships** 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 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.

2. Measures for condensed air

(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 **Pt 7, Ch 5, 1717.** of **Rules for the Classification of Steel Ships**: "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.

(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 **Par 4**).

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. 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 **Par 2**). Appropriate means should be provided to prevent such phenomena.

403. Hydrogen embrittlement

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

404. Susceptibility to leakage

1. 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 leakage characteristics 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.

2. Implementation of effective tightness test

(1) Tightness tests for cargo tanks and cargo pipes/valves are required by **Pt 7, Ch 5, 420. 3** (2), **513. 1** and **513. 2** (3) of **Rules for the Classification of Steel Ships** respectively. Helium or a mixture of 5% hydrogen and 95% nitrogen should be used as the medium for tightness tests, instead of air, because hydrogen is highly susceptible to leakage.

(2) For a hydrogen installation, the pipework should be leakage 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.

3. 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, **Pt 7, Ch 5, 1803.** of **Rules for the Classification of Steel Ships** 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 **Pt 7, Ch 5, Sec 18** of **Rules for the Classification of Steel Ships** are applicable and no special requirement is necessary.

405. 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. **Pt 7, Ch 5, 1202.** of **Rules for the Classification of Steel Ships** requires fixed ventilation systems or portable mechanical ventilation for such enclosed spaces. These requirements are applicable to liquefied hydrogen carriers and no special requirement is necessary in this regard.

406. Ignitability

1. **Pt 7, Ch 5** of **Rules for the Classification of Steel Ships** requires electrical bonds of the piping and the cargo tanks in paragraph **507. 4**, exclusion of all sources of ignition in paragraph **1101. 2**, electrical installations to minimize the risk of fire and explosion from flammable products in paragraph **1002. 1** and so on, in order to prevent ignition of flammable cargoes.

2. **Pt 7, Ch 5** of **Rules for the Classification of Steel Ships** requires compliance with the relevant standards issued by the International Electrotechnical 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. 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 ISO/IEC 80079-20-1.

407. Fire hazard

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. **Pt 7, Ch 5** of **Rules for the Classification of Steel Ships** already requires fire-fighter's outfits for ships carrying flammable products in **1106. 1** and safety equipment in **1403.**. This issue should be considered as the matter of cargo information required by **Pt 7, Ch 5, 1803.** of **Rules for the Classification of Steel Ships**. Due consideration should be given to the invisible nature of hydrogen fire.

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 **Pt 7, Ch 5, 1104.** and **1105.** of **Rules for the Classification of Steel Ships**. 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 **Par 3**.

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

(1) **Pt 7, Ch 5, 1105. 1** of **Rules for the Classification of Steel Ships** requires as follows: "Enclosed spaces meeting the criteria of cargo machinery spaces in **105. 9**, 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."

(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.

(3) On the other hand, NFPA 12 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. 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.

408. High pressure hazard

1. High pressure is a hazard common to hydrogen and other flammable gases listed in **Pt 7, Ch 5** of **Rules for the Classification of Steel Ships**. To prevent overpressure, **Pt 7, Ch 5** requires various measures such as pressure control and pressure design. Specifically, **Pt 7, Ch 5, 802.** of **Rules for the Classification of Steel Ships**, in regard to the provision of pressure control of cargo tanks, requires fittings of pressure relief valves to the cargo tanks. Furthermore, **Pt 7, Ch 5, 701. 1** of **Rules for the Classification of Steel Ships** requires temperature control by the use of mechanical refrigeration and/or design to withstand possible increases of temperature and pressure. In addition, **Pt 7, Ch 5, 1502.** of **Rules for the Classification of Steel Ships** 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.
2. Boil-off may be a more significant issue 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:
   (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
   (2) Notwithstanding the provision in **Pt 7, Ch 5, 704. 1** of **Rules for the Classification of Steel Ships**, thermal oxidation of hydrogen may be permitted in accordance with **Pt 7, Ch 5, 103.** of **Rules for the Classification of Steel Ships**.
3. The special requirements in these aspects are considered necessary.

409. Health hazard

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, **Pt 7, Ch 5, 1401.** of **Rules for the Classification of Steel Ships** requires suitable protective equipment taking into account the character of the products, therefore, no special requirement is considered necessary.

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 **Pt 7, Ch 5** of **Rules for the Classification of Steel Ships** on suitable protective equipment.

3. Oxygen depletion and asphyxiation

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

410. Wide range of flammable limits

1. Extinguishing hydrogen fire
   (1) As mentioned in **406.**, for flammable products **Pt 7, Ch 5** of **Rules for the Classification of Steel Ships** 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.
   (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 **407. 3**. No additional special requirement is considered to be necessary with regard to the wide range of flammable limits of hydrogen.
2. Disposal of cold hydrogen gas

   The wide flammability range makes disposal of cold hydrogen gas a major hazard. Cold plumes of released hydrogen may impede adequate dilution of hydrogen down to below 4% and may lead to 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.

