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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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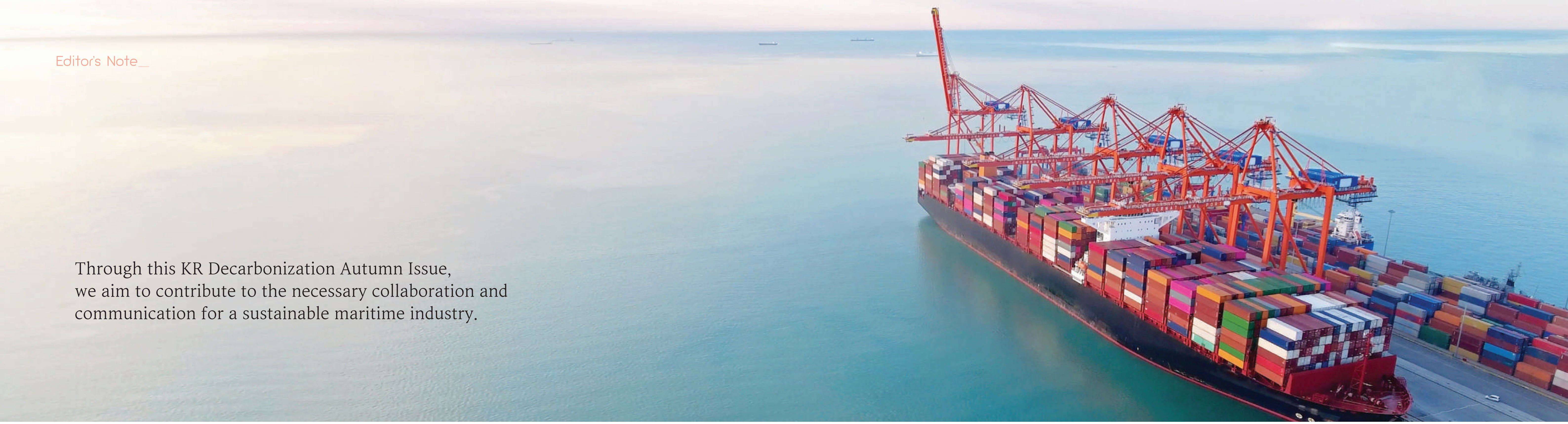


Through this KR Decarbonization Autumn Issue,
we aim to contribute to the necessary collaboration and
communication for a sustainable maritime industry.

At the 80th session of the MEPC in July 2023, the IMO made one of the most historic decisions to adopt the 2050 carbon neutrality target and implement mid-term measures by 2027. These decisions will have a substantial impact on the maritime and shipbuilding industries. Industries are now confronting the unprecedented challenges of shipping decarbonization, prompting various technical and economic responses while also accelerating the development of innovative technology. In the "Regulatory Updates" section, we highlight the key decisions and their implications stemming from the 80th MEPC meeting.

Many technical and operational measures are being developed to improve the Carbon Intensity Index (CII), a short-term measure of the IMO GHG strategy which came into force this year. The CII is the most prominent index indicating a ship's fuel efficiency, and it closely relates to the carbon cost resulting from the mid-term measures that will be implemented from 2027. In this Autumn issue, statistics on the CII for over 1,700 vessels, verified by KR based on fuel consumption for 2022, are presented. Considering that only around 200 vessels are Korean flagged, this data presents a more global picture. According to the data, 68% of ships received grades of C, D, or E. Given that ships with a C rating are at risk of being downgraded to a D if no countermeasures are taken, immediate action is required. Furthermore, the number of ships in these categories is likely to increase annually as CII criteria are gradually tightened. This underscores the significant challenges shipping companies face in improving fuel efficiency. This issue also provides various statistics and insights on CII, along with strategies for its enhancement.

Fuel transition is the key measure to comply with IMO or EU GHG regulations. There are a wide range of alternative fuels currently under consideration, including LNG, LPG, methanol, ammonia, ethanol, hydrogen, batteries, small modular reactors, etc. The fuel storage systems, in particular, have a substantial impact on vessel layout, cargo capacity, construction costs, and overall ship operation. This issue offers a comprehensive overview of various aspects of fuel storage systems, including their characteristics, design, materials, temperature, and pressure, specifically for alternative fuels. Additionally, the issue reviews their influence on retrofit costs.

KR participated at GasTech 2023, held in Singapore, and awarded AIP (Approval in Principle) and signed JDP (Joint Development Project) with industry partners for large-scale ammonia carriers, liquefied carbon dioxide carriers, and cybersecurity. Collaboration with the industry on decarbonization and digitalization is expected to be further strengthened. Additionally, in the spotlight for the future of renewable energy production, KR successfully developed and launched SeaTrust-FOWT, which is over 1,000 times faster than existing software for floating offshore wind structures. Furthermore, a JDP was signed for the development of support vessels for offshore wind turbine maintenance.

In this era of decarbonization and digitalization, the maritime industry is making concerted efforts to identify the right solutions. However, significant technical and commercial uncertainties make it challenging to ascertain the best course of action with confidence. Despite this, there's widespread agreement that the most effective approach to finding optimal solutions involves collaboration and communication. Through this KR Decarbonization Autumn Issue, we aim to contribute to the necessary collaboration and communication for a sustainable maritime industry.

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

KR Decarbonization Magazine

Insights_

IMO DCS-based CII rating analysis and CII improvement measures

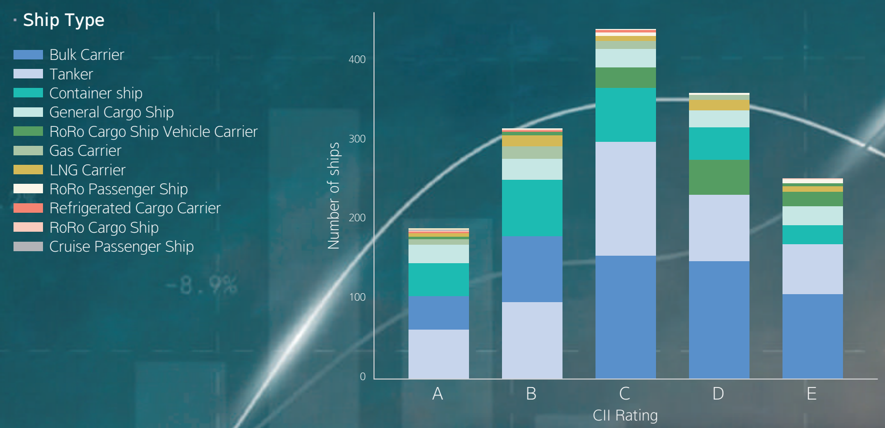
By KIM Donggi,
Deputy Senior Surveyor of KR Green Ship Technology Team

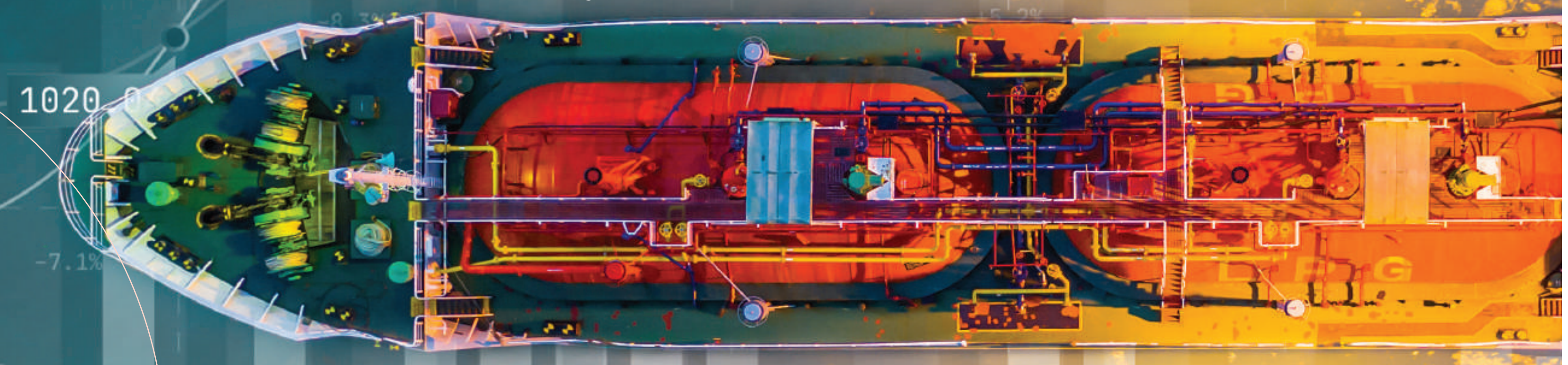
From 2023, it is mandatory for all ships 5,000GT or above to collect emissions data for reporting their annual operational CII and CII rating. As a result, shipping companies are currently focused on the anticipated CII rating results for their ships.

