

# Developing safety requirements and revised guidelines for liquefied hydrogen carriers through experiences of classification

**Tsubasa Andoh**

Manager, Technical Solution Department in Singapore  
ClassNK

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- ❑ Introduction – ClassNK activities to LH2 carriers –
- ❑ Existing regulatory framework for LH2 carriers
- ❑ Revision of Guidelines for LH2 carriers

# ClassNK activities relating to Hydrogen

## Production

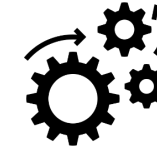


## Transportation

(See next pages)

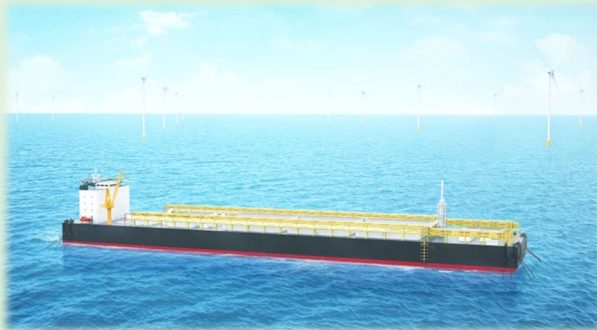


## Utilization



### Floating offshore hydrogen production plant

- Developed by J-DeEP (Japan Offshore Design & Engineering Platform Technology & Engineering Research Association)
- Extracting **hydrogen** from water through electrolysis, using surplus electricity from an offshore wind turbine.
- ClassNK issued Approval in Principle, April 2022.



Source: J-DeEP HP

### Hydrogen powered engine (project in Japan)

1. **HyEng Corporation Joint Development**
  - Development and onboard demonstration test (2027-) for three types hydrogen-fueled engine.
2. **JPN H<sub>2</sub>YDRO**
  - Delivered “Hydro BINGO”, the first hydrogen-powered ferry\*. (\*not registered in ClassNK)

### “Hydro BINGO”



Source: JPN H<sub>2</sub>YDRO HP

# Activities relating to LH2 carriers

## Classification of the “Suiso Frontier”

- ✓ World first LH2 carrier, delivered in Dec. 2021.
- ✓ Owned by “HySTRA”, design & built by “Kawasaki Heavy Industries”.
- ✓ Rule development, safety assessment, design approval and survey for classification.
- ✓ Gas trial including full load test and demonstrating LH2 loaded voyage / operation between Australia and Japan (2022).

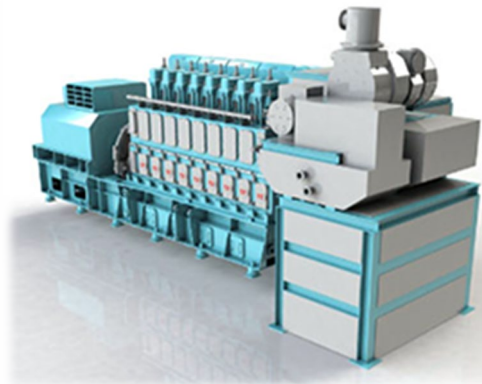


Source: HySTRA HP

# Activities relating to LH2 carriers

## Review and safety assessment for large LH2 Carriers

- ✓ Under development by “Kawasaki Heavy Industries (KHI)”.
- ✓ Rule development, safety assessment and design review are proceeding.
- ✓ Approval in Principle (AiP) have been issued for;  
*“160,000m3 LH2 carrier”* integrated design, followed by,  
*“Cargo Containment System”,*  
*“Dual-Fuel main boiler & related machinery system”,*  
*“Cargo Handling System”,* and  
*“Dual-Fuel generator engine & related machinery system”*



Source: ClassNK press

Image of Dual-Fuel generator engine



**160,000m3 Liquefied Hydrogen Carrier**  
(for illustrative purpose)

Source: KHI

# Activities relating to LH2 carriers

## Issuance of AiP to a membrane type containment system for LH2 carrier

- ✓ AiP for a Cargo Containment System (CCS) and Cargo Handling System (CHS) for LH2 carrier developed by GTT on July 2023.
- ✓ Feasibility of a new concept of membrane type containment system for LH2 carrier was confirmed.
- ✓ Design review in accordance with the relevant rules and guidelines and Hazard Identification (HAZID) workshop was conducted.



Source:GTT



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# Existing regulatory framework for LH2 carriers

## ➤ International regulations to liquefied hydrogen carriers:

### ❑ IGC Code

- Requirements to “hydrogen” have not been developed yet.