411. Prevention of dangerous purging operation

1. During cargo operations for maintenance, pipes and tanks should be purged with an inert gas or inert gases as illustrated in **Fig 1**. 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.
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. ⚓

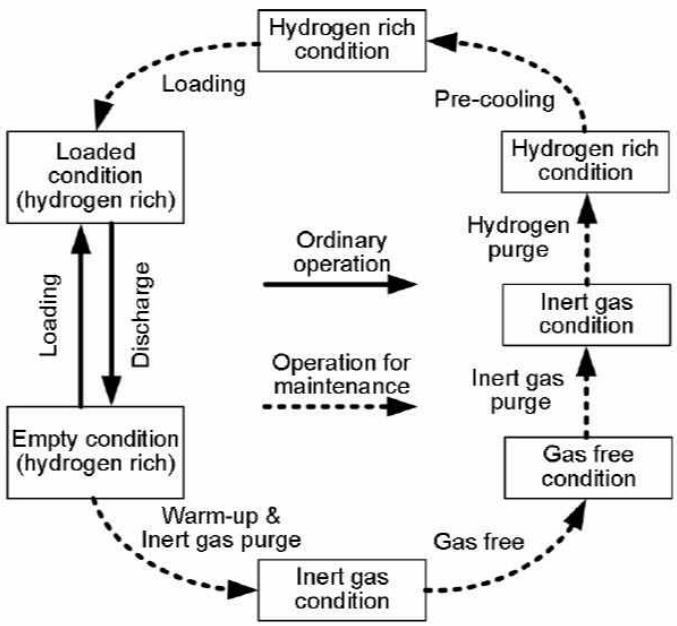

Fig 1 The procedure for purging pipes and tanks

References

1. ISO/TR 15916:2015, Basic consideration for the safety of hydrogen systems (ISO)
2. AIAA G-095A-2017 American Institute of Aeronautics and Astronautics, Guide to Safety of Hydrogen and Hydrogen Systems
3. NFPA 12: Standard on Carbon Dioxide Extinguishing Systems 2005 Edition (NFPA)
4. ISO/IEC 80079-20-1:2017 Explosive atmospheres - Part 20-1: Material characteristics for gas and vapour classification - Test methods and data
5. UN Recommendations on the Transport of Dangerous Goods - Model Regulations, twenty-second revised edition
6. NFPA 2: Hydrogen Technologies Code 2016 Edition (NFPA)
7. IEC/ISO 31010:2019 Risk management - Risk assessment techniques
8. Cryogenics Safety Manual - Fourth Edition (1998)
9. SAE ARP 5580-2001 "Recommended failure modes and effects analysis (FMEA) practices for non-automobile applications"
10. National Institute of Standards and Technology (NIST) RefProp database

Chatper 3 CARGO CONTAINMENT SYSTEMS OF INDEPENDENT CARGO TANKS USING VACUUM INSULATION

Section 1 Additional Requirements

101. Additional requirements

1. Additional special requirements for cargo containment systems of independent cargo tanks using vacuum insulation are prescribed in table 4 and these special requirements should apply in addition to the requirements in table 2.

Table 4 Special requirements for cargo containment systems of independent cargo tanks using vacuum insulation

No.	Special Requirements	Related Hazard
B-1	The insulation performance of vacuum insulation of cargo containment system should be evaluated to the satisfaction of the Administration based on experiments, as necessary.	General (see **Ch.2 401.** and **Ch.3 102. 1.**)
B-2	Notwithstanding special requirement A-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.	Susceptibility to leakage (see **Ch.2 404.**)
B-3	When selecting the most onerous scenario stipulated in special requirement A-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.	High pressure hazard (see **Ch.2 408.** and **Ch.3 102. 2.**)

102. Additional special requirements to mitigate hazards of liquefied hydrogen

1. Hazards of liquefied hydrogen to be considered
   (1) In addition to **Ch.2 401. 1.**, 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. Supporting structure and adjacent hull structure should be designed taking into account the cooling owing to loss of vacuum insulation.
   (2) For consideration on the special requirements for this chapter, bibliographic studies were conducted using the references at the end of this document, in particular, ISO/TR 15916, "High Pressure Gas Safety Act" (Japanese law), "Safety standard for hydrogen and hydrogen system" by AIAA2) and NFPA 2 "Hydrogen Technologies Code"3). 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.
2. High pressure hazard
   (1) In addition to **Ch.2 408.,** 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 vaporization of liquefied hydrogen might exceed the capacity of pressure relief valves. To prevent such dangerous deterioration of insulation, appropriate safety measures should be taken.

