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Decarbonization Magazine

Vol. 08 Autumn 2024 [ENGLISH]

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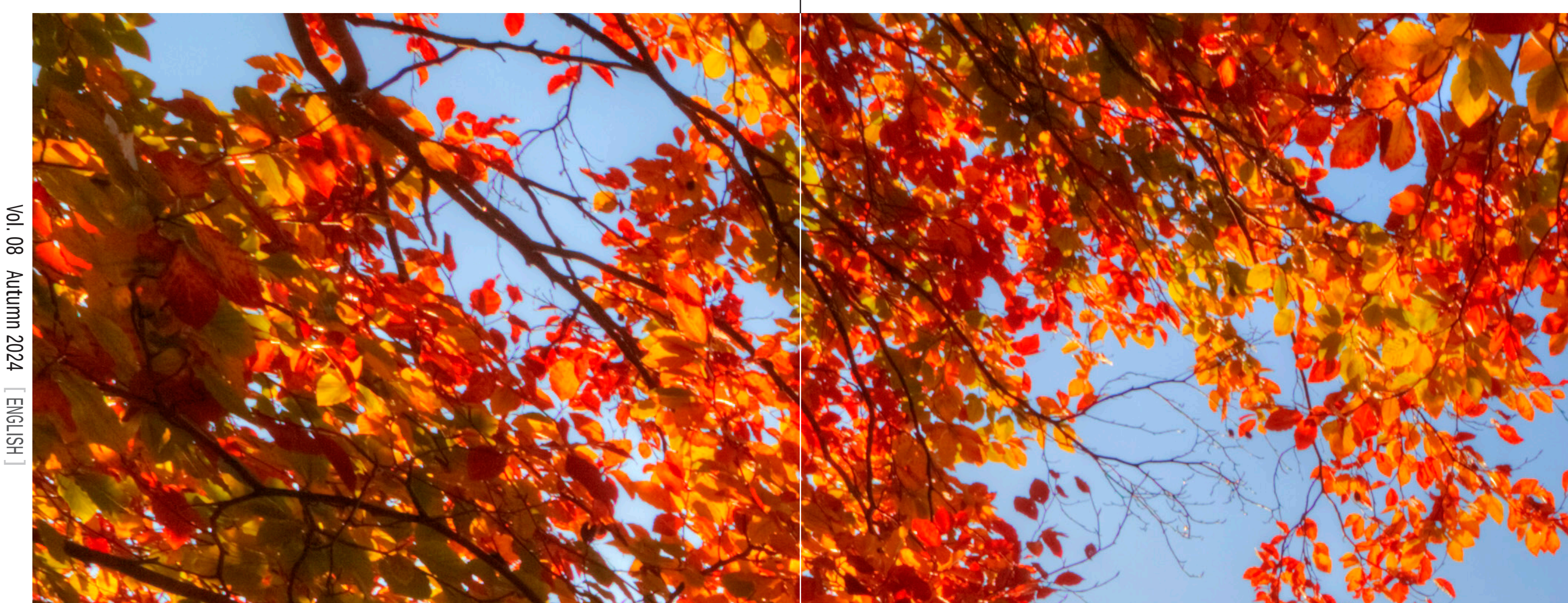

Vol. 08
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PROVIDING THE BEST SERVICES, CREATING A BETTER WORLD

KR is a world-leading, technical advisor to the maritime industry, safeguarding life, property and the environment through the pursuit of excellence in its rules and standards.

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Discussions surrounding the IMO's mid-term measures, which will significantly impact the shipping industry's future, are actively progressing toward approval at the MEPC 83rd session next spring. While considerable differences remain on key issues—including GFS (Goal-Based Fuel Standard) requirements, flexibility mechanism introduction, carbon fund scale, and carbon levies—much of the uncertainty surrounding these measures is expected to resolve by next spring. The focus now shifts to developing practical, concrete strategies to address industry changes following implementation. These strategies encompass alternative fuel selection, cargo owner cost-sharing, and green shipping route establishment.

This autumn edition presents statistical data and analysis on the CII (Carbon Intensity Indicator) ratings implemented in 2023. As anticipated, vessels with A and B ratings increased compared to 2022, while those with C and D ratings decreased. This shift primarily stems from speed reductions due to CII and EEXI (Energy Efficiency Existing Ship Index) regulations, along with partial adoption of biofuels.

To achieve domestic NDC (Nationally Determined Contribution) targets, increasing demand for overseas hydrogen imports will likely drive orders for ultra-large ammonia carriers and liquefied hydrogen carriers. Korea has become the first country to implement the CHPS (Clean Hydrogen Portfolio Standard), requiring power companies to produce a portion of their electricity from clean energy sources. With Japan and Europe expected to follow suit, various power generation methods are being explored: ammonia co-firing in coal plants, hydrogen co-firing in LNG facilities, and hydrogen power generation through fuel cells or engines. Initially, the most economical option—ammonia co-firing—will lead the transition toward hydrogen power generation. This edition also updates our summer coverage of liquefied hydrogen carrier technical developments.

Global engine manufacturers are accelerating ammonia engine development, with KSOE and HD Hyundai Heavy Industries focusing on four-stroke high-pressure variants. We feature an interview with Senior Executive Vice President Sang-ki Lee of HD Hyundai Heavy Industries, who leads their ammonia engine development. The discussion covers GHG reduction prospects, development progress and plans, exhaust gas aftertreatment systems, and critical operational safety considerations.

The Regulatory Updates section introduces alternative fuel and carbon reduction technology regulations under discussion by the IACS Safe Decarbonization Panel. As one of the IMO's key technical bodies, IACS actively participates in IMO convention development while maintaining close industry cooperation.

In the Inside KR section, we highlight several achievements: correcting a CII formula error, installing the world's first onboard carbon capture device on a 2,200 TEU vessel, publishing FuelEU Maritime guidelines for next year's implementation, and delivering a low-carbon sail cargo vessel with innovative GHG reduction technologies. Additionally, recent Gastec events in Houston featured multiple AIP (Approval in Principle) ceremonies for ammonia-powered container ships and ammonia fuel supply systems.

As IMO mid-term measure discussions advance rapidly, our next issue will provide focused analysis of the upcoming MEPC 82nd session deliberations.

Head of KR Decarbonization · Ship R&D Center SONG Kanghyun

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Insights_

2024 IMO DCS/CII Verification Results and Status

Kim Jinhee, Senior Surveyor of Green Ship Technology Team

The CII(Carbon Intensity Indicator) regulation, applying to ships engaged in international voyages of 5,000 GT and above, is enforced under Regulation 28 (Operational Carbon Intensity) of Annex VI of MARPOL(the International Convention for the Prevention of Pollution from Ships) adopted by the IMO. The first verification under this regulation took place in 2024. The CII, representing a ship's GHG emissions, is derived from reported and verified operational data in compliance with Regulation 27 (Collection and reporting of ship fuel oil consumption data) of MARPOL Annex VI.

Under the CII regulation effective since November 2022, ships subject to this regulation collected and reported their operational information for the period from January 1 to December 31, 2023. The CII values and ratings for each vessel were determined based on the reported data, with ratings assigned from A to E according to the IMO's CII rating criteria.

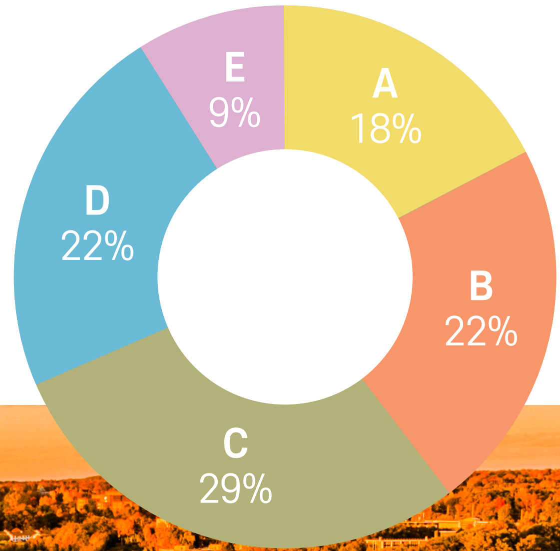
KR conducted the verification and certificate issuance this year through its GHG reporting and verification system for ships, KR GEARs. The following summarizes the current status of the verified CII ratings.

CII verification results of 2024

In compliance with IMO Regulation, KR verified a total of 1,652 ships by July 2024, of which 1,374 ships were subject to the CII regulation. The distribution and percentages of CII ratings across all verified ships are outlined below.