KR conducted preliminary CII rating analysis based on DCS data in 2022, in order to provide advanced CII rating information to shipping companies. This analysis was conducted using 2022 data to consider the ongoing monitoring of 2023 IMO DCS data.

CII rating analysis based on 2022 IMO DCS data

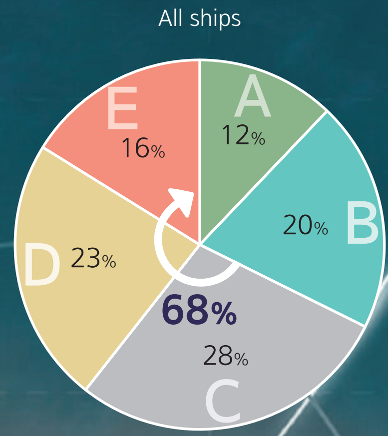
In 2023, about 2,000 IMO DCS data for 2022 were submitted and verified through KR GEARs, and A preliminary CII rating analysis was conducted. The preliminary CII rating analysis results can be viewed in the graphs below.



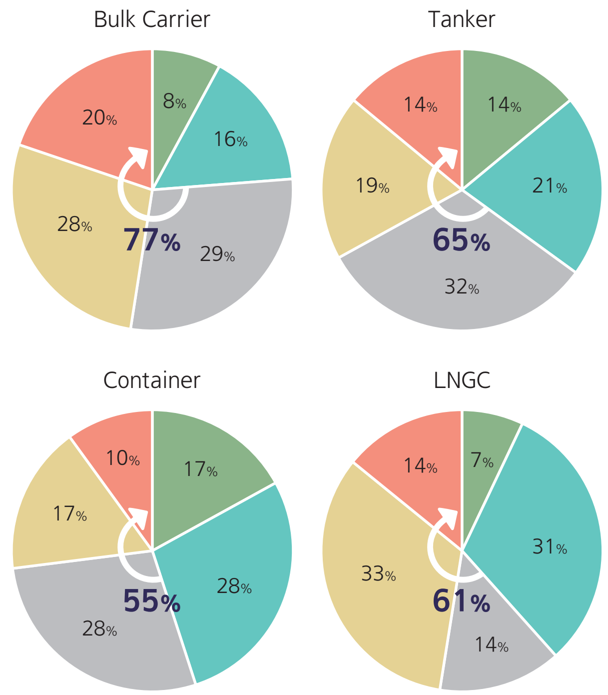


Digitalized regulatory responses, along with the right combination of technical measures, are essential to improve the CII rating of existing ships.

The current distribution of CII ratio was analyzed based on both the number of ships and their ratios. Upon analyzing the CII ratio for all ships, we found that 16% received an E grade, 23% received a D grade, and approximately 28% received a C grade. Through this analysis, it was confirmed that the proportion of ships graded from C to E totaled 68%. Given that C-graded ships are likely to be downgraded to D or E in the future due to yearly tightening of standards, it's clear that not just D and E-graded ships, but also C-graded ships should review and take appropriate measures to improve their CII ratio.



The circle graphs show the CII ratio of four of the ship types (bulk carriers, tankers, container ships, and LNG carriers) submitted to KR.

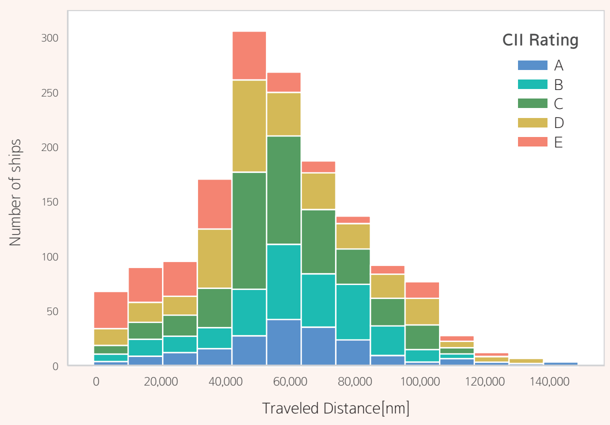


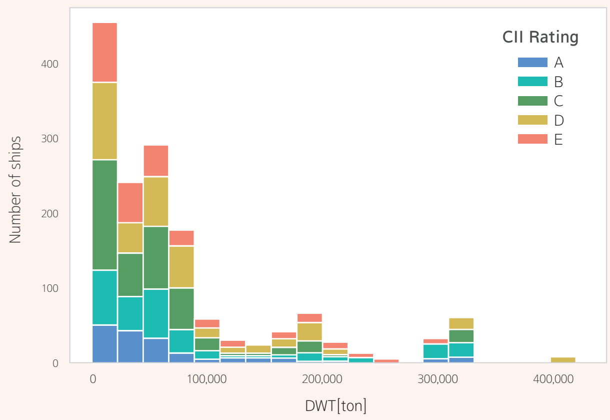
In the case of bulk carriers, the analysis showed that the ratio of C-E graded ships made up 77% of the overall CII rating ratio, which is higher than the overall average of 69%. On the other hand, container ships had a relatively lower percentage at 55%.

Unlike container ships, which mainly consist of liners and have shorter waiting times, bulk carriers and tankers—which have a higher proportion of trampers—tend to have longer waiting times, leading to a higher percentage of C to E CII grades. In the case of LNG carriers, many ships use steam turbines with low thermal efficiency as their propulsion system. As a result, it was found that 61% of these ships fall within the C to E grade range.

In addition, as a result of analyzing the CII based on the distance travelled and Deadweight Tonnage (DWT), ships with travelling short distances generally have a higher C-E grade ratio, and ships with small DWT compared to ships with large DWT have a higher C-E grade ratio. Furthermore, it has been observed that ships with relatively small DWT and a high proportion of short-distance voyages tend to have a higher proportion of E-grade. Ships with larger DWT and a higher proportion of long-distance voyages tend to have a higher proportion of D to E ratings.

CII rating analysis by traveled distance and DWT





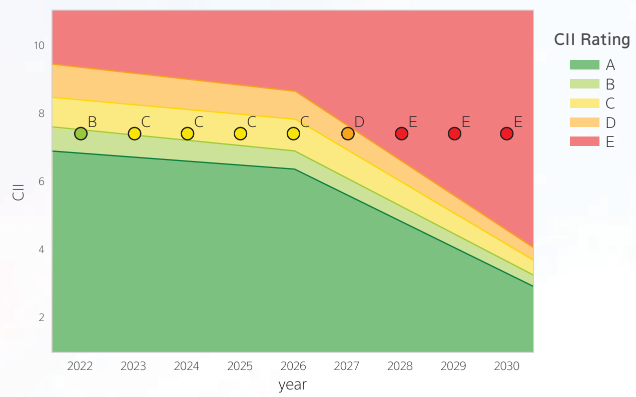
The IMO also recognizes that there are disadvantages in terms of CII depending on ship type, distance travelled, and port waiting time, and will review CII correction factors and voyage adjustments (short distance and port waiting time, Ship-to-Ship for self-unloading bulk carriers, steam turbine propulsion LNGC, fuel consumption of boiler and inert gas generator for gas carriers).

Data anylysis results for an individual vessel

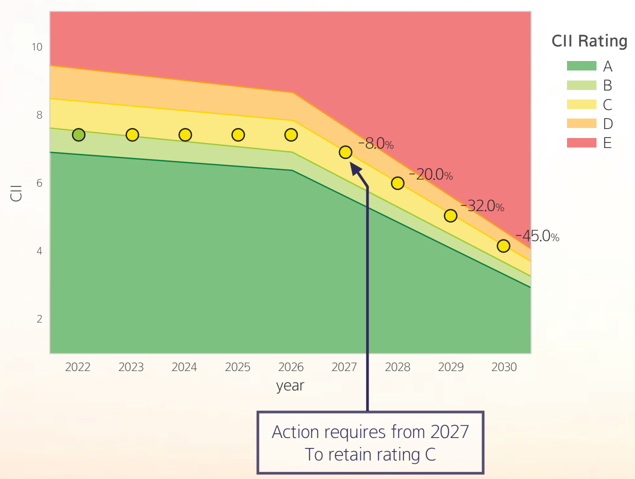
Having examined the analysis results for all ships and individual types of ships in the previous section, let's now turn our attention to the data analysis results for specific vessels. As an example, we analyzed the data of one handy-size bulk carrier, which received a CII rating of B in 2022. Taking into account the 40% reduction target in carbon intensity set by MEPC 80 compared to 2008 levels, we are assuming an annual reduction rate of 2.75% from 2027 to 2030. We have analyzed the projected CII grades from 2023 onwards for this vessel. The analysis is represented in the graph on the right. The graph illustrates the grade progression up to 2030 without implementing CII improvement measures. The graph on the right shows the required greenhouse gas reduction as a percentage to maintain at least a C-grade rating.

