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1. Introduction

ClassNK has been working towards decarbonization for marine industry, by developing safety requirements and dedicated guidelines for new technologies, including carriage of unconventional cargoes, alternative fuels (such as hydrogen, ammonia, etc.) and energy saving devices. Particularly with regards to transportation of liquefied hydrogen, ClassNK was the first classification society to issue guidelines for liquefied hydrogen carriers. And we conducted the safety assessment and survey for the world's first liquefied hydrogen carrier, the "Suiso Frontier", built by Kawasaki Heavy Industries, Ltd. and added the vessel to its register in 2021.

ClassNK is also currently progressing design review and safety assessment for the 160,000m³ liquefied hydrogen carrier under development by Kawasaki Heavy Industries, Ltd. and have issued an Approval in Principle (AiP) for its "160,000m³ LH₂ carrier" integrated design, followed by, AiPs for "Cargo containment system", "Dual fuel main boiler using boil-off gas and related machinery system & arrangements", "Cargo handling system", and "Dual fuel generator engine using hydrogen gas as fuel and related machinery system & arrangements", separately.

In this situation, ClassNK updated its "Guidelines for Liquefied Hydrogen Carrier" through the experiences of design review and survey for the liquefied hydrogen carrier and released Edition 2.0 in August 2023. Based on the experiences and accumulated knowledge, Edition 2.0 of the Guidelines clarifies the details of some requirements and adds some explanatory guidance to make the Guidelines more practical. In this paper, the examples of new requirements in Edition 2.0 of the Guidelines are introduced, after an introduction of existing regulatory framework to liquefied hydrogen carriers.



2. Existing regulatory framework for LH2 carriers

International regulations for liquefied hydrogen carriers

Regarding the international regulations to the design and construction of liquefied hydrogen carriers, IGC Code and “Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk, Resolution MSC.420(97)” which was adopted in November 2016 are the basic set of the requirements.

In the IGC Code, the specific requirements to hydrogen have not been developed yet. In the light of such situation, safety requirements to a carriage of liquefied hydrogen in bulk were developed and organized in the Interim Recommendations Res.MSC.420(97). In the Interim Recommendations Res.MSC.420(97), it was acknowledged that the Interim Recommendations were intended to facilitate establishment of a tripartite agreement for a pilot ship, which would be developed for the research and demonstration of safe long-distance overseas carriage of liquefied hydrogen in bulk. Therefore, based on the Interim Recommendations and classification guidelines, the “Suiso Frontier” mentioned above was built. Currently, a revision work of the Res.MSC.420(97) to specify the safety requirements for new concept of cargo containment systems for large LH2 carriers have been considered from CCC8 held in September 2022. And the draft amendments will be discussed in CCC9 which will be held in September 2023.

Class rules and guidelines

ClassNK have developed specific “Guidelines for Liquefied Hydrogen Carrier” and its first edition was released in March 2017. The first edition was developed by incorporating the Interim Recommendations Res.MSC.420(97) with more detailed and supplementary requirements. The design review and surveys of the “Suiso Frontier” was conducted in accordance with the first edition of the Guidelines.

ClassNK have been working for updates of the Guidelines through the experiences and insights obtained from design review and surveys for the liquefied hydrogen carrier classification. In the following sections, key points of the revisions of the Guidelines are introduced briefly.



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3. Revision of Guidelines for LH2 carriers

Guidelines for Liquefied Hydrogen Carriers Edition 2.0

ClassNK “Guidelines for Liquefied Hydrogen Carriers (Edition 2.0)” was developed and released in August 2023. Based on the experiences and accumulated knowledge, some updates were incorporated into the Guidelines to make the requirements further clarified, reasonable and practical. Some examples of newly incorporated requirements are introduced in the following subsections.

In addition, ClassNK will continue to revise the Guidelines to remain it up to date with the latest developments. Especially, incorporating the revisions of the Interim Recommendations Res.MSC.420(97) will be carried out as the nearest revision to come.

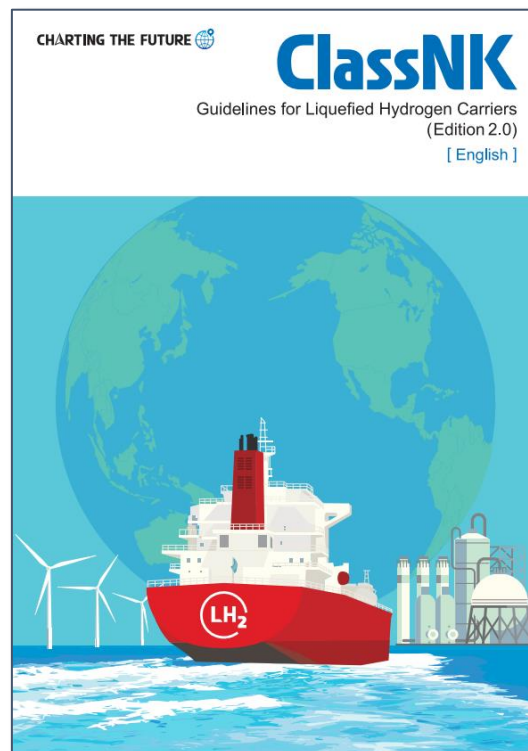


Fig.1 Guidelines for Liquefied Hydrogen Carriers (Edition 2.0), August 2023



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Safety requirements against LOX/LIN