Rating	A	B	C	D	E
Number of Ships	241	303	397	308	125

CII Rating Status of All verified Ships

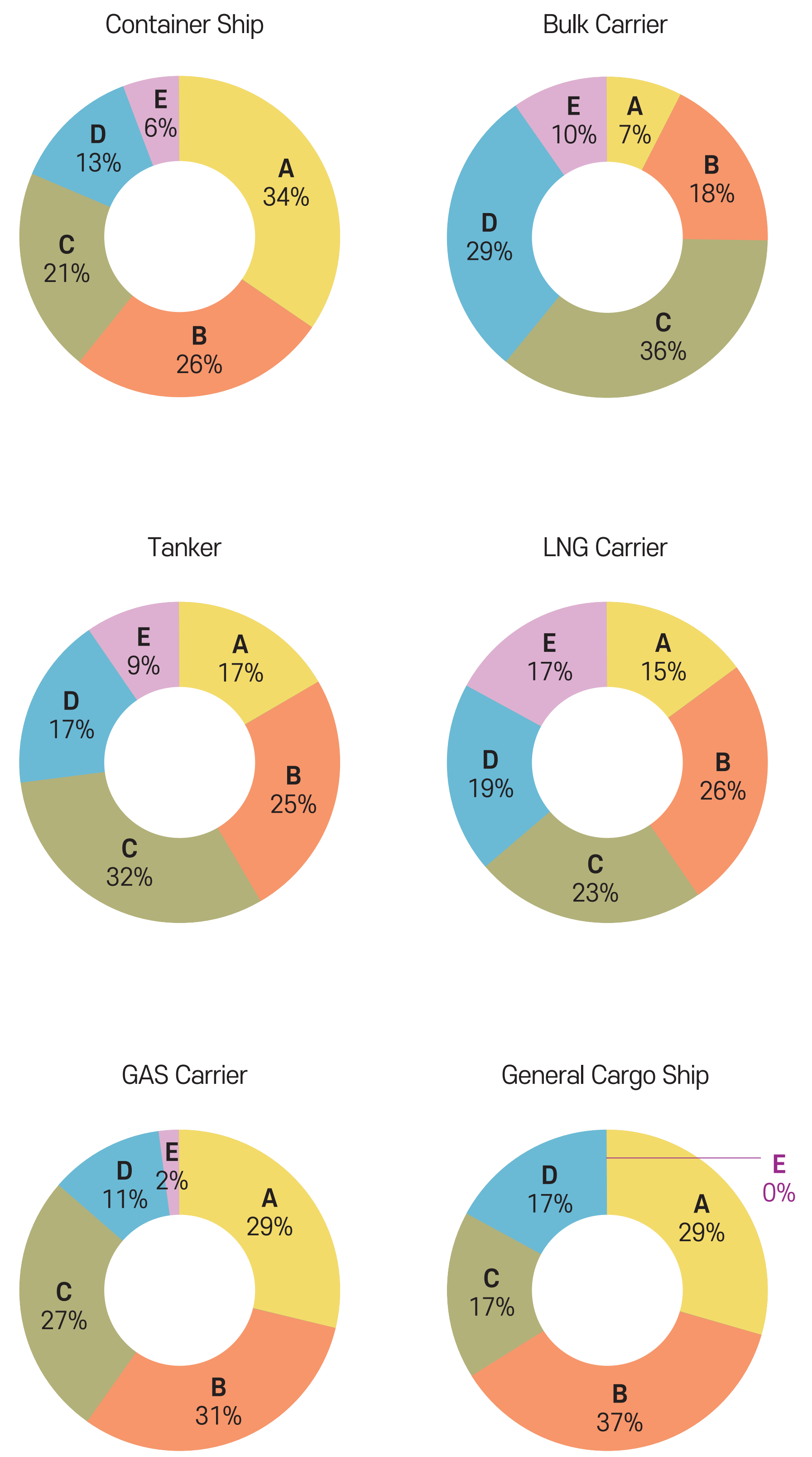


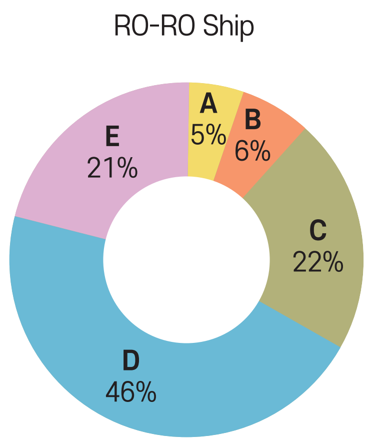
Additionally, by analyzing the results by ship type, the vessels were classified into 12 categories*. Ro-Ro cargo ships (vehicle carriers), Ro-Ro cargo ships, and Ro-Ro passenger ships were grouped under "Ro-Ro ships," while combination carriers and refrigerated cargo carriers were categorized as "Other ship types." The distribution of verified vessel types under the CII regulation is shown below.

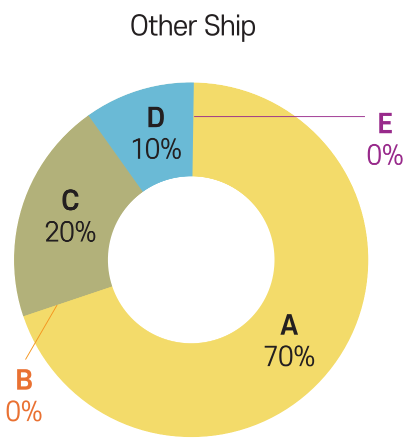
* Ship type subject to CII regulation : Bulk Carrier, Gas Carrier, Tanker, Container Ship, General Cargo Ship, Refrigerated cargo Ship, Combination carrier, LNG Carrier, Ro-Ro cargo ship(vehicle carrier), Ro-Ro cargo ship, Ro-Ro Passenger Ship, Cruise passenger Ship with non-conventional propulsion

Ship Type	Number of Ships	Proportion
Container Ship	267	19%
Bulk Carrier	462	34%
Tanker	360	26%
LNG Carrier	47	3%
GAS Carrier	52	4%
General Cargo Ship	71	5%
RO-RO Ship	105	8%
Other Ship (Combination Carrier, Refrigerated Cargo Carrier)	10	1%
Total	1,374	100%

And the following charts display the proportions of CII ratings for each ship type.

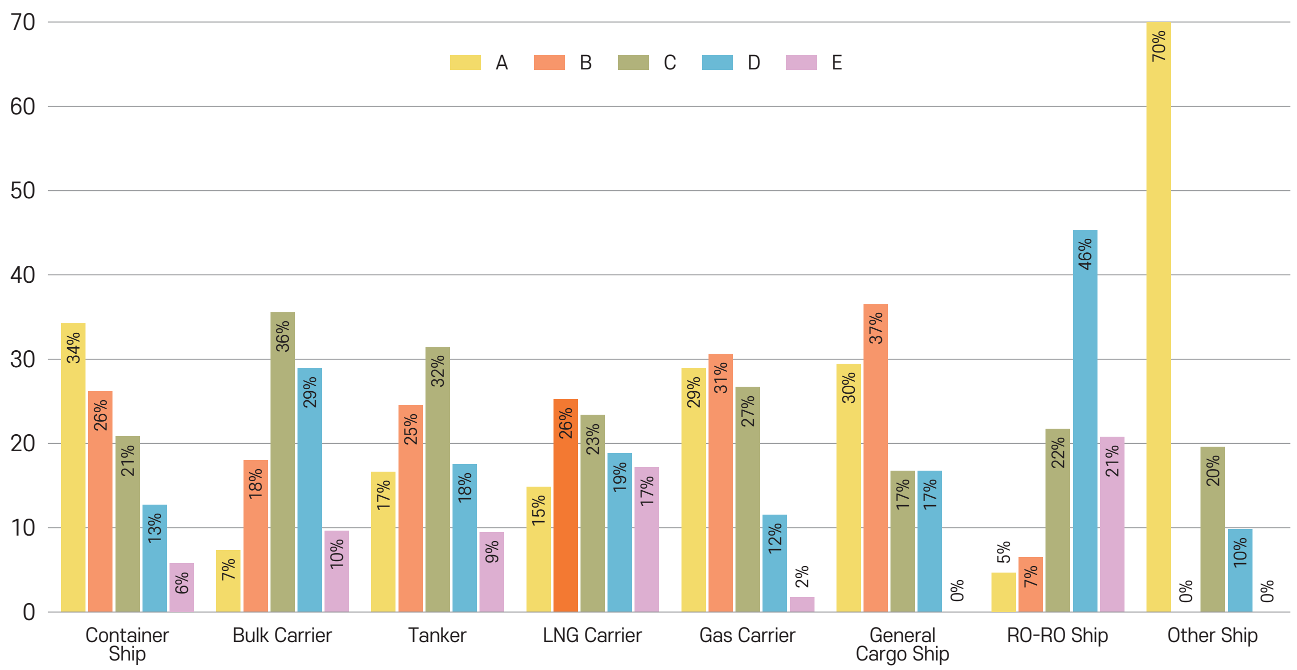






The graph below compares the distribution of CII ratings across different ship types.

CII Rating Distribution by Ship Type



KR's verification results for CII ratings showed a ratio of 4:6 between high ratings (A~B) and low ratings (C~E). An analysis by ship type reveals that over 50% of the ships for Container Ships, Gas Carrier, General Cargo Ships had high ratings. By contrast, bulk carriers and Ro-Ro ships demonstrated a higher proportion of low ratings, with 75% of bulk carriers and 89% of Ro-Ro ships falling into the low-rating categories.

Comparison with 2023 IMO DCS Verification Results

To assess the 2024 CII values and ratings, a comparison was made with the IMO DCS data from 2023. The 2023 data was adjusted using the same reduction rates applied in 2024 to enable a direct comparison of the CII rating distribution.