The CII rating of the example ship is expected to change to C grade from 2023 to 2026, D grade in 2027, and D to E grade from 2028. Improvement measures should be taken to maintain at least C grade from 2027.

CII rating change without improvement measures



GHG reductions(%) required to maintain a C rating



Measures to improve the CII rating of existing ships

What measures can the shipping company take to improve the ship's CII rating?

One of the first measures to implement in order to improve the CII rating is to reduce ship speed. However, when it comes to ship operation, the ship speed is reduced to the lowest feasible level. If further greenhouse gas reduction is needed, additional measures such as ship speed and route optimization through weather routing, on-time arrival, optimal trim maintenance, and periodic propeller and hull cleaning should be implemented in parallel.

Secondly, fuel conversion can be considered. The first feasible alternative at this point is to use biofuels. The IMO's MEPC 80 meeting recently approved MEPC.1/Circ.905 of the Interim Guidelines on the Use of Biofuels in terms of Rules 26, 27 and 28 (DCS and CII) of MARPOL Annex VI. It is expected that greenhouse gas reduction effects can be obtained by using biofuels that satisfy the requirements presented in these guidelines. However, given the instability in fuel supply, it's important to secure a reliable source to ensure sufficient fuel availability. Additionally, the higher cost compared to existing fuels must be taken into account.

Third, energy efficiency is improved by applying technology that can reduce ship resistance or improve propulsion efficiency. The easiest way is to apply low friction paint, replace the propeller with one that fits the lowered speed, and install an energy efficiency improvement device (ESD).

However, a cautious approach is needed, taking into account the uncertainty surrounding the greenhouse gas reduction impact of energy efficiency improvement devices, as well as CAPEX and OPEX considerations.

The measures introduced above are the most typical measures, and it is desirable to select an appropriate combination for each ship after reviewing all applicable measures, rather than applying only one of the measures mentioned above. For example, after applying route optimization technology through ship speed reduction and weather routing, a certain amount of biofuel can be used. Even in the case of biofuels, biofuels with different blending ratios can be supplied and used according to the required amount of greenhouse gas reduction.

Digitalization of regulatory response to effective decarbonization response

At the moment, if a ship doesn't meet the target C-rating required by the CII regulations, the only penalty is to submit SEEMP Part III with a plan of corrective action and get it approved again. There are no clear guidelines such as detention. This has resulted in some shipping companies not taking proactive measures. However, by January 1, 2026, there may be discussions about implementing stricter penalties, such as detention, for ships that haven't taken corrective actions. Therefore, it's crucial for companies to proactively work on reducing greenhouse gas emissions well in advance.

To support the shipping company's response to greenhouse gas regulations, KR is providing a one-stop total solution that can respond to CII, EU/UK MRV and ETS regulations through KR GEARs. Shipping companies can respond to CII regulations through CII monitor functions that can derive and manage CII ratings based on real-time operational data and CII simulator functions through the establishment of ship-specific improvement scenarios.

In addition to this, KR plans to annually provide a GHG Counter Measure Advisory Report based on verified DCS data. This report will include information on CII status, comparisons with other ships, and the necessary reduction quantities of greenhouse gas emissions to achieve expected CII grades by 2030 and higher. Each shipping company will receive a copy of the report, which is expected to serve as a valuable resource for future planning and decision-making related to CII regulations.

In conclusion, KR believes that, in response to the accelerating decarbonization efforts in the maritime sector, digitalization is essential for regulatory compliance. Regulatory digitalization enables effective proactive responses through quality data collection, management, and real-time operational monitoring. This, in turn, facilitates the formulation of strategies for CII regulation compliance and decarbonization efforts. KR is committed to continually updating KR GEARs functionality and providing the support for digitalization initiatives and maritime decarbonization.

The Evolution of Alternative Ship Fuels and Fuel Containment Systems

By SHIM Youngjin,
Senior Surveyor of KR Business Support Team

Various aspects of fuel storage systems and their impact on transitioning to alternative fuels to meet decarbonization needs in the shipping industry

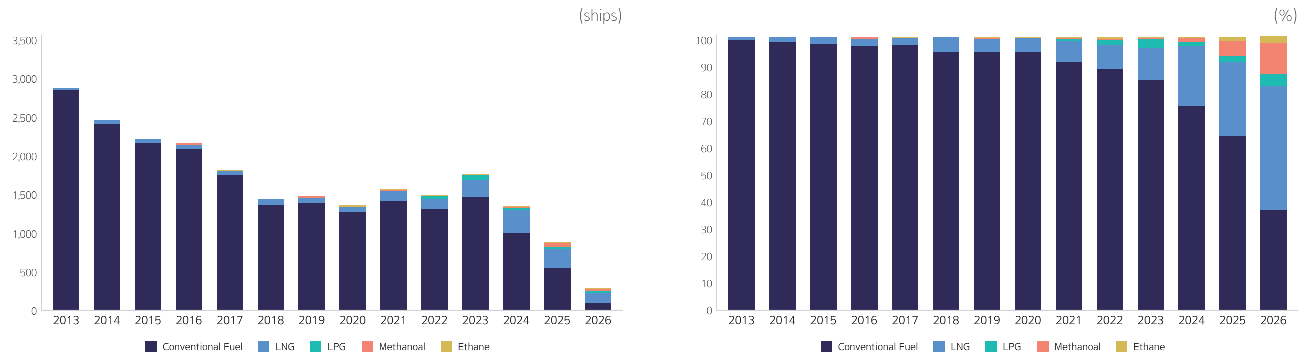
Outlook and selection of alternative ship fuels

Until recently, only one type of fuel based on fossil fuels was predominantly used for ships. However, from the mid-2000s onwards, we are now transitioning to an era where a diverse range of fuels are employed, according to the unique advantages and disadvantages of each fuel, variations in technology and commercial maturity, and the distinct requirements of different ship types. Discussions about future alternative fuels include LNG, LPG, methanol, ammonia, ethanol, hydrogen, batteries, and small nuclear reactors, among others. Over the past decade, the share of LNG as an alternative fuel has increased, and methanol is also gradually gaining traction. However, methanol fuel is predominantly being considered for specific vessel types like container ships. On the other hand, ammonia, hydrogen, and small nuclear reactor fuels are not yet used as ship fuels due to technical and toxicity-related challenges.

For these fuels to be used in ships, essential steps like engine development are necessary. In the case of ammonia, it is anticipated that after the development of main engines around 2024-2026, orders for ammonia-powered vessels will increase. Following that, Fuel Selection is expected to change with hydrogen, small nuclear reactor technology, and others.

Choosing a fuel is a complex decision that involves considering various factors like fuel prices, equipment costs, decarbonization regulation expenses, retrofitting costs, etc. Amidst such uncertainties of the future, shipping companies need to devise strategies that align with their situations. Due to various possibilities, concepts like fuel diversity, fuel mosaic, and fuel flexibility are becoming increasingly important. In this context, both alternative fuel engine technology and fuel storage system technology significantly impact aspects like vessel deployment, construction costs, and maritime operations. Therefore, let's explore fuel storage technology from the perspective of decarbonization in the maritime industry.