### ❑ **Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk (Res.MSC.420(97)), Nov. 2016**

- Safety requirements to a carriage of liquefied hydrogen were developed.
- Intended to facilitate establishment of a tripartite agreement for a “pilot ship”. (The “Suiso Frontier” was constructed, finally.)
- Revision work of 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, and the draft amendments will be discussed in CCC9 this September.

## ➤ Class rules & guidelines:

### ❑ **Guidelines for Liquefied Hydrogen Carriers (Edition 2.0) , August 2023, ClassNK**

- Original Edition 1.0 was established on Mar. 2017.
- Interim Recommendations Res. MCS.420(97) had been incorporated with additional more detail and practical requirements.
- The Guidelines was updated to Edition 2.0 through the experiences and insights obtained from design review and surveys for the liquefied hydrogen carrier classification. (Details are shown in the later slides)



# Interim Recommendations Res.MSC.420(97)

## ➤ Structure of the Interim Recommendations:

1. Introduction
2. Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk
3. Explanation on General Requirements
4. Special requirements against hazards of liquefied hydrogen

Table 1: Interim Recommendations for carriage of liquefied hydrogen in bulk  
(Minimum Requirements)

Product name	Ship type	Independent tank type C required	Control of vapour space within cargo tanks	Vapour detection	Gauging	Special requirements
Hydrogen	2G	-	-	Flammable	Closed	See Table 2

Table 2: Special Requirements for carriage of liquefied hydrogen in bulk  
(Total 29 Special Requirements)

No.	Special Requirement	Related hazard
6	At places where contact with hydrogen is anticipated, suitable materials should be used to prevent any deterioration owing to hydrogen embrittlement, as necessary.	Hydrogen embrittlement (see 4.3)

# Comparison of physical properties of Hydrogen and Methane

- Characteristics hydrogen was identified through comparison of physical properties to methane.
- Appropriate safety requirements had been developed in the Interim Recommendations Res.MSC.420(97)

	Hydrogen	Methane
Boiling temp. (K)	20.3	111.6
Liquid Density [Liq./Gas] (kg/m <sup>3</sup> )	70.8/0.084	422.5/0.668
Maximum burning velocity (m/s)	3.15	0.385
Flammability range (% vol)	4.0 – 75.0	5.3 – 17.0
Detonation range (% vol)	18.3 – 59.0	6.3 – 13.5
Minimum ignition Energy (mJ)	0.017	0.274
Autoignition temp. (°C)	585	540
Toxicity	Non	Non

## Hazards of liquefied hydrogen (examples)

- Low temperature (Material brittleness, LOX/LIN formation)
- High flame speeds
- Wide flammability range
- Wide detonation range
- Low ignition energy
- High pressure (BLEVE, RPT)

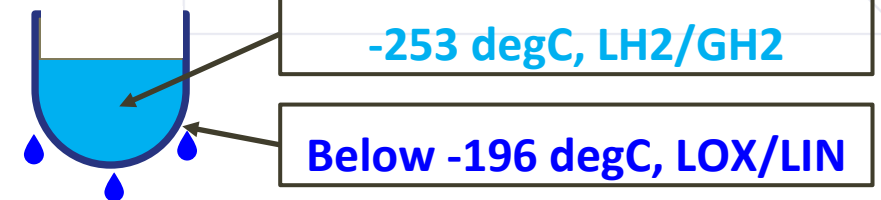


Image of LOX/LIN formation

# Guidelines for Liquefied Hydrogen Carriers Edition 1.0

- Guidelines for the design and construction of LH2 carriers, incorporating IMO interim recommendations Res.MSC.420(97), March 2017.
- Re-structuring and partly supplementing the interim recommendations with additional more detail and practical requirements.

e.g. Special Requirements in Interim Recommendations:  
**No. 12 “Vacuum insulation for CCS”**