A comparison of the overall CII rating distribution indicates a decrease in the number of ships rated E in 2024 compared to 2023.

Rating / Year	A	B	C	D	E
2023	12.1%	20.3%	28.3%	23.1%	16.2%
2024	17.5%	22.1%	28.9%	22.4%	9.1%

And the table below compares high and low CII rating distributions by ship type.

Ship Type	2023		2024	
	A~B	C~E	A~B	C~E
Container Ship	44%	56%	61%	39%
Bulk Carrier	26%	74%	25%	75%
Tanker	39%	61%	41%	59%
LNG Carrier	41%	59%	40%	60%
Gas Carrier	53%	47%	60%	40%
General Cargo Ship	57%	43%	66%	34%
RO-RO Ship	9%	91%	11%	89%
Other Ship	80%	20%	70%	30%

Container ships, general cargo ships, and gas carriers saw an increase in the proportion of high CII ratings in 2024 compared to 2023. Conversely, bulk carriers, tankers, LNG carriers, and Ro-Ro ships showed little change in rating distribution.

Additionally, a comparison of average ship speed per year* by ship type for the 2023 and 2024 data revealed that, with the exception of LNG carriers and general cargo ships, all ship types experienced a speed reduction in 2024 compared to 2023.

* Distance traveled per year/ hours traveled per year, Unit : NM/Hour

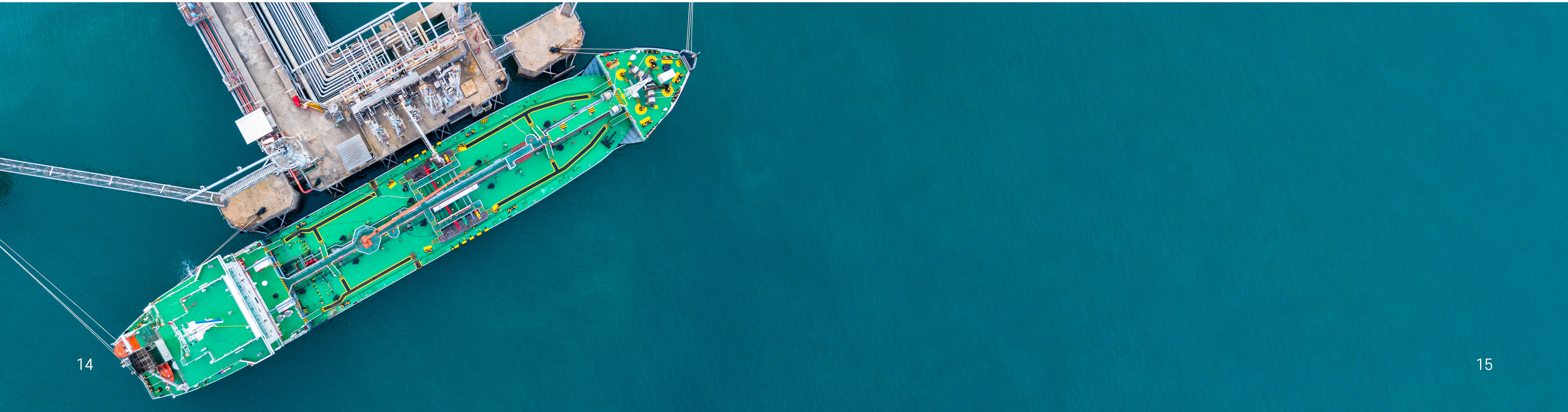
Ship Type	2023	2024	Difference
All Ships	11.84	11.93	↑0.09
Container Ship	13.31	12.70	↓0.61
Bulk Carrier	11.02	11.02	-
Tanker	11.05	11.03	↓0.02
LNG Carrier	14.11	15.18	↑1.07
Gas Carrier	13.61	13.55	↓0.02
General Cargo Ship	10.25	10.44	↑0.19
RO-RO Ship	15.73	14.77	↓0.96
Other Ship	13.29	12.93	↓0.36

General review of CII Verification Results and Status

Since this is the first year of CII regulation enforcement, there have been limited cases of adopting low-carbon fuels, such as biofuels, or implementing energy-saving technologies and GHG reduction technologies, largely due to practical challenges.

Analysis of data from 2023 and 2024 showed that the proportion of high-rated ships (A or B) increased by approximately 7%, while the proportion of E-rated ships decreased compared to the previous year. Vessels assigned an E rating in CII verification for a single year are required to implement improvement measures within their SEEMP (Ship Energy Efficiency Management Plan) Part III, which is subject to verification by a classification society. Fewer vessels belonged to E rating in 2024 than in 2023, likely due to efforts to mitigate administrative burdens and ensure compliance with the regulations.

Upon reviewing CII ratings by ship type, the distribution for most ship types, except for container ships and general cargo ships, remained similar in 2024 compared to 2023. This outcome suggests that the unique operational characteristics of each ship type should be considered when assessing their CII performance.



For container ships, the proportion of high CII ratings (A or B) increased from 44% in 2023 to 61% in 2024. An examination of the reported data, based on the assumption that the improvement results from ship speed optimization, indicated a reduction of approximately 4.6% in speed compared to 2023. In contrast to regular liner ships, such as container ships, bulk carriers often face extended port waiting times, leading to shorter voyage distances, which negatively impact their CII values.

Ro-Ro ships, particularly Ro-Ro cargo ships (vehicle carriers), continue to report a high proportion of lower CII ratings (C, D, E). These ratings reflect the economic challenges inherent in their operations, often driven by shippers' requirements or loading schedules. Despite a reduction in operating speeds in 2024 compared to 2023, these vessels still require relatively high speeds due to their operational demands, which contributes to the lower ratings.

LNG carriers and gas carriers, sharing operational similarities with Ro-Ro ships, may also be subject to lower CII ratings due to their operational profiles. However, as they primarily use LNG, which has a lower emission factor than conventional fossil fuels (HFO, LFO, MG/MDO), their CII ratings generally outperform those of Ro-Ro ships.

Apart from ten vessels verified in 2024 that used low-carbon fuels (biofuels), there were limited instances of implementing optimal measures to improve CII ratings. With CII standards tightening each year, ships currently rated C may fall to a D rating in the coming years if operational data remains unchanged. This underscores the growing need for vessels to develop and implement action plans to achieve regulatory compliance. Therefore, it is essential for the maritime industry and related sectors to closely monitor regulatory compliance by analyzing annual CII rating trends.

Navigating Towards a Clean Energy Era: The Core Technologies of Liquid Hydrogen Carriers

ROH Giltae, Principal Surveyor of Alternative Fuel Technology Research Team

Introduction

Green hydrogen offers a sustainable alternative to fossil fuels and is expected to play a pivotal role in the decarbonization of various industries. However, due to regional differences in its production costs, intercontinental maritime transportation of green hydrogen is inevitable. Consequently, the demand for liquid hydrogen carriers is also projected to continuously increase. According to a report published by the International Energy Agency (IEA) in 2023, the cumulative number of liquid hydrogen carriers is expected to reach approximately 200 by 2050.

According to the growing global demand for hydrogen, Japan's "Hydrogen Frontier" has garnered attention as a notable first demonstration of a liquid hydrogen carrier. This vessel is designed to transport liquefied hydrogen from Australia to Japan and commenced its first voyage in December 2021. Leading the way with 'Hydrogen Frontier', various countries around the world are currently engaged in the R&D, and demonstration of liquid hydrogen carriers. (See Table)

This article will first describe the differences between liquid hydrogen carriers and conventional LNG carriers. Then, it will provide an overview of the current status and considerations for key technologies for liquid hydrogen carriers.

Development Status of Domestic and International Liquid Hydrogen Carriers

Delivered/ Planned Year	Company (Country)	Ship length (m)	LH_2 volume (m^3)	Power Source	CCS Type	Etc.
2021 (Delivered)	KHI (Japan)	116	2×1,250	DG*	Type C (Spherical)	Japan ↔ Austrailia
2025-2027	KSOE (S. Korea)	-	20,000	FC*	Membrane	AiP (2020)
2027	C-Job & H2Europe (Netherlands)	141.8	3×12,500	FC*	Type C (Spherical)	Scotland ↔ Germany
Concept Ship	Moss Maritime (Norway)	137	2×4,500	-	Type C (Spherical)	Bunker vessel
Concept Ship	Jamila (UK & Kuwait)	370	4×70,600	GT-CC	Type C (Cylinder)	-
Concept Ship	SHI (S. Korea)	-	160,000	-	Membrane	AiP (2021)
Concept Ship	SHI (S. Korea)	-	20,000	FC*	Type C	AiP (2022)
Concept Ship	KHI (Japan)	346	4×40,000	DF-ST	Type C (Spherical)	AiP (2022)
Concept Ship	GTT & Total Energies, etc. (France)	-	150,000	-	Membrane	AiP (2022,2023)
Concept Ship	CB&I, Shell (US, UK)	-	-	-	Type C (Spherical)	AiP (2023)
Concept Ship	Shell & Houlder (UK)	-	20,000	-	-	-

* Electric Propulsion Ship

Source: Int. J. Hydrogen Energy, 2024
※ Note. DG: Diesel generator, FC: Fuel Cell, GT-CC: Gas-Turbine Combined-Cycle, DF-ST: Dual-Fuel Steam Turbine.