World Fleet Fuel Selection Status



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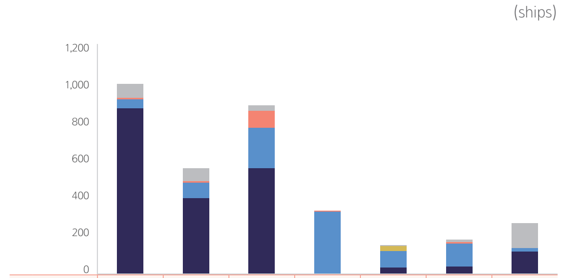
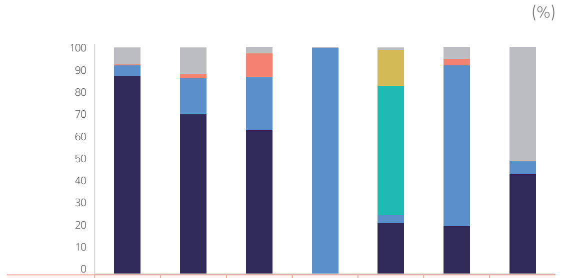
Order Book by Ship Type and Fuel Status



	Bulk Carrier	Tanker	Container Ship	LNG Carrier	LPG Carrier	RORO Ship	General Cargo Ship
Unkown	77	66	26	2	2	10	132
Ethane					24		
Methanol	6	11	93			4	
LPG					85		
LNG	44	86	205	329	5	126	15
Conventional Fuel	879	396	565		35	39	119



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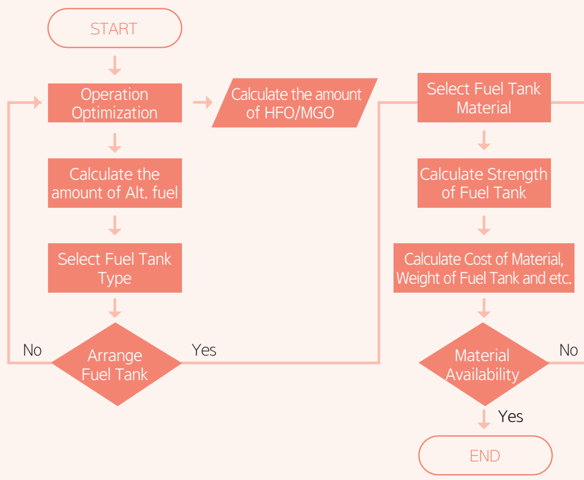
Types and materials of future alternative fuel containment systems

· Choosing alternative fuel containment systems

The various options for alternative fuels make ship design more complex. Even for similar types of ships, the choice of alternative fuel affects the type, placement, and materials of fuel tanks. These differences have an impact on the whole ship.

The following flow chart suggests a successful design process for an alternative fuel storage system.

Alternative Fuel Storage Tank Design Flow Chart



Insights_

The first important step is to optimize the ship's operations. The amount of fuel needed depends on the route and distance the ship travels. Once we calculate the quantity of conventional fuels like Heavy Fuel Oil (HFO) or Marine Gas Oil (MGO) required for the journey, we can then determine the amount needed if we switch to an alternative fuel. Different alternative fuels have varying energy densities, so the amount of fuel needed for the same distance varies. For instance, if we want to use e-methanol fuel for the same journey as MGO, we would need a fuel tank for methanol that is 2.4 times larger than the MGO tank.

Fuel Comparison Table

Solution	MGO	LNG	Bio-diesel	Methanol	e-Ammonia	Hydrogen
Fuel Type	Fossil fuel		Carbon-neutral fuel		Zero carbon fuel	
Storage condition	Room Temp. Normal pressure	-163℃	Room Temp. Normal pressure	Room Temp. Normal pressure	-33℃ or 10bar	-253℃
Fuel tank size relative to MGO	1	1.7	1	2.4	2.8(-33℃) 3.4(10bar)	4.2
Relative CAPEX	1	~1.3	1	~1.15	~1.2	Very High
Fuel cost & Availability	Cheap and plentiful		Supply instability Hard to predict price	Highly CO_2 capture cost	Cheapest among carbon-neutral fuels	Excessive transportation and storage costs

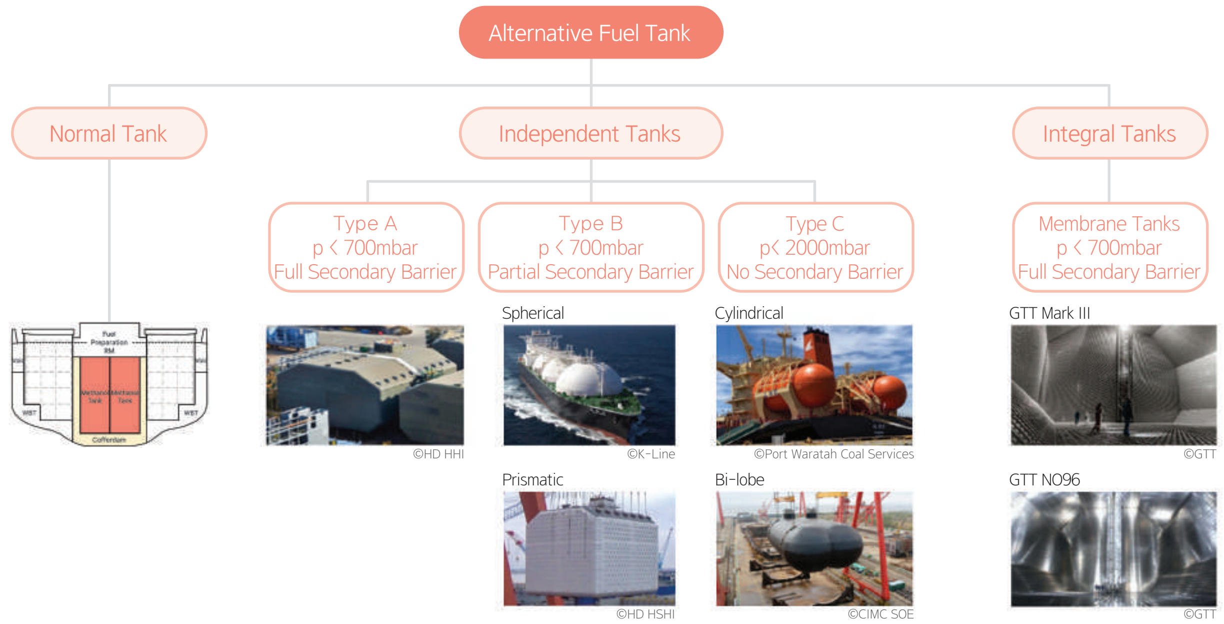
Excellent　Acceptable　Undesirable

· Types of alternative fuel containment system

Once we have determined the quantity of alternative fuel we require, we must decide on the type and location of the fuel tank. Ship fuel storage tanks generally fall into three categories: those using regular ship hull space, independent type A, B, and C tanks according to IMO standards, and membrane-type tanks. When a relatively small amount of fuel is needed, independent type C tanks are used, and for larger fuel quantities, independent type A, B, or membrane-type tanks are employed. However, for methanol fuel tanks, a common type similar to traditional HFO fuel tanks is possible, allowing for more flexibility in tank size and design compared to other fuel tanks.

Illustrates the typical tank types that can be used for alternative fuels.

Classification of Alternative Fuel Tank Type



Independent Type A tanks are designed according to criteria recognized by the traditional ship strength analysis methods used by KR. They should have a design vapor pressure of less than 0.07 MPa and can be designed similarly to the ship's structure, which offers space efficiency compared to indepedent Type C tanks. To ensure against liquid fuel leakage, a full secondary barrier is also required. Independent Type B tanks are precision-designed using detailed analysis methods to determine stress levels and fatigue life. They should have a design vapor pressure of less than 0.07 MPa, and provisions for safe handling and removal in case of partial secondary barrier rupture or leakage are necessary. Independent Type C tanks are based on pressure vessel standards, and they are designed to ensure that surface defects do not progress more than half the thickness of the tank's outer shell over the tank's lifespan. As a result, secondary barrier installation is not required. Membrane tanks have thin walls made of a membrane that prevents liquid leakage, and the load of the fuel is supported by the adjacent internal hull through insulating material on the outer side of the tank.

Once the type of the fuel tank is determined, the placement of the tank needs to be chosen. For independent Type A, B, or membrane tanks, due to factors like tank size and secondary barriers, it is difficult to place them outside of below the cargo area main deck, regardless of ship type. On the other hand, independent Type C tanks can be positioned both above and below the main deck, but they tend to occupy relatively more space. Common locations for independent Type C tanks include the upper deck of the foredeck for bulk carriers, the upper deck of the cargo area for tankers, and the lower deck of the cargo area for roll-on/roll-off (ro-ro) ships.

Common Alternative Fuel Tank Type and Location

Ship Type	Fuel Tank Type	Fuel Tank Location
LNG Carrier	Type B, Membrane Type	Under Deck
Tanker	Type C	On Deck (Cargo Area)
Bulk Carrier	Type C	On Deck (Stern)
Container Ship	Type B, Membrane Type	Under Deck
	Type C	On Deck (Stern)
RoRo Ship	Type C	Under Deck (Cargo Area)
Coastal Service Small Ship	Type C	On/Under Deck

If a fuel tank of the required capacity cannot be accommodated on the vessel, there may be instances where the fuel tank size needs to be reduced or the shape of the existing hull altered. These challenges in fuel tank placement are among the factors that complicate the transition to alternative fuels for currently operating vessels that did not account for alternative fuel tanks in their initial design.