## ❑ Special requirements (ClassNK guidelines)

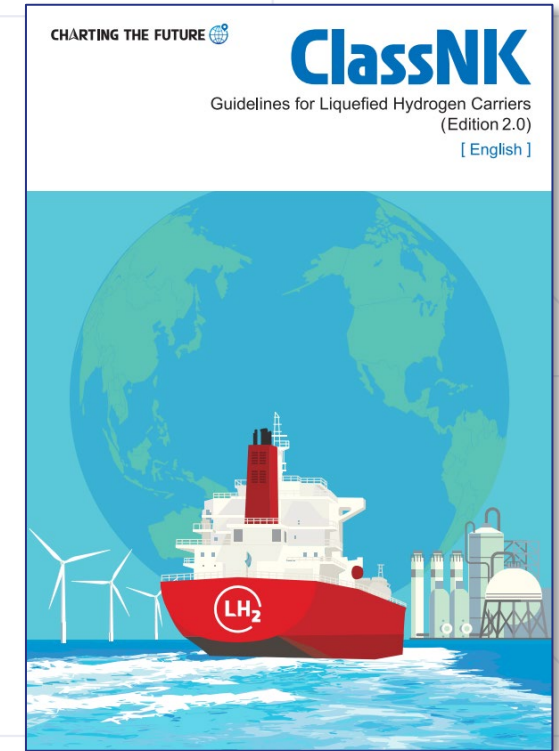
No	Special Requirement	IGC code	IR
2.2.3 -2.	(Consideration of ageing deterioration) <b>The ageing deterioration</b> is to be considered as follows. -2. Consideration of ageing deterioration is to be based on appropriate scenarios such as vacuum decay from seals and valves leaks, and outgassing from materials located inside the vacuum space.	4.19.3	12

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# Guidelines for Liquefied Hydrogen Carriers Edition 2.0

- **Edition 2.0 of the Guidelines have been developed and released in August 2023**, through the experiences of design review, safety assessment and survey for the liquefied hydrogen carrier classification.
- Based on the experiences and accumulated knowledge, some updates were incorporated into the Guidelines to make the requirements further clarified, reasonable and practical.
- Continuous revision work of the guidelines will be carried out, in terms of incorporating the revision of Interim Recommendation, etc.



**Guidelines for Liquefied  
Hydrogen Carriers (Edition 2.0),  
August 2023**

# Safety requirements against LOX/LIN

[Original requirements in Edition 1.0]

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

*Cargo pipes containing liquid hydrogen and cold hydrogen vapour, ..., 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.*

...

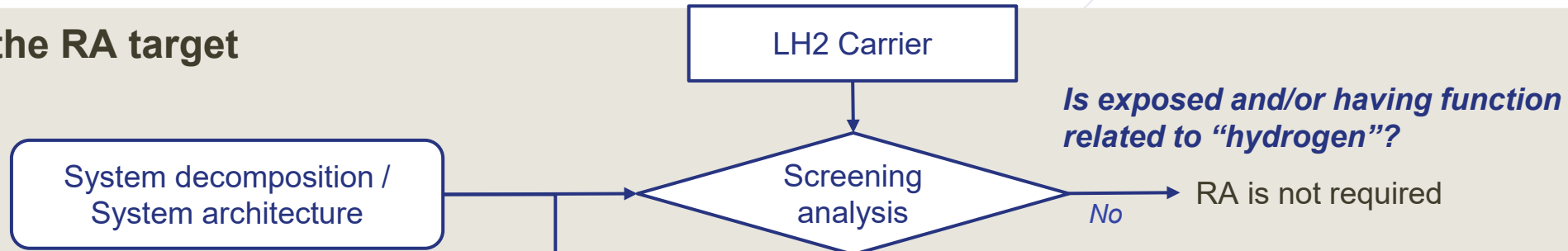
## [Added in Edition 2.0] More detail/practical requirements

- ✓ Where : The formation of LOX within the insulation is unavoidable, or the insulation is omitted to prevent the contact of the insulation with LOX.
- ✓ Safety measures : Appropriate measures to be provided such as the exclusion of flammable substance nearby, ventilation and the installation of trays.
- ✓ To prevent : Possible hazards due to LOX/LIN, such as fire due to enriched oxygen circumstance, material brittleness of hull structures due to low temperature.

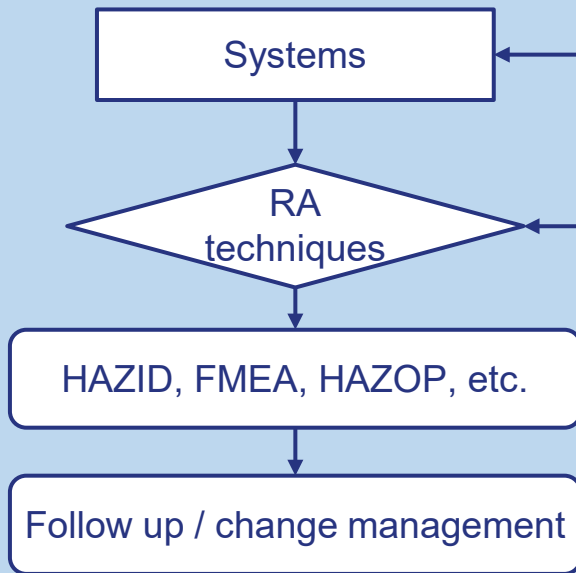
# Holistic risk assessment procedure guidance – Annex 2 –

[Added in Edition 2.0] Recommended detail procedures of risk assessment required by 2.2.18-1 of the Guidelines (IR-No.25).