Japan's Suiso Frontier:
The World's First Liquid Hydrogen Carrier

Source: HESC, 2020

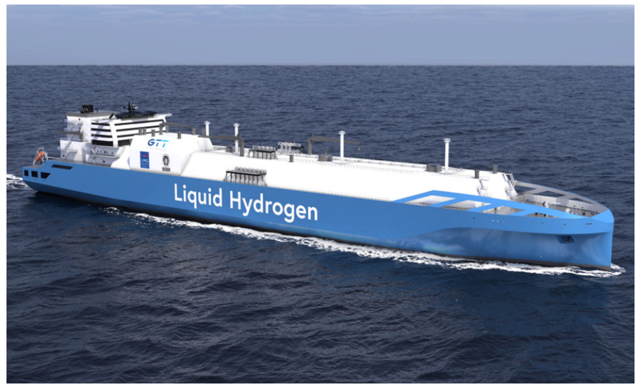
Concept of Liquid Hydrogen Carrier by
C-Job Naval Architects & LH_2 Europe

Source: C-Job, 2022

Concept of Liquid Hydrogen Carrier
Under Development by KSOE

Source: KSOE, 2021

Concept of a 150k-Class Liquid Hydrogen Carrier
Under Development by GTT and Total Energies

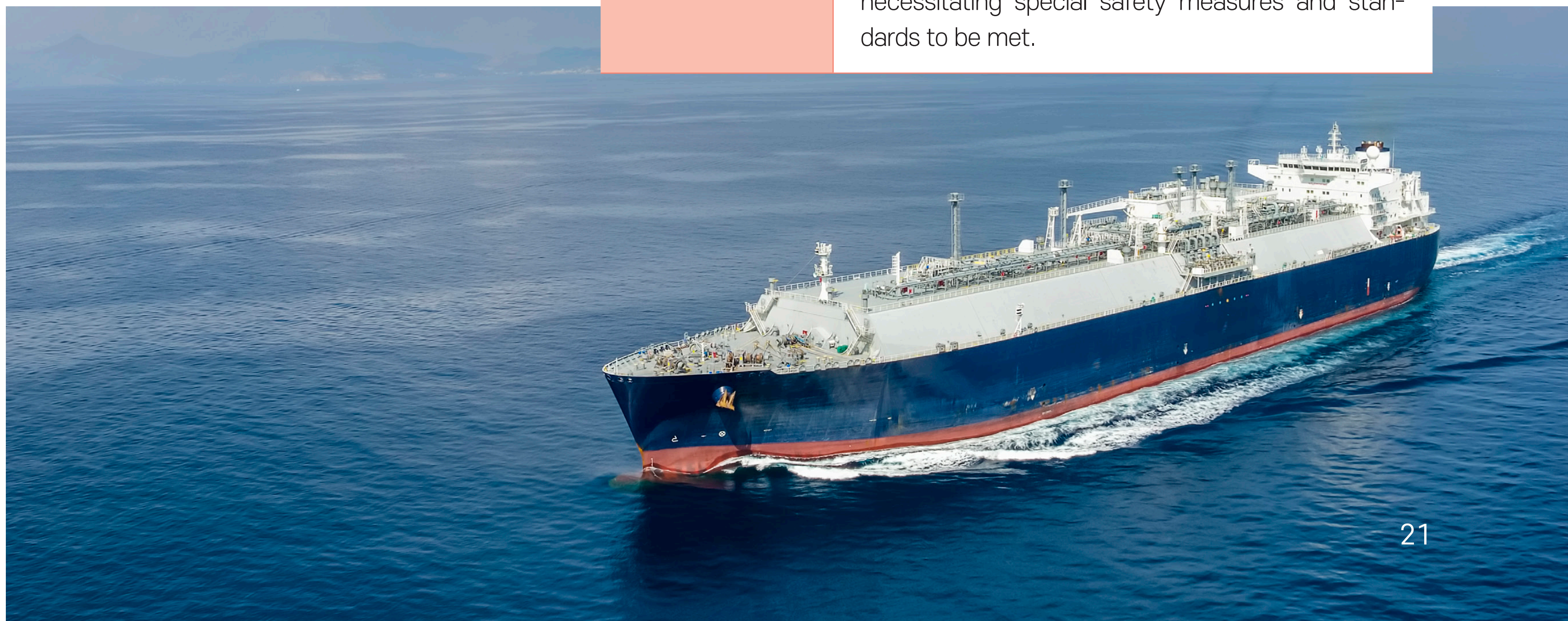


Source: GTT, 2024

Differences from LNG Carriers

Although liquid hydrogen carriers and LNG carriers utilize similar technical approaches, the distinct characteristics of their cargoes necessitate different design and operational technologies. These differences arise primarily from the physical and chemical properties of hydrogen (H_2) and methane (CH_4). The key differences are as follows:

Temperature & Pressure Control	Liquid hydrogen must be maintained at a much lower temperature (-253°C) compared to LNG (-162°C) to remain in its liquid state. This necessitates advanced insulation and cryogenic technologies beyond those used in LNG carriers.
Cargo Tank Design	For storing liquid hydrogen, currently applicable commercial technologies primarily use vacuum-insulated tanks or compressed C-TYPE tanks. However, for storing large volumes of hydrogen, similar to LNG, membrane tanks are more suitable. Research on cargo containment technology related to this is being conducted both domestically and internationally.
Safety and Environmental Regulation	The natural gas in LNG carriers is heavier than hydrogen and can linger in the air longer if leaked, posing an explosion risk, making safety measures crucial. In contrast, hydrogen is very light and highly diffusive, allowing it to disperse quickly into the atmosphere in the event of a leak. However, it still poses explosion and fire risks when concentrated, necessitating special safety measures and standards to be met.



Key Technologies of Liquid Hydrogen Carriers

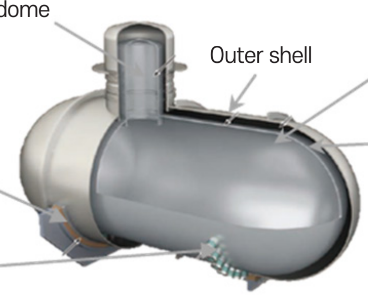
Cargo Containment System (CCS)

Liquid hydrogen carriers primarily use compressed C-TYPE tanks and membrane tanks for cargo containment. These two types of tanks are designed to meet different operational environments and requirements, with the main technical differences outlined below.

Independent Tanks Type C	C-TYPE tanks are cylindrical or spherical tanks capable of withstanding pressure, designed to store liquids or gases in high-pressure states. The walls of C-TYPE tanks have a double structure composed of vacuum and insulation materials, minimizing thermal loss. These tanks effectively reduce boil-off rates of liquid hydrogen by blocking thermal exchange through their own vacuum space. However, they are not well-suited for transporting large volumes of cargo due to spatial constraints.
Membrane Tank	Membrane tanks are designed to prevent direct contact with the liquid by lining the interior with a flexible membrane, allowing the tank to adapt to the thermal expansion of the liquid. Typically structured in layers, each layer is optimized for the storage conditions of liquid hydrogen, providing thermal and mechanical properties. These membrane tanks can be adjusted to fit the shape of the carrier's cargo hold and can freely expand and contract, making them suitable for transporting large volumes of liquid hydrogen.

Types of Representative Cargo Containment Systems
for Liquid Hydrogen Carriers

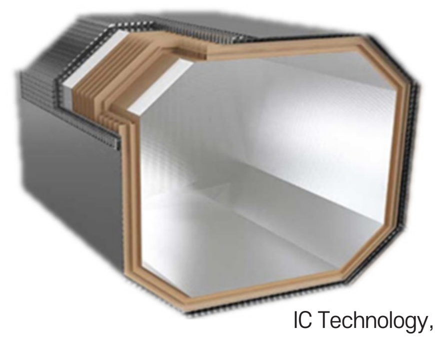
Cargo Hold Pressure Vessel



Kawasaki Heavy Industries, Japan

▸ CCS Overview	· Type C tank complying with pressure vessel standards · Tank size with 1,250m³
▸ Insulation System	· Double-shell vacuum insulation structure · Appliaction high reflectivity metalized Radiation Shield
▸ Material and Structure	· Austenite stainless steel fo cryongenic environment · Saddle of GFRP with excellent thermal properties

Cargo Hold Membrance



IC Technology, Norway

▸ CCS Overview	· Memberance type CCS with stainless secondary barrier · Target to ZBO (Zero Boil Off)
▸ Insulation System	· Double-shell vacuum insulation structure · Helisum circulation cooling system
▸ Material and Structure	· Flexible micro leak detection system (FMLDS) in vacuum membrance

Source: PNU Hydrogen Ship Technology Center

Bunkering System

The bunkering system is a technology that safely and efficiently supplies hydrogen to ships, incorporating the latest advancements in automation and remote control functions. Liquid hydrogen bunkering technology is still in the development stage, and the related component technologies are as follows.