· Materials of alternative containment systems

The materials for fuel storage tanks are determined by the characteristics of each alternative fuel, the design temperature, and the design vapor pressure. For LNG fuel, a design temperature of -163 degrees Celsius and a design vapor pressure of less than 0.7 bar are required. Consequently, materials like austenitic stainless steel, nickel alloy steel, aluminum alloy steel, and high-manganese steel are used for LNG fuel tanks to maintain strength, toughness even in extremely low temperatures, and sufficient impact resistance. On the other hand, for methanol, which boils at 64.7 degrees Celsius at atmospheric pressure, the use of low-temperature resistant steel is unnecessary. However, since methanol can corrode certain materials, additional measures for fuel tank coating are necessary. Ammonia fuel tanks typically require the use of low-temperature resistant steel capable of enduring -55 degrees Celsius. Liquid hydrogen fuel tanks, on the other hand, require materials that are not sensitive to hydrogen.

When choosing materials for fuel tanks, the cost of materials will likely have the most significant impact. However, in the design process, the weight of the fuel tank is as important as the cost of materials. Due to varying densities of alternative fuels and differences in material properties, the required thickness for a fuel tank to meet structural strength can vary. This can result in variations in the weight of the fuel tank supporting structures, potentially necessitating additional reinforcement.

The following table illustrates the relationship between the density of alternative fuels, required material thickness, and the resulting increase in the weight of the fuel tank, using the example of an LNG fuel tank made from 9% nickel alloy steel.

Fuel Tank Weight increase ratio of Type C tank

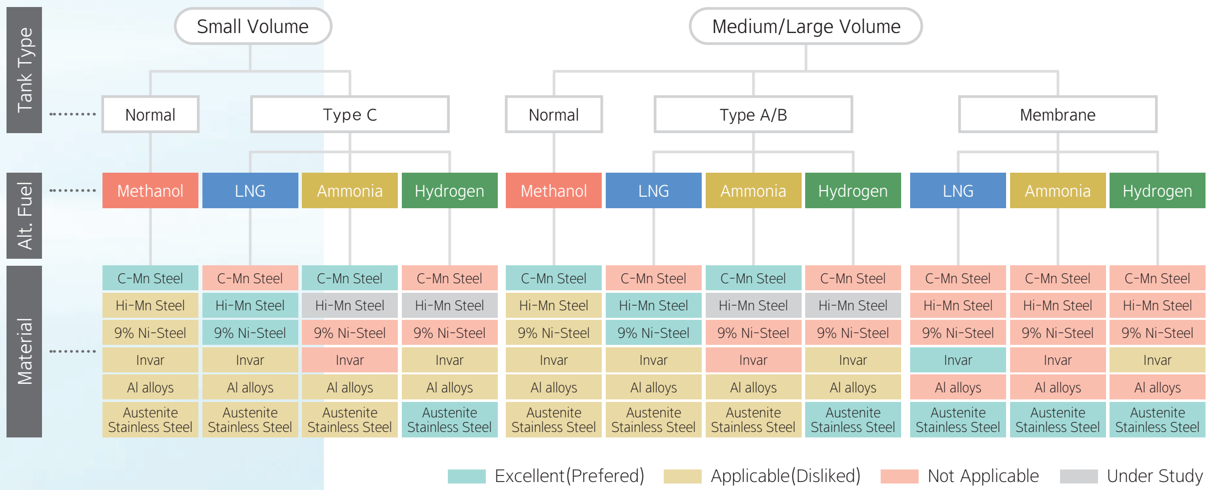
Alt. Fuel	Density (kg/m³)	Alternative Fuel Tank			
		Material	Allowable Stress (N/mm²)	Plate Thickness (mm)	Steel Weight increase ratio
LNG	470	Nickel Alloy (9% Ni)	213.3	17.0	1.00
		Austenite Stainless Steel (304L)	116.7	31.1	1.98
		Aluminum Alloy (5083)	68.8	52.8	1.06
		Hi-Mn Steel (HMN40)	188.6	19.2	1.13
Methanol	786	Nickel Alloy (9% Ni)	213.3	28.4	1.67
		Austenite Stainless Steel (304L)	116.7	52.0	3.30
		Aluminum Alloy (5083)	68.8	52.8	1.06
		Hi-Mn Steel (HMN40)	188.6	19.2	1.13
Ammonia	603	Austenite Stainless Steel (304L)	116.7	39.9	2.53
		Aluminum Alloy (5083)	68.8	52.8	1.06
		Hi-Mn Steel (HMN40)	188.6	19.2	1.13
Hydrogen	71	Austenite Stainless Steel (304L)	116.7	4.7	0.30
		Aluminum Alloy (5083)	68.8	52.8	1.06

Considering all these factors, for standalone Type A, B, and C tanks for LNG fuel, the main materials will likely be 9% nickel alloy steel or high-manganese steel, and for membrane-type tanks, austenitic stainless steel or INVAR are used as primary barrier material. For methanol and ammonia fuels, carbon-manganese steel is expected to be the primary material, while for hydrogen fuel, austenitic stainless steel is likely to be the main choice.

When it comes to aluminum materials, the weight of the fuel tank is not significantly different from that of a 9% nickel alloy steel. However, the need for a tank with more than three times the thickness increases welding costs and the risk of welding defects, which reduces the preference for this material.

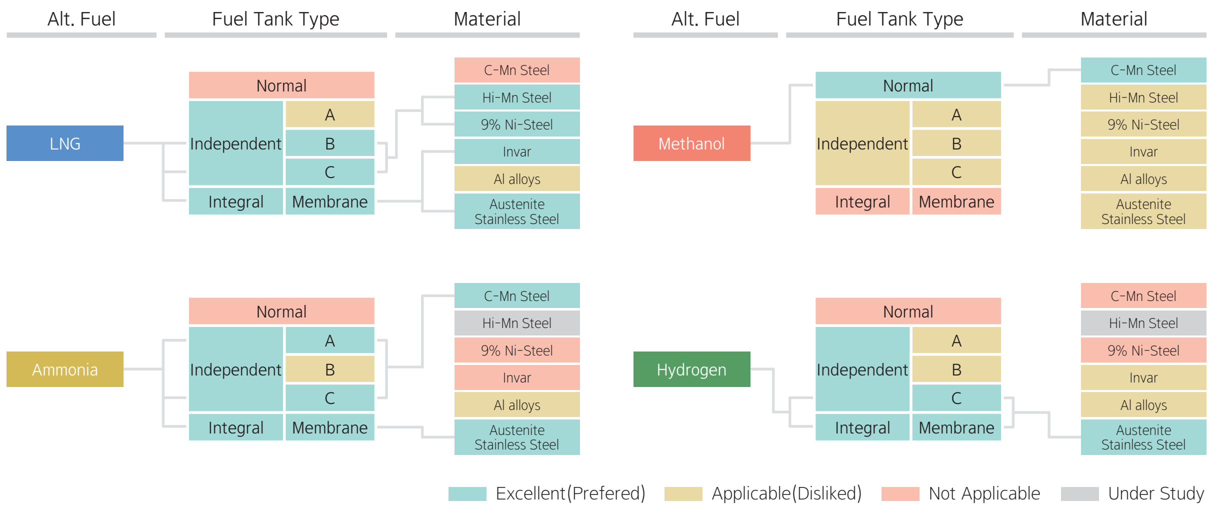
The diagram below illustrates the sequence from required fuel capacity, fuel tank type, to fuel tank material selection as described so far.

Classification of Fuel Tank Material (1)



The following diagram illustrates the preferred fuel tank types and materials for each alternative fuel, presented in a different order. Considering the materials for fuel tanks during the design phase is an important factor in preparing for fuel conversion.

Classification of Fuel Tank Material (2)