References

1 ISO/TR 15916:2015, Basic consideration for the safety of hydrogen systems (ISO)
2 American Institute of Aeronautics and Astronautics, "Safety Standard for Hydrogen and Hydrogen Systems (Guide to Safety of Hydrogen and Hydrogen Systems)", 2005 (AIAA)
3 NFPA 2: Hydrogen Technologies Code 2016 Edition (NFPA)

Chatper 4 CARGO CONTAINMENT SYSTEMS OF INDEPENDENT CARGO TANKS USING INSULATION MATERIALS AND HYDROGEN GAS IN THE INNER INSULATION SPACES

Section 1 Application of the Requirements in this Chapter

101. Design of cargo containment systems

The safety measures set out in this chapter should apply to cargo containment systems of independent cargo tanks using insulation materials and hydrogen gas in the inner insulation spaces as described below. Figure 2 illustrates a cargo containment system of independent cargo tanks using insulation materials and hydrogen gas in the inner insulation spaces. In this cargo containment system, an inner shell corresponds to a cargo tank. An insulation structure is installed outside of the inner shell. The insulation structure consists of an inner insulation space, an outer shell and an outer insulation layer from the inside. The inner insulation layer, which is located outside the inner shell, is a part of the inner insulation space. The inner insulation space needs to be filled with the appropriate gas to prevent condensation and/or solidification of a large amount of gas caused by the low temperature of the inner shell surface, which will be almost equal to the boiling point of hydrogen. Thus, the inner insulation space is filled with hydrogen gas and no liquid.

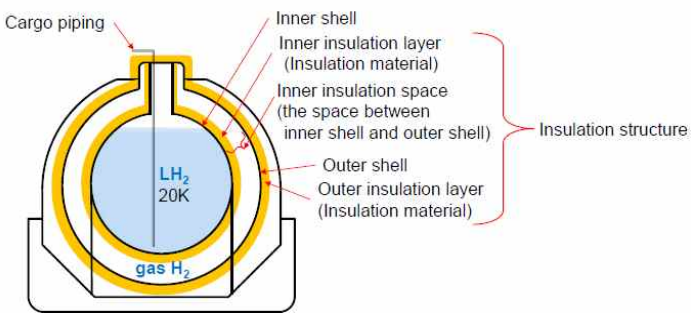

Fig 2 Illustration of cargo containment system

102 Conditions for the application of the requirements in this chapter

The safety requirements set out in this chapter should apply under the following conditions of use:

1. The inner shell satisfies the requirements of the **Pt 7, Ch 5** of **Rules for the Classification of Steel Ships** for a cargo tank; and

   Note: This chapter focuses on the safety measures for the inner insulation space and the outer shell, as a part of the insulation structure for which no specific requirements are specified in the **Pt 7, Ch 5** of **Rules for the Classification of Steel Ships**.

2. Appropriate measures are adopted to prevent leakage of gas from the inner insulation space to ensure the reliability of the insulation structure, taking into account that the space is filled with flammable gas.

Section 2 Additional requirements

Special requirements for the cargo containment systems are prescribed in table 5 and these special requirements should apply in addition to the requirements in table 2.

Table 5 Special requirements for cargo containment systems of independent cargo tanks using insulation materials and hydrogen gas in the inner insulation spaces

No.	Special Requirements	Related Hazard
C-1	The outer shell of the cargo containment system should be located at the distance from the ship's outer shell, as required in **Pt 7, Ch 5 204. 1** and **2** of **Rules for the Classification of Steel Ships** for cargo tanks of type 2G ship.	
C-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 **Pt 7, Ch 5 Sec. 4** of **Rules for the Classification of Steel Ships**, and should be approved by the Administration.	
C-3	Notwithstanding special requirement C-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.	
C-4	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.	See **Ch.4 301.**
C-5	The outer shell should be subjected to pneumatic pressure testing to check its strength.	See **Ch.4 302.**
C-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 Administration based on experiments, as necessary. When applying **Pt 7, Ch 5 419.1.(1)(E)** of **Rules for the Classification of Steel Ships**, 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.	
C-7	The pressure of the inner insulation space should be monitored taking into account the requirement for a cargo tank in **Pt 7, Ch 5 1304.** of **Rules for the Classification of Steel Ships**.	See **Ch.4 303.**
C-8	Under normal conditions, appropriate measures should be taken to maintain the pressure of the inner insulation space within the design limits.	See **Ch.4 303.**

Table 5 Special requirements for cargo containment systems of independent cargo tanks using insulation materials and hydrogen gas in the inner insulation spaces(continued)