Emergency Shutdown Systems (ESD)	To ensure rapid shutdown in case of any abnormal situations during the bunkering process, safety valves and automatic shut-off systems should be installed to promptly halt the supply.
Hose & Coupling System	The hoses and couplings used to transfer liquid hydrogen to the carrier must be made of materials that can withstand cryogenic temperatures and maintain excellent sealing performance. Additionally, they should be easy and quick to connect and disconnect.
Control & Monitoring System	For the safe refueling of liquid hydrogen, the temperature and pressure during the refueling process must be monitored in real-time. This ensures that the hydrogen remains securely sealed, preventing accidents due to leaks or overpressure. Furthermore, the bunkering process should be managed through an automated remote control system, with all operations being monitored and controlled centrally.
Boil-off Handling (BOH) System	Since a significant amount of Boil-Off Gas (BOG) can be generated during the bunkering process, measures must be taken to minimize the impact of potential safety incidents.

BOG handling system

Handling Boil-Off Gas (BOG) is one of the critical technical challenges for liquid hydrogen carriers. BOG refers to the hydrogen gas that gradually vaporizes from the liquid hydrogen in the storage tanks. Efficiently managing and utilizing BOG is crucial for enhancing safety and minimizing energy loss during transportation. The following technologies can be applied to address BOG handling:

Re-liquefaction Systems	The re-liquefaction system is a technology that converts the generated BOG back into a liquid state. This system uses heat exchangers and compressors to cool the hydrogen gas and re-liquefy it within the temperature and pressure range of liquid hydrogen. While this technology is very effective in improving energy efficiency and minimizing hydrogen loss, it is expensive and complicates the system.
Utilizing BOG as Fuel	BOG can be used as fuel for the ship's propulsion or power generation systems. This method is energy-efficient as it allows direct utilization of BOG without the need for re-liquefaction. In other words, BOG can be used to generate electricity or provide propulsion through hydrogen-fuelled power system installed on the ship. This concept is similar to the DFDE (Dual Fuel Diesel Electric) system used in LNG carriers. However, unlike LNG carriers that use dual-fuel generators/engines, liquid hydrogen carriers can use fuel cells, hydrogen engines, or hydrogen turbines as power sources since hydrogen is the primary fuel.
Pressure Management	The pressure in the tanks can be adjusted to manage the amount of BOG generated. By reducing or maintaining the pressure at appropriate levels, the vaporization of hydrogen can be minimized.
GCU (Gas Combustion Unit)	In case of safety requirements, it may be necessary to burn BOG through the GCU. The capacity of the GCU must be sufficient to consume the generated BOG, and this must be verified. From this perspective, periods of low-speed maneuvering and/or periods without BOG consumption due to ship propulsion or other operations must be taken into account.

IMO Regulations

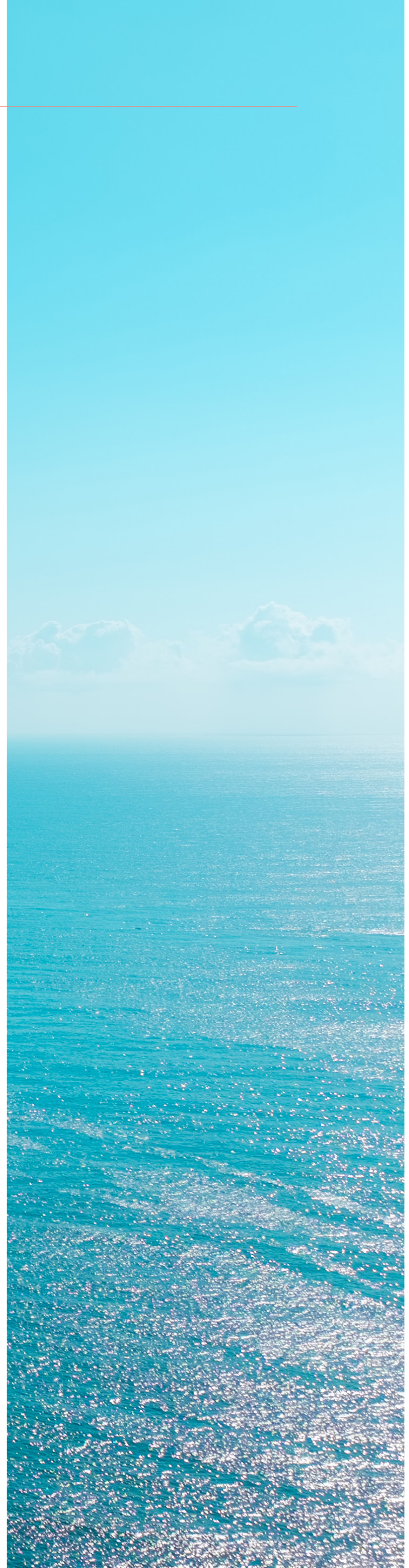
In November 2016, during the 97th MSC meeting, the document MSC. 420 (97) 'Interim Recommendations for Carriage of Liquefied Hydrogen in Bulk' was adopted. This document serves as an interim standard specifically applicable to the world's first 1.25k-class liquefied hydrogen carrier, 'Suiso Frontier.' In July 2021, during the 104th MSC meeting, Japan proposed an amendment to the recommendation to accommodate the transportation of large volumes of liquefied hydrogen. Subsequently, at the 9th CCC meeting in 2023, an agreement was reached on the draft amendment of the interim recommendations, and this document is scheduled to be submitted to the MSC. (The 108th IMO MSC meeting is scheduled to be held from May 15 to 24, 2024.)

Conclusions

In South Korea, there is a policy for introducing green and blue hydrogen via liquid hydrogen carriers. To meet the increasing demands for the hydrogen in S. Korea, Korea Gas Corporation (KOGAS) announced plans to establish infrastructure for importing 100,000 tons of liquid hydrogen from overseas by 2029. Additionally, in November of last year, the government unveiled the "K-Shipbuilding Next-Generation Leader Strategy," which includes a portfolio for securing core technologies for liquid hydrogen carriers as part of future low-carbon ship technologies.

However, there are still many technical challenges to be addressed for liquid hydrogen carriers. Overcoming these challenges will require government support and international technological cooperation for the long-term. Moreover, establishing international regulations will be crucial for verifying safety and enhancing reliability.

Korean Register has been engaged in research and development related to liquid hydrogen carriers for many years, steadily improving its technological capabilities. And our KR plans to continue its efforts to solve the technical challenges associated with key technologies of liquid hydrogen carriers and contribute to the transition of the ecosystem towards the hydrogen industry.



Key Technologies Related to Liquid Hydrogen Carriers

Reliquefaction System

· Minimize H_2 Loss: tank pressure accumulation system
· Control heat ingress into cargo tank

Loading/Operation

· Loading arm is designed specifically for safe handling and operation with extremely-low-temperature LH_2

Transfer System

· Vacuum insulated flexible pipe&joint that permits 360-degree rotation while maintaining thermal insulation

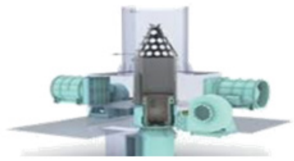
System

· Hydrogen can cause explosions if it is not handled property
· Gas snuffing system, Emergency release system (ERS)

Cargo Heater/Compressor

· Tank warming (gas freeing operation)
· The gas is heated about 80°C and pumped to the tank

Gas Combustion Unit



· Redundancy (Vapor / BOG hanling)
· Safe disposal of contaminated H_2

※ Source
1. International Energy Agency (IEA). 'Energy technology perspectives' (Jan. 2023)
2. Kim, K., et al. 'Economic study of hybrid power system using boil-off hydrogen for liquid hydrogen carriers' International Journal of Hydrogen Energy 61 (April 2024)
3. Press Release, "Leading the World with the 'Next-Generation K-Ship Strategy'" (Nov. 2023)
4. Ministry of Oceans and Fisheries & KMC, "International Maritime Decarbonization Trends" (Nov. 2023)

Interview_

Interview with Ammonia Engine Expert

Rhee Sangkee, Executive Vice President of Design & Engineering
Engine & Machinery Business Unit, HD Hyundai Heavy Industries

Q. Due to the uncertainty surrounding fuel options in the shipping industry's path to carbon neutrality, it is expected that various fuels, rather than a single dominant one, will be used. How do you assess the importance of ammonia fuel among these alternative fuels?

A There are several fuels being considered for greenhouse gas (GHG) reduction, including biofuels, LNG, methanol, ammonia, and hydrogen. In the transition to carbon-neutral fuel for shipping, the share of each fuel may vary depending on the ship owner or type of vessel. However, LNG is expected to continue being used, and biofuels will likely serve as transitional fuels. That said, the limited production of biofuels may restrict the amount available for maritime use, leading to the potential use of various e-fuels (e-LNG, e-Methanol, e-Diesel) based on green hydrogen.

Ammonia, on the other hand, is expected to be less costly to produce and to have fewer production limitations than other fuels. Given its well-established bunkering and supply infrastructure, if operational safety for ship propulsion can be ensured, ammonia could have a competitive advantage over other fuels. This is also true for hydrogen. While hydrogen may seem like the ideal fuel, if its transportation challenges, due to the need for cryogenic conditions for liquefaction and its low energy density, are not resolved, ammonia is likely to hold a competitive edge under current conditions.

Q. There is significant interest in HD Hyundai's HiMSEN ammonia dual-fuel engine. Can you share the current development progress?