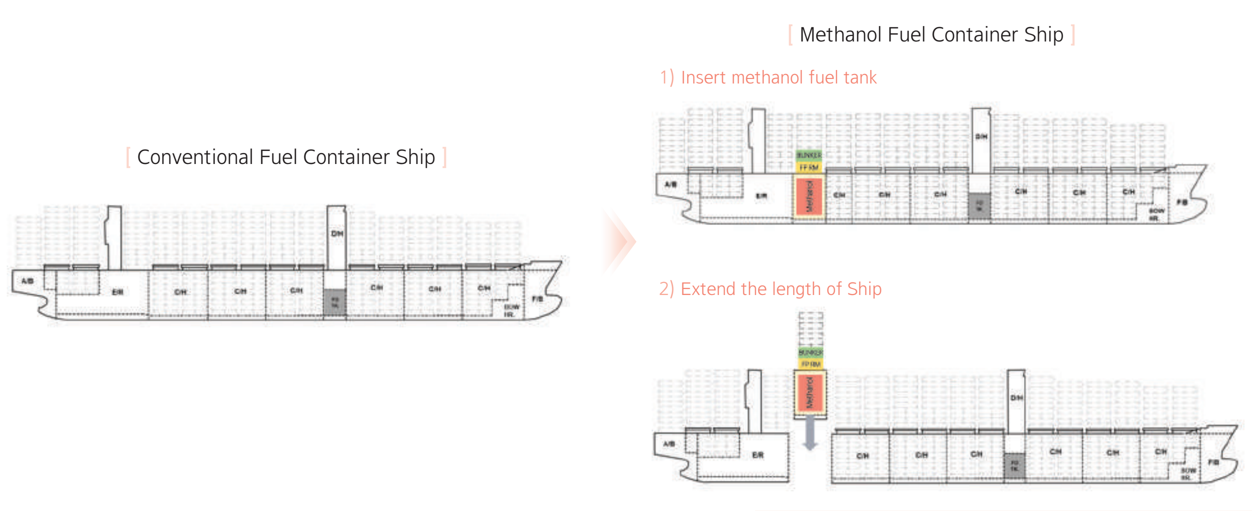


Impact of fuel storage selection on future alternative fuel transition

· Methanol fuel retrofit conversion for container ships

As interest in methanol increases, there is a growing trend to retrofit existing fuel-powered container ships to run on methanol. However, transitioning to a fuel not initially considered and planning for its future use in a retrofit is quite challenging and requires significant investment. There are two methods of conversion of container ships to methanol propulsion: inserting methanol fuel tanks into existing cargo hold spaces to replace cargo space with fuel tank capacity or extending the ship's length by the required length of the methanol fuel tanks. The method of inserting fuel tanks is expected to result in cargo loss and constraints in tank design. On the other hand, extending the ship's length to accommodate fuel tanks will avoid cargo loss, but it introduces many additional considerations due to the extended hull length. Both options present complex challenges.

Example of Methanol Fuel Retrofit

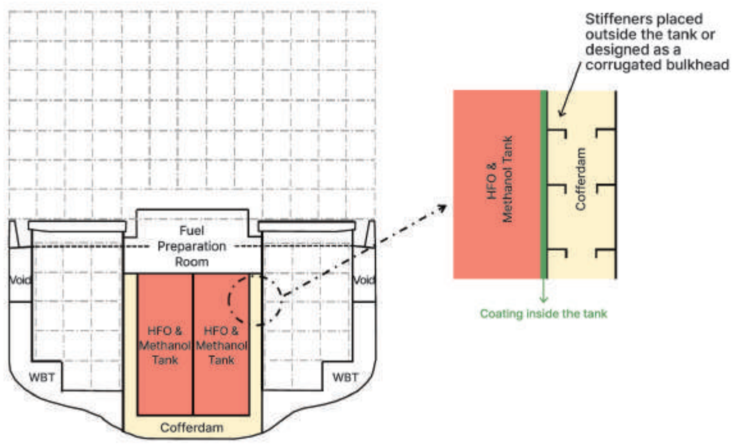


· Utilization of existing HFO tanks as methanol fuel tanks

Can we repurpose existing HFO tanks for methanol fuel? This is generally considered difficult. The challenge arises from the properties of methanol, which can corrode certain materials, making tank coating crucial. Moreover, due to its toxicity, a cofferdam* must be placed around the methanol fuel tank. HFO tanks designed without accounting for these methanol-specific properties would likely lack tank coating and cofferdam structures. Specifically, the reinforcing materials inside HFO tanks hinder the quality of tank coating. Therefore, if designing tanks for a vessel prepared for both HFO and methanol storage, the cofferdam structure should be considered from the outset. Reinforcement materials should either be placed outside the tank for coating purposes, or a corrugated bulkhead should be used to form the fuel tank.

* Cofferdam : an empty space arranged so that compartments on each side have no common boundary

Example of HFO & Methanol Fuel Tank design



· Impact of fuel storage on retrofit costs

As mentioned earlier, retrofitting for a different fuel propulsion involves significant costs and time. Research reports on fuel conversion retrofits show that costs can vary by vessel type, ranging from as low as 50% to over 100% of the vessel's value, and the conversion process can lead to 4 to 6 months of lost earnings due to downtime. These factors make it challenging to retrofit operational ships for alternative fuel propulsion. This is one of the reasons why there is an increasing focus on building new ships designed for alternative fuels, which can help reduce the costs associated with future retrofits.

Conclusion: Importance of fuel storage technology

We have examined various aspects of fuel storage systems and their impact on transitioning to alternative fuels to meet decarbonization needs in the shipping industry. The role of fuel storage systems in a successful transition to alternative fuels is both significant and vital. Since the introduction of LNG-powered ships, vessels prepared for alternative fuels have been considered. However, the tangible benefits of these preparations have been met with skepticism to date. The uncertain future makes immediate decision-making and investment during the design phase challenging. Nevertheless, the push for decarbonization in shipping is growing, affecting not just new builds but also existing vessels, and coming from multiple angles. Fuel storage systems demand significant collaboration and practical solutions from shipping companies, shipbuilders, energy providers, and others. This article aims to serve as a starting point for these discussions, and we hope that KR can contribute to these collaborative efforts.

CCUS Industry and LCO_2 Carrier

By LEE Dongbeom,
Senior Surveyor of KR Liquid Cargo Ship Team

To ensure the safe transport of LCO_2, there are many factors to consider when designing the tank

CCUS technology and carbon neutrality efforts

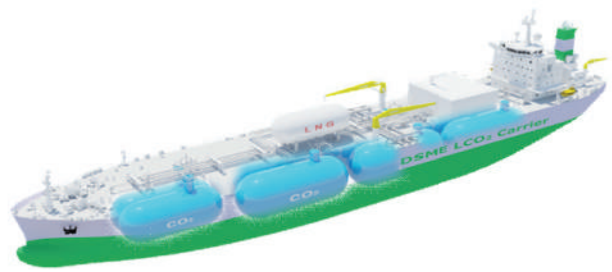
The rising emissions of greenhouse gases pose global challenges related to climate change and global warming. Both countries and companies are striving for carbon neutrality to fight these issues. Carbon Capture, Utilization, and Storage (CCUS) technology has gained traction as one solution in the fight against greenhouse gas emissions.

CCUS industry and LCO_2 carriers

Its high demand has spurred the expansion of the CCUS industry and galvanized the need for specialized liquefied carbon dioxide (LCO_2) carriers. Stable and large-scale transport of captured carbon dioxide (CO_2) by CCUS processes to storage facilities requires specific conditions, such as low temperatures and high pressure. LCO_2 carriers are designed to handle these particular tasks.

While CO_2 exists in a gaseous state at room temperature, it is crucial to transport CO_2 in a liquid state. IMO Type C tanks should be employed for the efficient bulk transportation of liquefied CO_2. LCO_2 carriers must be designed carefully considering the triple point conditions, where gas, liquid, and solid states coexist. Special attention is crucial to prevent any phase transition during the operation. Furthermore, while the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code) classifies CO_2 only as an asphyxiate cargo, many countries classify CO_2 as a toxic substance. As a result, the International Maritime Organization (IMO) has initiated discussions on this matter. If CO_2 were to be classified as a toxic substance, it would be subject to additional safety requirements in the IGC Code related to the transport, storage, and handling of toxic substances. However, the toxicity of CO_2 is not as severe as other toxic substances, so it is expected that some regulations may be exempted. As such, it's important to monitor the future discussions and decisions of the IMO.

Hanwha Ocean 40K LCO_2 Carrier

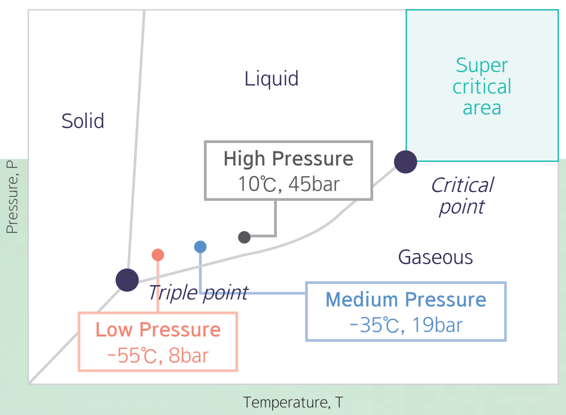


Various factors to consider in designing tanks for the safe transportation of LCO_2

· Tank pressure

The design pressure of the tank can be classified into low pressure and medium pressure. The choice depends on several factors, including the amount of cargo transported, the distance to the final storage facility, impurity levels, and the state of the captured CO_2. From an operational flexibility perspective, medium pressure offers advantages over low pressure. However, increasing pressure during tank design results in thicker tank shells. It poses a challenge for medium pressure tanks as there are limitations in steel thickness for cargo tanks, making it challenging to achieve larger tank sizes. Conversely, low pressure tanks allow larger sizes. However, there is a higher risk of dry ice formation due to operating temperatures and pressures being close to the triple point compared to situations with medium pressure.