No.	Special Requirements	Related Hazard
C-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 **Pt 7, Ch 5 802.** and **803.** of **Rules for the Classification of Steel Ships**. 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 **Pt 7, Ch 5 803. 1. (2)** of **Rules for the Classification of Steel Ships**. When applying **Pt 7, Ch 5 803. 2.** of **Rules for the Classification of Steel Ships**, 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.	See **Ch.4 303.**
C-10	The requirements in **Pt 7, Ch 5 Sec. 5** of **Rules for the Classification of Steel Ships** other than **503.** and **510.** of the Ruels, i.e. the requirements for cargo piping outside the cargo areas, should be applied for piping handling hydrogen for the inner insulation space.	
C-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 A-15).	
C-12	The special requirement A-8 should be applied to the tightness test of outer shell.	
C-13	The special requirements A-3 and A-4 should be applied to piping handling hydrogen for the inner insulation space.	
C-14	The special requirements A-8 and A-26 should be applied to exposed parts of piping handling hydrogen for the inner insulation space.	
C-15	Special requirement A-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.	See **Ch.4 304.**
C-16	Notwithstanding special requirement A-22, piping handling hydrogen for an inner insulation space may pass through other inner insulation spaces.	
C-17	The requirements for type C independent tank should be applied to the inner shell.	
C-18	Manholes for access from or to the inner insulation space through the inner shell should not be permitted.	
C-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.	

Section 3 Explanation of special requirements

301. Welding of the outer shell

1. As mentioned in **Ch.4 102.**, the outer shell is a part of the insulation structure that has the function to contain hydrogen gas in the inner insulation space, but not to contain liquefied hydrogen.
2. Due to the high leakage of hydrogen, which is filled in inner insulation space, it is essential to ensure the reliability of tightness of the outer shell. This reliability is subject to evaluation and approval by the Administration. To ensure the tightness of the outer shell, equivalent welding requirements for the inner shell, i.e. cargo tank, should be applied to the outer shell as far as practicable. Therefore, all joints of the outer shell should be of the in-plane butt weld full penetration type, referring to **Pt 7, Ch 5 420. 1.** of **Rules for the Classification of Steel Ships**. On the other hand, it may not be practicable to use in-plane butt weld for the outer shell due to the construction procedure and structure. Considering that only gas is filled in the inner insulation space, no liquid pressure is applied on the outer shell. Therefore, using tee welds of the full penetration type is deemed acceptable for those areas, depending on the results of the test carried out at the approval of the welding procedure.
3. A manhole, when installed on the outer shell, can be sealed by gaskets or by welding. Welding is deemed to be a more reliable method to prevent hydrogen leakage, and removal of the backing rings is typically not possible due to the construction procedure. Considering that no liquid pressure is applied on manholes and backing rings, there is no significant concern from strength point of view. Therefore, not removing backing rings is deemed acceptable, unless any conceivable harmful effects, such as fatigue strength, are identified.

302. Testing of outer shell

While pressure testing is to be conducted on the outer shell to check for strength, filling the inner insulation space with water is unrealistic because the insulation materials are installed in the inner insulation space. In addition, it is assumed that only gas is stored in the inner insulation space, therefore, a pneumatic pressure test is sufficient to reproduce the operational condition of the outer shell. This special requirement is related to **Pt 7, Ch 5 420. 3.** and **423. 6. (7)** of **Rules for the Classification of Steel Ships**.

303. Pressure of the inner insulation space

Keeping an appropriate pressure of the inner insulation space is essential for preventing the inner and the outer shell from rupturing and buckling.

304. Leak detection for piping handling hydrogen for the inner insulation space located inside the inner insulation space

The purpose of special requirement A-7 is to avoid forming flammable atmosphere. Because the inner insulation space is filled with hydrogen, no additional risk is created by leakage of hydrogen from the places, located inside the inner insulation space, where leakage of hydrogen may occur such as valves, flanges and seals of piping handling hydrogen for the inner insulation space. Thus, special requirement A-7 does not contribute to improve safety for such piping, which is different from the piping for cargo handling. Provision C-15 is necessary to enable the design for control to change atmosphere or for maintenance.

References

1 ISO/TR 15916:2015, Basic consideration for the safety of hydrogen systems (ISO)
2 American Institute of Aeronautics and Astronautics, "Safety Standard for Hydrogen and Hydrogen Systems (Guide to Safety of Hydrogen and Hydrogen Systems)", 2005 (AIAA)
3 NFPA 2: Hydrogen Technologies Code 2016 Edition (NFPA)

Guidelines for Ships for carrying Liquefied Hydrogen in Bulk

Published by
KR
36, Myeongji ocean city 9-ro, Gangseo-gu,
BUSAN, KOREA
TEL : +82 70 8799 7114
FAX : +82 70 8799 8999
Website : http://www.krs.co.kr

Copyright© 2021, **KR**
Reproduction of this Rules and Guidance in whole or in parts is prohibited without permission of the publisher.