A The world's first 4-stroke H22CDF-LA engine, which uses high-pressure ammonia combustion, completed its type approval test with classification societies in October. The HiMSEN ammonia engine has been developed with the goal of achieving high output and reducing greenhouse gas emissions by more than 90%. Additionally, our 2-stroke main propulsion ammonia engine also employs a high-pressure system. When used together with the HiMSEN ammonia engine, the fuel supply systems for ships become simplified, which is another advantage. Next year, we plan to expand our ammonia dual-fuel engine portfolio by conducting classification type approval tests for the HiMSEN H32CDF-LA engine.

Q. The shipping industry is curious about the flow rate of pilot oil in 2-stroke and 4-stroke ammonia engines. Some argue that using traditional diesel as pilot fuel may prevent these engines from being fully carbon-neutral. What is HD Hyundai's target for pilot oil quantity in upcoming engine type approval tests, and are you considering biomass-based carbon-neutral pilot fuels?

A While the use of a certain amount of pilot fuel is inevitable, we are striving to minimize the amount of pilot fuel in the HiMSEN ammonia engine to maximize GHG reduction. Since using diesel as the pilot fuel would prevent the engine from being truly carbon-neutral, we are preparing to use biofuels that meet the International Maritime Organization's (IMO) carbon-neutral fuel standards as pilot fuel. For example, our methanol HiMSEN DF engine has been proven to ignite using biofuels and has been validated on ships.

Q. The industry has noted that you recently developed the world's first 4-stroke methanol engine in a short period of time and are now close to conducting actual type approval tests for a high-pressure ammonia engine. What has been the driving force behind shortening the development period for these engines?

A We have accumulated over 30 years of design expertise with HiMSEN engines and have cultivated excellent R&D personnel through our Engine Research Institute within the Engine & Machinery Business Unit. By building on the platform of HiMSEN engines, which dominate the 4-stroke market, we have focused on optimizing new technologies for green fuel supply and injection systems.

In addition, close collaboration with Advanced Research Center of Korea Shipbuilding & Offshore Engineering (our parent company) and networking with leading domestic and international universities and research institutions, including KR (Korean Register), has helped us enhance the engine's completeness and safety while shortening the development period.

Q. There is a lot of curiosity about the emissions from ammonia engines, including concerns over ammonia slip and the emissions of nitrous oxide (N_2O), which has a high global warming potential. To address these issues, it seems that an aftertreatment systems are ready during engine development. Could you introduce the methods you've established for reducing and managing emissions in the HiMSEN ammonia engine?

A We are paying close attention to emissions during the development of ammonia engines. While maximizing efficiency was the key focus for previously developed engines (LNG, diesel, etc.), the priority for ammonia engines is to minimize nitrous oxide emissions and reduce ammonia slip, or ensure that any unburned ammonia is removed in the aftertreatment system.

Other developers of 2-stroke engines are known to follow a similar strategy. HiMSEN ammonia engines are continuously improve the engine performance and reduce the unnecessary emissions generated such as slip of Ammonia with nitrous Oxide. We effort to make a high efficiency combustion to find the minimize emission levels. At the moment the actual test results cannot veil but we can support to the customer to establish their strategies.

Q. Can you explain the safety philosophy behind the HiMSEN ammonia engine?

A Whilst there is limited experience in operating ammonia engines, there are learnings from other fueled engines. For example, the HiMSEN ammonia engine uses double-walled fuel supply piping and purging systems, similar to other low-flashpoint fuel engines. Additionally, ammonia slip is minimized by the engine itself, and the ammonia concentration is further reduced after passing through the aftertreatment system.

We are also working to make the HiMSEN ammonia engine easy to operate and maintain, with a user-friendly design.

Q. Once ammonia engines are developed, improvements may still be necessary. How do you plan to address such issues?

A Several methanol-powered ships equipped with methanol engines are currently in operation. We receive feedback from ship engine manufacturers and shipyards regarding the performance, safety, and stability of these engines, which helps address any issues and establish the product in the market.

Even after receiving type approval from the classification society, HiMSEN methanol engines continue to undergo performance and durability improvement tests. Any necessary improvements will be communicated to shipowners. We expect a similar process for ammonia-powered ships and engines.

Q. Ammonia fuel is expected to play a significant role in global decarbonization. How do you view the competition between ammonia fuel cells and ammonia engines?

A It is generally true that fuel cells are more efficient than internal combustion engines. While solid oxide fuel cells (SOFCs) could be applied to medium-to-large vessels, they lack the acceleration performance of internal combustion engines. Therefore, in electric propulsion ships, a hybrid propulsion system might be considered, where 4-stroke internal combustion engines manage the load fluctuations caused by changes in operating conditions, while SOFCs handle the base load.

However, for medium-to-large vessels, the key challenge for the expanded application of electric propulsion systems will be how to minimize the cost and space required for SOFC installation. Even though SOFCs are more efficient, their efficiency would still be lower than 2-stroke internal combustion engines when accounting for electricity conversion losses, which would need to be offset by new technologies. SOFCs may be applied in the short term as supplementary power (PTI), but their inherent challenges must be addressed. Also, if ammonia SOFCs are used, the efficiency losses due to reforming would need to be considered.

Q. After developing the ammonia engine, the next step seems to be hydrogen engines. HD Hyundai has already completed the development of LNG-hydrogen co-combustion technology. Could you tell us about your plans for hydrogen engine development?

A Hydrogen engines are expected to be used as propulsion for hydrogen carriers. This year, we plan to test a hydrogen-diesel co-combustion engine, and we are preparing to test a fully hydrogen engine in the near future. Recently, we started a government R&D project with KR and others to develop a hydrogen injector. Once the hydrogen engine is developed, we expect to complete our lineup of engines for all alternative fuels.

Q. Lastly, what recommendations or advice would you give to shipowners and engineers regarding ensuring the safety of ammonia usage?

A In the early days of LNG dual-fuel engines, there were many concerns about handling LNG at 300 bar. However, LNG has since been recognized as a safe alternative fuel and is widely used.

Methanol, although harmful to humans, is being safely operated as an alternative fuel, and the systems of methanol and ammonia engines are not significantly different. While it's true that ammonia has different risks compared to other fuels, safety technologies for ammonia fuel propulsion and transport are currently being developed.

Based on our experience with LNG, LPG, and methanol, we expect to overcome the safety challenges of ammonia as well.

To address global warming, eco-friendly fuels that can replace HFO and LNG must be applied to ships. Addressing the associated costs and safety risks is a shared challenge, but we believe it also presents a golden opportunity for the Korean shipbuilding industry to differentiate itself from competitors, such as China.

Regulatory Updates_

IACS's Proactive Safe Decarbonisation Initiatives

The International Association of Classification Societies (IACS) is at the forefront of maritime decarbonisation. The IACS Safe Decarbonisation Panel (SDP) is leading initiatives to ensure the safe adoption of alternative fuels and technologies in the maritime industry. This article highlights their proactive measures and future plans.

1. Ammonia as Marine Fuel

IACS has published Unified Requirement (UR) H1* in January 2024. This UR controls ammonia releases in ammonia-fueled vessels, setting safety thresholds for ammonia concentrations in manned spaces. The SDP's Project Team (PT) is also working on a draft UR for ammonia treatment systems, aligning with the IMO's guidelines.

* UR H1 on Control of Ammonia Releases on Ammonia Fuelled Vessels

2. Hydrogen Fuel Innovations

The PT on hydrogen is developing URs for materials, testing, Type C tanks, and swappable tanks. These efforts aim to manage hydrogen's unique challenges as a marine fuel, ensuring its safe and effective use in the maritime sector.

3. Electrical Energy Storage Safety

IACS is addressing safety concerns related to lithium batteries. A draft UR on lithium battery approval has been produced, with further rounds of correspondence underway. The SDP is also focusing on plant configuration and necessary URs to mitigate risks, particularly those related to explosive and toxic hazards.

4. Carbon Capture

IACS has identified six feasible technologies for shipborne carbon capture and completed the first risk analysis session. The development of a draft UR on carbon capture is progressing smoothly, crucial for reducing the maritime industry's carbon footprint.

5. Gas Dispersion Analysis

IACS is developing guidance for simulating gas releases using models like Computational Fluid Dynamics (CFD). This aims to standardize the review methodology for gas dispersion analysis reports, ensuring effective management of hazardous gas concentrations.

6. Nuclear Power for Maritime Use

IACS has initiated a project team focused on nuclear power for maritime applications, collaborating with the IMO, IAEA, and WNTI. The goal is to identify licensing schemes, propose roles for IACS and class societies, and recommend requirements for nuclear-powered vessels.

7. Collaborative Efforts

IACS has partnered with the Singapore Maritime and Port Authority (MPA) to share information, develop technical standards, and conduct joint studies on gas dispersion. This collaboration aims to foster a safer and more sustainable maritime industry.

8. Conclusion

IACS is leading in advancing maritime safety and sustainability. Through rigorous safety standards and strategic collaborations, IACS is laying a solid foundation for the safe adoption of alternative fuels and technologies. The initiatives of the IACS SDP will play a pivotal role in shaping a greener and safer future.