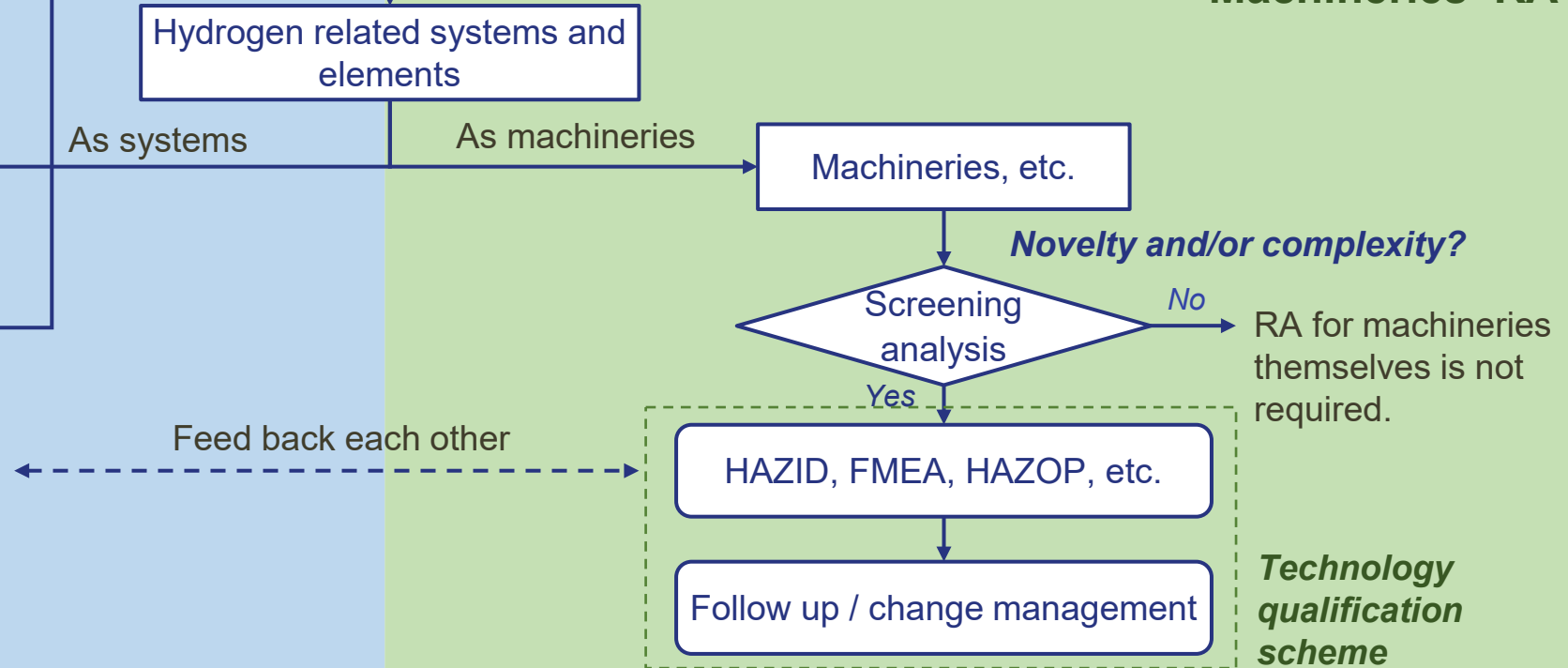
## • Define the RA target



## • System RA



## • Machineries RA



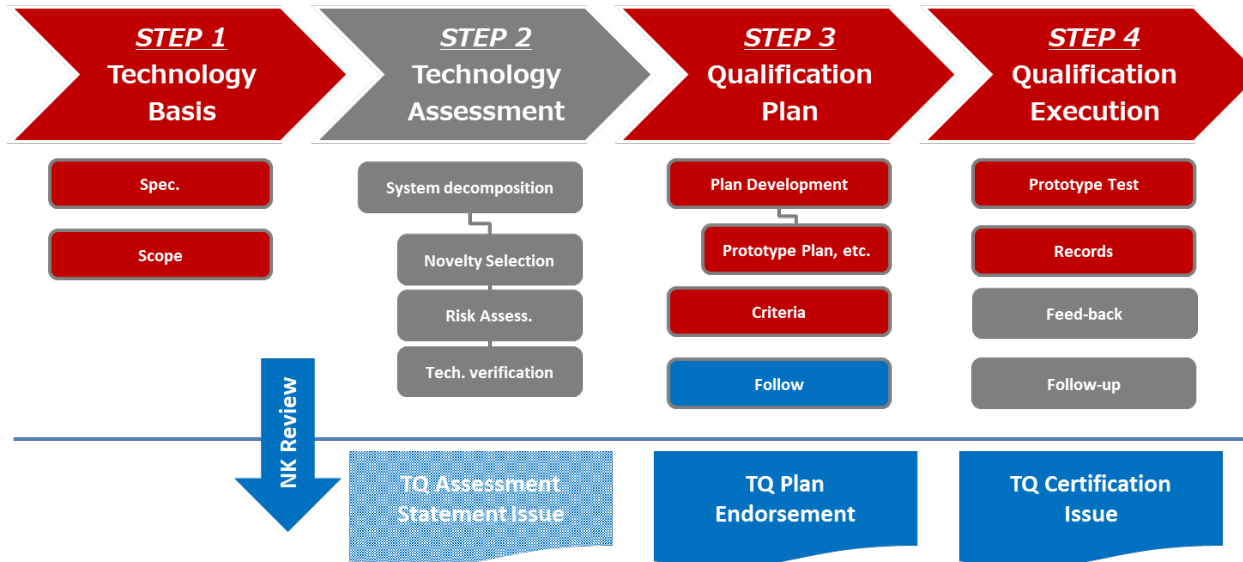


# Risk based safety assessment to machineries, etc.

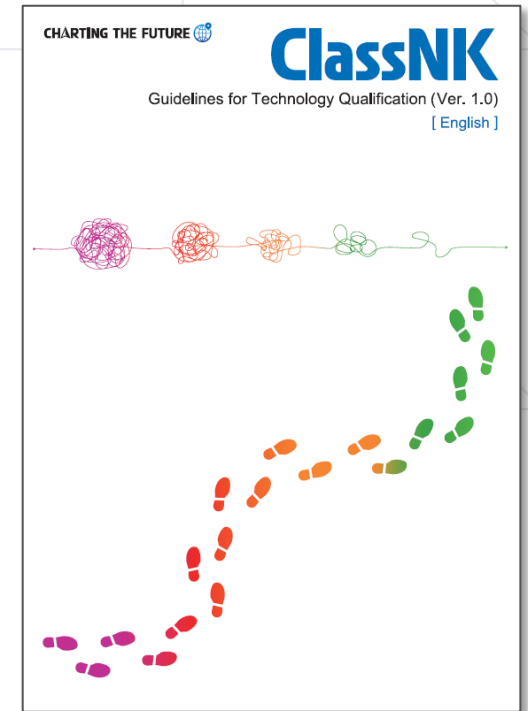
## - Application of Technology Qualification scheme -

[Added in Edition 2.0] Detail procedures of risk assessment to machineries (2.2.18-3 of the Guidelines)

- ✓ Hydrogen related machineries, etc. to be applied risk based safety assessment in accordance with the guidelines for technology qualification (TQ) depending on their novelty and/or complexity.
- ✓ The TQ scheme includes process of risk-based technology assessment, development and execution of qualification plan, issuance of certification.



Process of Technology Qualification



Guidelines for Technology Qualification, Mar.2022

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

[Added in Edition 2.0] Recommended detail assessment procedures relating to 2.2.18-2-10 of the Guidelines

- ✓ Evaluation of hydrogen fire risk and comprehensive measures to be considered in the risk assessment. (GL 2.2.18-2-10.)
- ✓ Comprehensive measures may include: eliminating ignition source, gas detection, ventilation, isolation of piping/machineries, fire fighting system, fire insulation, etc.
- ✓ The detail guidance of the assessment is developed in Annex 3.

## **Flow of formulating and verifying comprehensive measures :**

1. Development of philosophy of comprehensive measures against hydrogen fire
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

# Summary

- ClassNK is striving to contribute to safety assessments of various hydrogen related projects, especially for liquefied hydrogen carriers, and to develop safety requirements.
- We have been focusing on 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 this September.
- We have updated and released Edition 2.0 of the Guidelines for LH2 carriers through the experiences of design review, safety assessment and survey for the liquefied hydrogen carrier classification to make the requirements further clarified, reasonable and practical.
- We will continue to revise the Guidelines to remain it up to date with the latest developments. Incorporating the revisions of the Interim Recommendations Res.MSC.420(97) will be carried out as the nearest revision to come.