Triple Point of Carbon Dioxide



· Triple point
T = -56,6℃(216,5K)
p = 5,2bar(75,4psi)

· Critical point
T = 31℃(304,2K)
p = 73,8bar(1070,38psi)

· Low temperature

CO_2 is transported at low temperatures, around -55 degrees Celsius for low pressure and -35 degrees Celsius for medium pressure tanks. Consequently, the selection of tank materials that meet the low temperature requirements specified in the IGC Code is of utmost importance.

· High density

In a liquid state, CO_2 exhibits a density of around 1.15 ton/m^3, which makes it approximately twice as dense as LPG. The challenge necessitates further scrutiny regarding fatigue, as per UI GC7, and consideration of sloshing due to the higher density.

· Purity

The vapor pressure of CO_2 varies significantly based on its purity. Typically, LCO_2 carriers are designed with a consideration of high purity CO_2. When accounting for vapor pressure fluctuations due to purity, it is crucial to consider higher vapor pressures. Additionally, the moisture content of CO_2 can also impact tank corrosion and requires careful attention.

· Tank plate thickness

The IGC Code permits steel plate thicknesses up to 40mm for independent Type C tanks. Steel plates with thicknesses ranging from over 40mm to under 50mm necessitate either Post Weld Heat Treatment (PWHT) or Engineering Critical Assessment (ECA) under IACS UR W1. For larger tanks, considering the challenges of Post Weld Heat Treatment (PWHT), there is a greater likelihood of employing Engineering Critical Assessment (ECA). To facilitate this, IACS intends to establish a project team to develop an ECA procedure.

· Tank shape

Ease of fabrication and design efficiency may determine the shape of the tank as a single cylindrical Type C tank. Another option is a multi-lobe Type C tank, which is more challenging to fabricate and design but easier to use.

Ammonia and LCO_2 carrier

Recently, there has been a growing number of articles discussing advancements in ships capable of transporting both ammonia and LCO_2. The plan is to use one ship to carry ammonia to power plants and then use the same vessel to transport emitted CO_2 to storage facilities. This strategic approach offers notable operational efficiencies. However, how the residual ammonia left after ammonia transport affects CO_2 purity needs to be considered. Failing to properly clean the tank before loading carbon dioxide after discharging ammonia could impact CO_2 purity. Additionally, the vapor pressure dynamics of CO_2 could have significant effects. It is imperative to subject the cargo handling system (CHS) to a comprehensive cleansing procedure. This might necessitate separate cargo handling systems for both ammonia and CO_2. Cross-loading of LCO_2 with ammonia in a single tank poses practical challenges.

Our roles

In close synergy with various shipyards, KR has successfully completed the verification of structural integrity and fitness for the cargo tanks and holds of LCO_2 carriers. Through rigorous analysis in accordance with requirements mandated by the IGC Code, KR has confirmed the structural integrity of cargo tanks under various load conditions, including permanent, functional, environmental, and accidental loads. Beyond this, the structural reliability of cargo holds, and tank support structures has undergone validation across a range of design load conditions. KR is committed to being a steadfast partner for pioneering entities navigating decarbonization, a mission fostered by such close collaborations.

Regulatory Updates_

MEPC 80 Key Highlights

1. The uptake of zero or near-zero GHG emissions technologies, fuels and/or energy sources is expected to increase

The revised 2023 strategy for reducing greenhouse gas (GHG) emissions from international shipping includes the adoption of technologies, fuels, and energy sources that produce zero or near-zero GHG emissions. Consequently, we can anticipate that upcoming discussions will focus on the development of mid-term measures.

- Evaluation of the total energy use of various fuels in international shipping (e.g. 5th IMO GHG Study)
- Estimation of a 5% reduction in GHG emissions corresponding to total energy use.
- The following GHG reduction pathway may be established for international shipping:
  1) Define "zero or near-zero GHG emission" alternative fuels and set a fleet ratio capable of using these fuels between 5-10%.
  2) Regulate the actual consumption of certified zero or near-zero GHG emission alternative fuels to be 5-10% of the total annual fuel oil consumption per individual ship. Provide appropriate incentives for early adopters, considering that ships using alternative fuels will mostly be designed for dual-fuel usage.
  3) For ships not using alternative fuels, regulate through a goal-based approach that allows the use of all available alternative fuels including biofuels and its blends. Aim to reduce total GHG emissions corresponding to the total annual fuel oil consumption of each ship by 5-10%, etc.

In addition to the levels of ambition above, the indicative checkpoint for the 20~30% reduction of GHG emissions from international shipping by 2030 will be implemented at the same time as the current 40% carbon intensity reduction requirements. This means that future decisions on the remaining carbon intensity reduction factors for the years 2027 to 2030, which were left blank, will be significantly affected and further strengthened reduction factors will likely be introduced.

2. Relationship between Bio-fuels and Carbon Intensity Indicator(CII)

MEPC 80 approved MEPC.1/Circ.905 which provides the possibility to improve the carbon intensity of international shipping by using sustainable bio-fuels. Eligible Bio-fuels have to have been certified by an international certification scheme such as ISCC, RSB etc. Their well-to-wake GHG intensity values must not exceed 33gCO_{2eq}/MJ, and they may be assigned a Cf equal to the value of the well-to-wake GHG emissions of the fuel by multiplying its lower calorific value (LCV). Therefore, the following scenario can be expected:

1) Where the WtW GHG intensity value for a specific bio-fuel is 24.6gCO_{2eq}/MJ, its LCV value is 0.04035 MJ/g, and it is blended with no more than 30% biofuel by volume
2) Conversion factor (Cf) for the bio-fuel can be calculated as follows:
   $Cf = E(gCO_{2eq}/MJ) \times LCV(MJ/g) = 24.6 \times 0.04035 = 0.993CO_{2eq}$
3) The Cf values for the bio-fuel blends can be calculated as follows:

	Blend(%)	Cf(gCO_{2eq}/g)	Cons(ton)	LCV(MJ/g)
FO	70	3.151	9,128	0.0412
Bio-fuels	30	0.993	3,912	0.0375

$E(MJ) = Cons(g) \times LCV(MJ/g);$

$$\therefore Cf_{B30} = \frac{E_{FO} \times Cf_{FO} + E_{Bio} \times Cf_{Bio}}{E_{FO} \times E_{Bio}}$$

$$= \frac{9.128 \times 10^6 \times 0.0412 \times 3.151 + 3.912 \times 10^6 \times 0.0375 \times 0.993}{9.128 \times 10^6 \times 0.0412 + 3.912 \times 10^6 \times 0.0375}$$

$$= 2.545gCO_{2eq}/g$$

KR Decarbonization Magazine

Inside KR_

KR Grants Approval to SHI's 200K CBM Class Ultra-Large Ammonia Carrier with Ammonia Fuel

KR granted an Approval in Principle (AiP) for a 200K CBM Class Ultra-Large Ammonia Carrier with Ammonia Fuel. The innovative vessel design, created by Samsung Heavy Industries (SHI), was unveiled at Gastech 2023 in Singapore on 6 September.

A joint development project (JDP) between KR and SHI resulted in the development of this ultra-large ammonia carrier featuring an ammonia fuel system. The carrier is a green ship designed to carry large quantities of ammonia, using the cargo as fuel, and has zero carbon dioxide emissions during operation.

Ammonia, known for its distinctive odor that aids quick leak detection is also relatively lightweight, allowing effective control of leaking gases. It also offers the benefit of low explosive properties. However, it presents certain challenges such as corrosive properties towards metals and toxicity, necessitating meticulous safety-focused design considerations.

In this project, SHI carried out the conceptual design of the fuel system and the basic design of the vessel, taking into account ammonia's unique characteristics. Additionally, SHI devised systems for fuel supply, ventilation, and gas monitoring tailored to the ammonia fuel system. The basic design was completed to meet classification rules to ensure the safety of the enlarged tank and hull.

KR verified the safety of the ammonia fuel system and supported the optimization of the tank and hull structure. The classification society also verified the design suitability of the ultra-large ammonia carrier by thoroughly reviewing domestic and international regulations.

JANG Haeki, Executive Vice President (CTO) of SHI Engineering Operations, stated, "Clean ammonia is an environmentally friendly energy source and is expected to play a significant role in energy transportation in the future hydrogen society. Ultra-large ammonia carriers will also be in demand in the future to handle the increasing volume of cargo. This approval of the ultra-large ammonia ship with ammonia fuel system enables rapid commercialization, and we will continue to make our efforts to develop green technologies to lead the next-generation ship market."