KR Decarbonization Magazine

Inside KR_

KR Enhances Korean-Flagged Vessel Ratings Through CII Calculation Error Correction

KR, in collaboration with the Ministry of Oceans and Fisheries, has corrected errors in the CII calculation and successfully reached an agreement on these amendments at the 81st IMO MEPC meeting. This revision benefits 76 bulk carriers and car carriers by improving their CII ratings by at least one grade.

What is Carbon Intensity Indicator (CII)?

The Carbon Intensity Indicator (CII) is an international regulation targeting ships engaged in international voyages with a gross tonnage of 5,000 tons or more. This regulation calculates the CII value based on the annual fuel consumption and the distance sailed by the ship, comparing it to international standards and assigning a grade from A to E. An A grade indicates the highest performance, while an E grade represents the lowest.

CII has been in effect since 2023, providing a standard for assessing the environmental performance of ships and reducing carbon emissions.

KR's Verification Results

Using 2023 IMO fuel consumption (DCS) data, KR verified the CII calculations for the affected ships.

(Unit: Number of ships)

Ship Type	Number of KR-Verified Ships for CII	Changes in CII Ratings		
		+1 Grade	+2 Grade	+3 Grade
Bulk Carriers (Over 279,000 DWT)	41	23	17	-
PCTC (Over 57,700 GT)	60	24	11	1

Among the 101 bulk carriers over 279,000 DWT and vehicle carriers over 57,700 GT, 76 ships, accounting for 75%, showed an improvement of at least one grade in their CII rating as a result of the corrected calculation error.

Calculation Error and Correction

KR discovered that, instead of applying the actual capacity (DWT or GT) of ships, an incorrect fixed value was applied to large bulk carriers over 279,000 DWT and vehicle carriers (PCTC) over 57,700 GT.

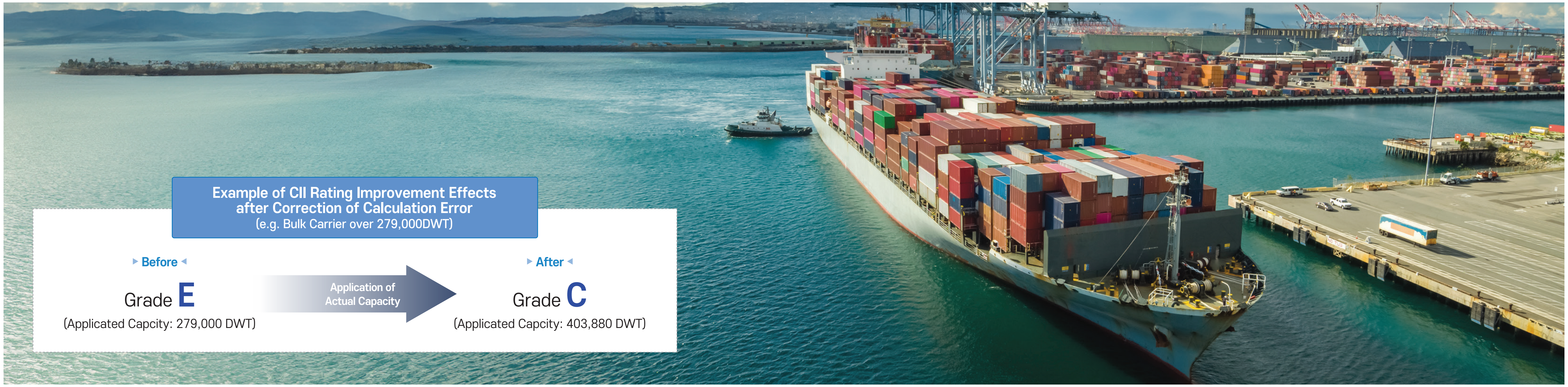
This resulted in these ships being assigned lower CII grades, potentially disadvantaging the competitiveness of South Korean-flagged ships in the field of greenhouse gas reduction.

Importance of CII Ratings

If a ship receives a CII rating of D for three consecutive years or E in any single year, it must establish a Corrective Action Plan (CAP) to comply with IMO regulations. However, vessels with low CII ratings may face various economic disadvantages due to the nature of the commercial shipping market.

For instance, such disadvantages may include reduced second-hand vessel transactions, decreased profitability from installing eco-friendly equipment or operating at reduced speeds to meet regulations, exclusion from port fee reduction incentives at certain ports, rejection in the charter market, and diminished residual value of second-hand vessels.

With the recent correction of the CII calculation errors, some national ships have now received accurate CII ratings in a timely manner. KR will continue to work with relevant authorities to enhance the competitiveness of South Korean-flagged vessels following IMO regulatory updates. Meanwhile, the IMO plans to complete revisions of related regulations, including the short-term measures for greenhouse gas reduction and the CII rating system, by January 1, 2026.



KR Conducts Risk Assessment on Korea's First Onboard Carbon Capture System

KR has announced the successful installation of an onboard carbon capture system (OCCS) with purely domestic technology, and it will soon undergo internal verification testing.

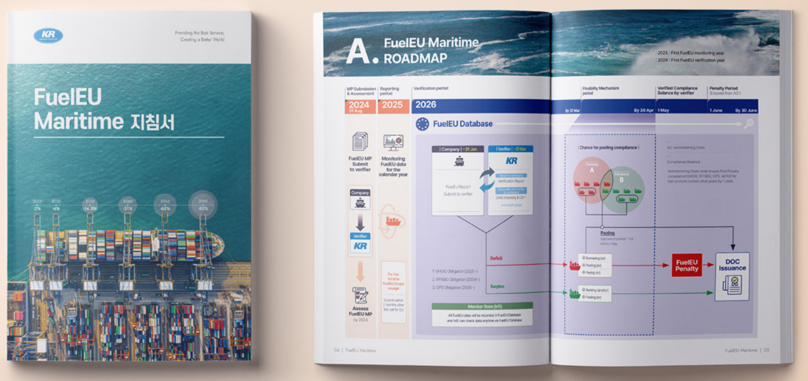
The project began in April 2023 as a collaborative effort with HMM, Samsung Heavy Industries (SHI), and PANASIA. As a result of this collaboration, the system was installed on the 2,200 teu container ship, HMM Mongla. KR conducted the risk assessment and application of relevant regulations in this OCCS project.

The OCCS applies a technology that captures, liquefies, and stores carbon dioxide from the exhaust gases generated during the ship's operation. This technology has the potential to be recognized by international organizations such as the International Maritime Organization (IMO) as one of the most promising carbon reduction technologies, making it a proactive solution for reducing greenhouse gas emissions from ships in the future.

Amidst the growing global interest in carbon capture technology, this system is expected to demonstrate technological leadership in the international maritime industry. It is hoped that this will assist global maritime leaders when they meet to discuss the possible future adoption of OCCS at the meeting of the IMO's Marine Environment Protection Committee.

A KR official stated, "Carbon capture technology is highly regarded as one of the effective measures for reducing greenhouse gases, drawing significant attention from the international community and the shipping industry. Based on the experience and outcomes of this successful project, KR will make every effort to support the shipping industry in timely decarbonization."

New Release:
FuelEU Maritime Guidelines



In July 2021, the European Commission announced the 'EU Fit for 55' plan aimed at reducing greenhouse gas emissions. The goal of this plan is to cut emissions by 55% compared to 1990 levels by 2030.

As part of this initiative, the FuelEU Maritime regulation has been introduced. This regulation is designed to encourage vessels calling at ports in Europe and the European Economic Area (EEA) to use renewable and low-carbon fuels.

In response, KR has published a new guideline to help shipping companies effectively comply with the FuelEU Maritime regulation. Starting from August 1, 2024, this guideline will be available through KR-GEARs and will provide instructions on developing and submitting the Monitoring Plan to verification bodies. Shipping company representatives are encouraged to refer to this guideline for their operational needs.

KR Celebrates Arrival of Innovative Low-Carbon Sailing Cargo Ship "SV Juren Ae" in the Marshall Islands

On July 31st, KR proudly announced the successful delivery of the innovative low-carbon sailing cargo ship, SV Juren Ae (IMO no. 1021245), to the Marshall Islands Shipping Corporation (MISC).

Funded by the International Climate Initiative (IKI*), this vessel is the result of a collaborative effort led by the German International Cooperation Agency (GIZ), as part of the project "Transition to Low-Carbon Sea Transport in the Republic of Marshall Islands" launched in 2017 by the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV). Key project partners include KR, the University of Applied Sciences Emden/Leer, MISC, Asia Shipbuilding Co. Ltd., and Kostec Co. Ltd., among others.

*International Climate Initiative (IKI): A climate protection program funded by the German government, supporting global projects that address climate change and environmental protection.

The SV Juren Ae boasts several innovative features, including the Indosail-Sailing Rig system. This partially automated sail system, designed by the German naval designer HSVA and inspired by traditional Indonesian sails, is complemented by installed photovoltaic (PV) units and a hybrid power system, resulting in a reduction of CO_2 emissions by approximately 80% compared to similar-sized ships.