In the **2.2.2-2** of the Guidelines, the requirements about thermal insulation of cargo process piping, pressure vessels and equipment to prevent the condensation of the surrounding air or oxygen are specified as below.

“2.2.2-2 (Thermal insulation of cargo process piping, pressure vessels and equipment)

Cargo pipes containing liquid hydrogen and cold hydrogen vapour, and other cargo equipment handling cryogenic cargo are, in principle, to be provided with adequate measures such as thermal insulation to prevent their exposed surface from reaching -183 deg.C or below which could cause condensation of the surrounding air or oxygen.

...”

In the Edition 2.0 of the Guidelines, more detailed and practical requirements are incorporated in this provision. The incorporated requirements cover the conceivable design that the formation of liquefied oxygen (LOX) within the insulation is unavoidable, or the insulation is intentionally omitted to prevent the contact of the insulation with LOX. For such spots, appropriate safety measures such as the exclusion of flammable substances nearby, ventilation to avoid the formation of highly enriched oxygen, and the installation of trays recovering liquid air. Those measures are to prevent the possible hazards due to LOX/LIN, such as fire due to enriched oxygen circumstance, and/or material brittleness of hull structures due to low temperature.



Holistic risk assessment procedure guidance - Annex 2 -

Risks related to liquefied hydrogen cargo are required to be assessed appropriately by the provisions of **2.2.18** of the Guidelines. This risk assessment should be conducted holistically for liquefied hydrogen carriers not to oversight any risks associated with liquefied hydrogen, however, as the risk assessment target components should be focused on, efficient way to assess them is important as well.

In this regards, the guidance for risk assessment with reference to the provisions of **2.2.18** of the Guidelines are developed in **Annex 2** of the Edition 2.0 of the Guidelines. The purpose of this guidance is to provide recommended procedures for conducting such risk assessment adequately and effectively.

In the recommended procedures, the assessment flow is mainly divided into three parts; system decomposition and screening analysis to determine the risk assessment target, system-level risk assessment and equipment-level risk assessment.

A screening analysis to determine the target components to be evaluated, which should be related to liquefied hydrogen cargo, will be conducted in the first part. For preparation of the screening analysis, system decomposition and analysis will be carried out. The purpose of this task is to accurately understand the design of the ship to be assessed by decomposing and analysing its system and components.

After the identification of the target components, system-level risk assessment will be conducted. This is the risk assessment for system, in which the target components are organized into physical or functional groups. Appropriate risk assessment methods such as HAZID, HAZOP and FME(C)A, etc. are selected in accordance with each system (group) characteristics and carried out.

In parallel to system-level risk assessment, equipment-level risk assessment will be carried out. This is the risk assessment for individual machineries, installations, etc. The procedures for equipment-level risk assessment are introduced in the next section.