The ship's propeller and engine are used for low-speed maneuvering, while the propeller also functions as a turbine to generate electricity. This innovative design enables a ship to achieve a service speed of approximately 12 knots (about 22.2 km/h) under sail, and around 7 knots (about 13 km/h) with the auxiliary diesel engine. Additionally, the ship is equipped with a battery system charged by surplus wind power, allowing for electric propulsion during low-speed operations.

KR regards the success of the SV Juren Ae project as a significant milestone that demonstrates the feasibility of sustainable technologies in the maritime industry. With the increasing pressure of global greenhouse gas regulations, KR remains committed to supporting innovative technology projects that help customers adapt flexibly.

The SV Juren Ae will be operated by MISC in the Marshall Islands and the broader Pacific region, offering a promising solution for low-carbon maritime transport, particularly in regions with high fuel prices like the Pacific islands.

KR Partners with HD Hyundai to Develop MW-Class Hydrogen Engines for Ships

KR (Korean Register) has launched a collaborative initiative with HD Korea Shipbuilding & Offshore Engineering (HD KSOE) and HD Hyundai Heavy Industries to develop core technologies for megawatt (MW)-class hydrogen engines for ships.

The MW-class hydrogen engine project represents a key advancement in marine mobility, designed to meet International Maritime Organization (IMO) greenhouse gas regulations. This initiative falls under the 2024 Materials and Components Technology Development Program, a government-supported effort led by the Korea Planning & Evaluation Institute of Industrial Technology (KEIT). Specifically, the project focuses on developing and evaluating critical materials and components for hydrogen injection and supply systems in MW-class internal combustion engines.

Hydrogen-powered engines, which produce zero emissions, present a cost-effective, safer, and more durable alternative to hydrogen fuel cells, particularly in large-scale applications. Notably, MW-class hydrogen engines boast an energy conversion efficiency close to 50%, giving them a competitive edge as an eco-friendly power source suitable for medium to large vessels and hydrogen carriers.

At the heart of this joint project lies the high-capacity direct hydrogen injection system, a crucial component for marine internal combustion engines. While no commercially viable solution currently exists, expectations are high given the participation of HD KSOE and HD Hyundai Heavy Industries, which successfully developed Korea's first 1.5MW LNG-hydrogen dual-fuel engine. This synergy is anticipated to drive meaningful progress in the commercialization of hydrogen-based propulsion systems.

KR will collaborate with 16 partners, including the two HD Hyundai affiliates, to develop hydrogen injection and supply systems for MW-class engines. The project will also involve integrating the technology into HiMSEN engines, with comprehensive land-based performance demonstrations planned. KR will serve as the lead research institution for the four detailed consortiums involved and will oversee one of the core sub-projects. With a government R&D budget of approximately KRW 13.9 billion (USD 10.4 million) allocated through 2027, the project is poised to accelerate Korea's entry into the green engine market.

Kim Dae-heon, EVP of KR R&D Division, stated,

"This joint research initiative will establish the foundation for 100% hydrogen-fueled direct injection engines, enabling Korean shipbuilders to lead in the eco-friendly engine market. KR remains committed to advancing technologies that meet environmental regulations and will continue to provide extensive support to clients and the wider maritime industry".

KR Grants Approval in Principle to Samsung Heavy Industries for 9,300 TEU Ammonia-Fueled Container Ship

At GASTECH 2024, KR (Korean Register) announced that it has awarded an Approval in Principle (AiP) to Samsung Heavy Industries (SHI) for their "9,300 TEU Ammonia-Fueled Container Ship".

As the global maritime industry intensifies efforts to meet stricter decarbonization targets, ammonia is gaining prominence as a potential zero-carbon fuel. In light of the current trends, recent LNG-fueled container ships have adopted designs that allow the use of ammonia fuel for its sustainable option.

Ammonia fuel presents advantages in terms of cost-effectiveness and efficiency compared to other alternative fuels. However, due to its high toxicity and corrosive properties, it requires a specially designed fuel propulsion system, as well as

additional safety assessments that take the operational requirements into consideration.

The development of this 9,300 TEU ammonia-fueled container vessel marks a key step in advancing ammonia fueled propulsion technology.

SHI have developed an entirely new structural layout and the vessel's design which includes specialized fuel tanks, fuel supply systems, ventilation, and gas detection systems, incorporating the unique properties of ammonia fuel.

KR verified this newly developed vessel's design and ammonia fuel system, ensuring compliance with classification rules and international regulations, and granted AiP after confirming the integrity and safety of the entire system.

LEE Hyungchul, Chairman and CEO of KR, said: "This joint development is a significant step toward the commercialization of large ammonia-fueled container ships. KR will continue to provide technical support for the innovations in decarbonization solutions."

JANG Haeki, Executive Vice President and CTO of SHI, said: "Our 9,300 TEU ammonia-fueled container ship incorporates the leading eco-friendly technologies of SHI. We will continue to accelerate the development of carbon-neutral solutions to secure our competitive edge in the next-generation ship market."

KR and HD Hyundai Heavy Industries Engage in Joint Development of Enhanced Ammonia Fuel Supply System through Risk Assessment

At GASTECH 2024 in Houston, KR (Korean Register) announced on September 17 that it has signed a Memorandum of Understanding (MoU) with HD Hyundai Heavy Industries (HD HHI) to develop an enhanced ammonia fuel supply system.

The International Maritime Organization (IMO) has established a target to achieve Net-Zero greenhouse gas emissions by 2050.

In line with this regulatory goal, there is a global acceleration in the development of alternative fuel technologies.

Ammonia is emerging as a promising alternative fuel due to its sustainable advantages, including ease of storage and transportation, and avoidance of the emission of carbon and sulfur compounds.

This agreement represents a collaborative effort between HD HHI and KR to advance the development of an ammonia fuel supply system. HD HHI will design key system configurations to integrate ammonia fuel into ammonia carriers. KR will conduct a comprehensive risk assessment of the system and grant an Approval in Principle (AiP).

JUNG Jaejun, Executive Vice President of HD HHI, remarked: "Ammonia, as a zero-carbon fuel, offers significant benefits in operational economics and supply stability. Through this risk assessment, we are dedicated to developing an enhanced ammonia fuel supply system, contributing to global carbon-neutral initiatives."

KIM Yeontae, Executive Vice President of KR's Technical Division, added: "This joint development is an important foundation for the commercialization of ammonia-fueled vessels. KR will continue to provide essential technical support for advancing decarbonization solutions."

KR Grants AiPs to HD Hyundai Mipo's Innovative Ammonia and LNG Bunkering Vessels

KR (Korean Register) has awarded an Approval in Principle (AiP) to HD Hyundai Mipo (HD HMD) for their innovative 23K Ammonia Bunkering Vessel and 18K LNG Bunkering Vessel on September 18, at GASTECH 2024, paving the way for green shipping.

The development of these vessels represents a significant advancement in the maritime industry's efforts to meet the International Maritime Organization's (IMO) ambitious greenhouse gas reduction targets, which include at least 20% by 2030 and 70% by 2040, with a goal of achieving Net-Zero emissions by 2050.

The IMO's move has galvanized the industry to explore cleaner maritime bunker fuels, with ammonia emerging as a promising solution due to its zero carbon emissions and low technical barriers. Leading global shipping and energy companies

are intensifying their focus on developing ammonia engines and fuel cell systems to commercialize decarbonized vessels.

At the same time, as many shipping companies have adopted LNG as a transitional fuel, the demand for LNG-fueled vessels is growing steadily, which has also led to increasing interest in LNG bunkering vessels.

In response to this emerging trend, KR and HD HMD have been leading in addressing the challenges associated with this transition.

HD HMD developed the initial design for the 23K ammonia bunkering vessel, tailoring the cargo system to the distinctive properties of ammonia. KR conducted a rigorous review of the design, assessing it against classification rules and applicable domestic and international regulations, ensuring the design's safety and compliance with industry standards and granted AiP to the vessel as a result.

On the same day, KR granted another AiP to HD HMD's 18K LNG bunkering vessel. HD HMD, leveraging its expertise in gas carrier technology, led the initial design and developed the cargo systems for the vessel. KR reviewed the design in line with classification rules and domestic and international regulations, confirming its safety and compliance.

Dong-jin LEE, Head of Initial Design Division at HD HMD, said: "Ammonia and LNG are rapidly gaining traction as low-carbon alternative fuels. As the number of vessels powered by these fuels increases, we anticipate a rising demand for ammonia and LNG bunkering vessels. With these AiPs from KR, HD HMD has not only laid the groundwork for the commercialization of ammonia bunkering but has also secured a diverse portfolio of bunkering vessels, aiming to take a leading position in the construction of bunkering vessels."

Yeontae KIM, Executive Vice President of KR's Technical Division, said: "The collaborative development of the 23K ammonia bunkering vessel and the 18K LNG bunkering vessel is highly significant as the maritime industry increasingly focuses on alternative fuels to meet environmental regulations. KR is committed to ongoing technical support for developing environmentally friendly ships and technologies and guiding our customers through the energy transition."

In keeping with our passion for the protection of the natural environment,
KR offers survey and certification services for renewable energies, including wind and ocean power.
KR is continuously working on new and innovative green ship technologies
to reduce emissions and fuel usage, using these advances
to enable our customers to meet their environmental goals.

KR Decarbonization Magazine

Vol. 08 Autumn 2024

Korean Register

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