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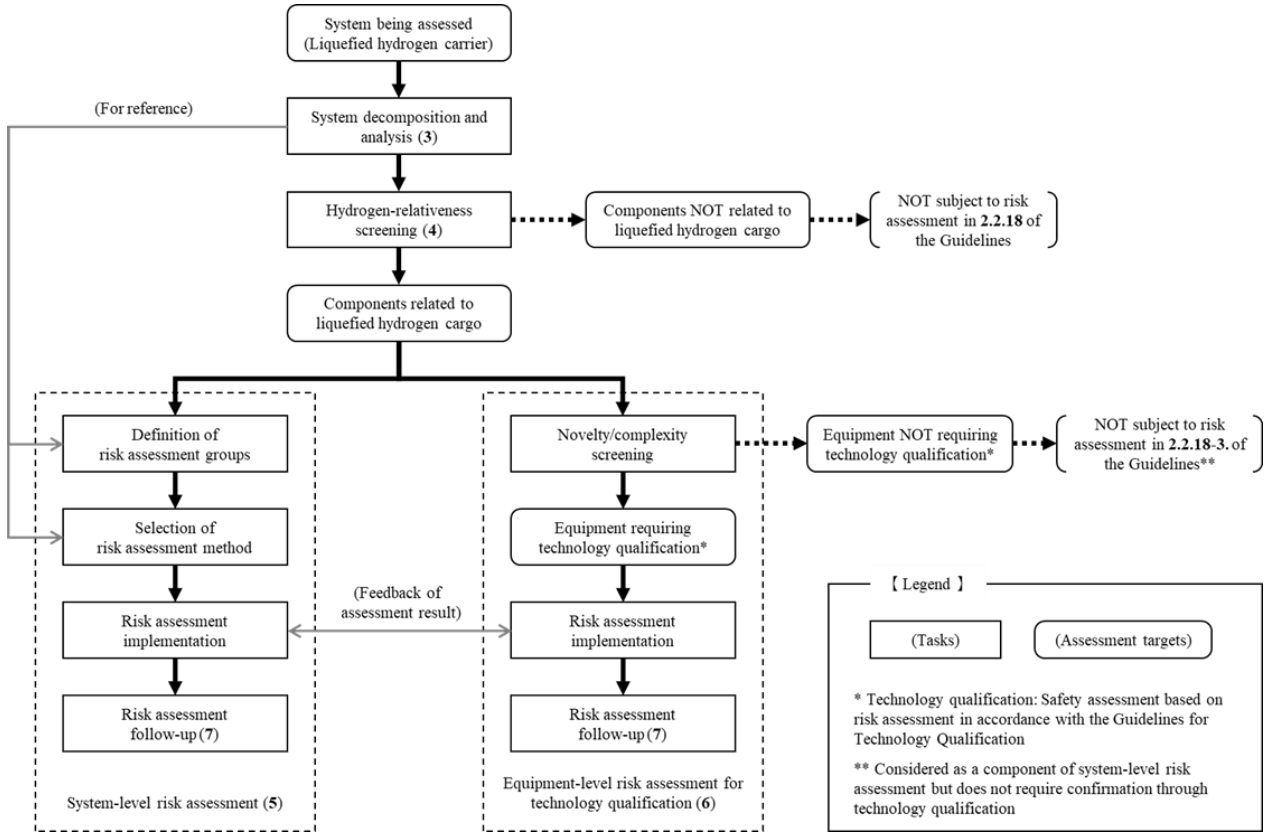


Fig.2 Overall flow of risk assessment (Annex 2 of the Guidelines)



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Risk based safety assessment to machineries, etc. - Application of Technology Qualification scheme -

In the provision of **2.2.18-3** of Edition 2.0 of the Guidelines, the requirement of risk-based safety assessment for equipment was newly incorporated. It requires that safety of the equipment associated with liquefied hydrogen cargo may be verified by risk-based approach, considering the novelty of its intended purpose and design specification. In such cases, the verification is to be in accordance with ClassNK “Guidelines for Technology Qualification”. The technology qualification scheme includes process of conducting risk-based technology assessment, development and execution of a qualification plan, and issuance of certification, finally.



Fig.3 Guidelines for Technology Qualification (Ver. 1.0), March 2022



Guidance for verification of comprehensive measures against hydrogen fire – Annex 3 -

Comprehensive measures against hydrogen fires should be considered in the design of liquefied hydrogen carriers in accordance with **2.2.14-1** of the Guidelines. And the validity of the measures should be assessed in the risk assessment in accordance with **2.2.18-2-10**. In this regard, the guidance for verification of comprehensive measures against hydrogen fires are developed and incorporated in **Annex 3** of the Edition 2.0 of the Guidelines. The purpose of this guidance is to provide recommended procedures for formulating the comprehensive measures against hydrogen fire and to outline the considerations to be taken in the risk assessment.

The flow of formulating and verifying comprehensive measures are as below:

- (1) Development of comprehensive measure philosophy
- (2) Clarification of fire safety measures
- (3) Identification of fire scenarios
- (4) Examination of fire safety measures
- (5) Risk estimation
- (6) Verification of comprehensive measures
- (7) Reporting

4. Conclusions

1. ClassNK have been striving to contribute to rule development, safety assessments and design review for liquefied hydrogen carriers.
2. ClassNK have contributed to the revision work of the Interim Recommendations Res.MSC.420(97) to specify the safety requirements for new concept of cargo containment systems for large LH2 carriers, and the draft amendment will be discussed in CCC9 which will be held in September 2023.
3. ClassNK have updated and released Edition 2.0 of its “Guidelines for Liquefied Hydrogen Carriers” in August 2023 through the experiences of design review, safety assessment and surveys for the liquefied hydrogen carrier classification to make the requirements further clarified, reasonable and practical.
4. ClassNK will continue to revise the Guidelines to remain it up to date with the latest developments. Especially, incorporating the revisions of the Interim Recommendations Res.MSC.420(97) will be carried out as the nearest revision to come.