A KR official emphasized, "Through this project, the two companies have laid an important foundation for the commercialization of ultra-large ammonia ships. KR will continue to provide outstanding technical support for the development of green ships in cooperation with various stakeholders in the shipping industry."

KR approves LCO_2 cargo tank design developed by Hyundai Mipo and HD KSOE

KR has granted an Approval In Principle (AIP) for a liquefied carbon dioxide (LCO_2) cargo tank design, developed by Hyundai Mipo Dockyard (HMD) and HD Korea Shipbuilding & Offshore Engineering (HD KSOE), during GASTECH 2023, held in Singapore on 7 September.

This AIP is the outcome of a successful collaborative joint project involving KR, HMD and HD KSOE. HMD designed the cargo tank, HD KSOE conducted an engineering critical assessment (ECA), and KR ensured the design's suitability by reviewing classification rules and international regulations.

The development of the LCO_2 cargo tank underscores the commitment of these three companies to reduce carbon emissions, aligning with the global push for carbon neutrality and a sustainable future. Notably, the demand for LCO_2 carriers is projected to rise, as carbon capture, utilization, and storage (CCUS) technologies are poised to play a pivotal role in reducing global carbon dioxide emissions.

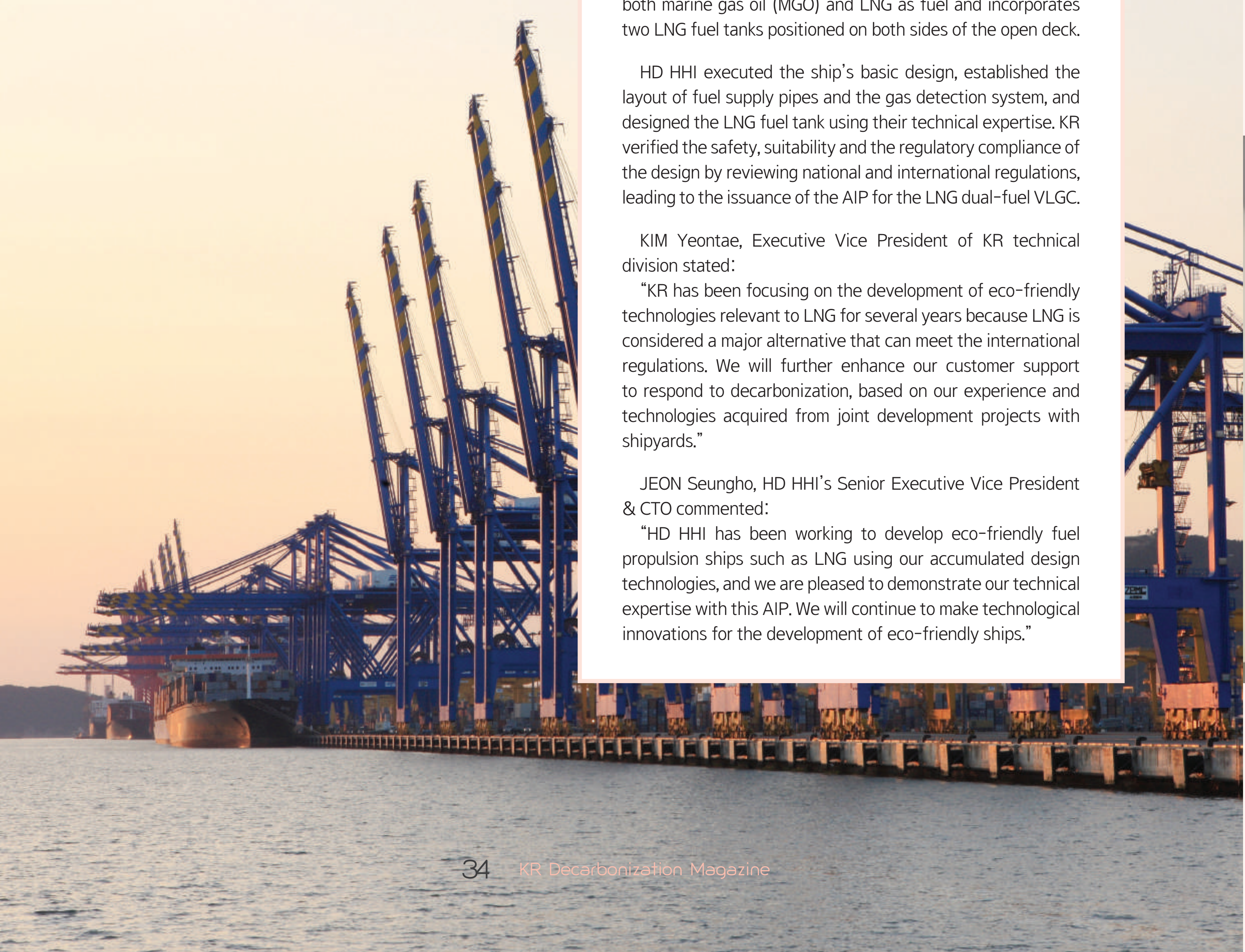
To liquefy carbon dioxide for efficient mass transportation, it is essential to maintain low temperatures and high pressures. Achieving economical transportation hinges on considering the triple point of carbon dioxide, where the temperature and pressure allow the three phases of gas, liquid, and solid to coexist in equilibrium. Special attention must be devoted to preventing carbon dioxide from undergoing phase changes during operation. Consequently, designing cargo tanks necessitates advanced technology and expertise.

The newly developed LCO_2 cargo tank design incorporates an independent IMO Type-C tank to maintain the triple point of carbon dioxide. The structural safety of the cargo tank was further verified by applying the ECA evaluation technique. Moreover, its design enables the loading of a larger cargo capacity compared to existing vessels of similar size, promising even more cost-effective operations.

KIM Yeontae, Executive Vice President of KR's Technical Devision, commented, "Through this AIP, we have laid an important foundation for commercializing the ECA evaluation method and the construction technology for LCO_2 cargo tanks. KR will work to support the development of CCUS-related technology as well as other decarbonization response technologies."

Representatives of HMD and HD KSOE said, "The newly developed LCO_2 cargo tank is proof of our efforts to reduce carbon emissions at this time of transition towards decarbonization, and the essence of our eco-friendly technology and expertise. We will continue to develop innovative technologies for a sustainable future."

KR awards AIP to HD Hyundai Heavy Industries' LNG dual-fuel VLGC



KR has awarded an Approval in Principle (AIP) for an LNG dual-fuel VLGC (Very Large Gas Carrier) jointly developed by KR and HD Hyundai Heavy Industries (HD HHI) at Gastech 2023 in Singapore on 7 September.

Currently, the global maritime industry is grappling with the development of various countermeasures to meet strengthening greenhouse gas regulations, and market interest in eco-friendly fueled ships such as LNG is particularly high.

The newly approved LNG dual-fuel VLGC, which has been developed in response to the recent circumstances, utilizes both marine gas oil (MGO) and LNG as fuel and incorporates two LNG fuel tanks positioned on both sides of the open deck.

HD HHI executed the ship's basic design, established the layout of fuel supply pipes and the gas detection system, and designed the LNG fuel tank using their technical expertise. KR verified the safety, suitability and the regulatory compliance of the design by reviewing national and international regulations, leading to the issuance of the AIP for the LNG dual-fuel VLGC.

KIM Yeontae, Executive Vice President of KR technical division stated:
"KR has been focusing on the development of eco-friendly technologies relevant to LNG for several years because LNG is considered a major alternative that can meet the international regulations. We will further enhance our customer support to respond to decarbonization, based on our experience and technologies acquired from joint development projects with shipyards."

JEON Seungho, HD HHI's Senior Executive Vice President & CTO commented:
"HD HHI has been working to develop eco-friendly fuel propulsion ships such as LNG using our accumulated design technologies, and we are pleased to demonstrate our technical expertise with this AIP. We will continue to make technological innovations for the development of eco-friendly ships."

KR Awards Approval in Principle to HD Hyundai Heavy Industries' Innovative Tank Shape (Hi-ICON) with Sloshing-Restrained Technology

KR has awarded an Approval in Principle (AIP) to HD Hyundai Heavy Industries (HD HHI) for a new type of tank shape designed for various liquefied gases and fuels. The announcement was made during Nor-Shipping 2023 in Oslo, Norway on 8 June. The new tank shape, developed by HD HHI, is designed to improve safety and productivity.

The new tank shape aims to address the challenge of sloshing that impacts the transportation of liquefied gases, such as LNG. Sloshing refers to the wave-like movement of liquid inside a tank during sea transport. It is crucial to ensure structural stability by minimizing sloshing flow caused by the ship's motion, as excessive sloshing can exert significant impact forces on the tank walls, jeopardizing its structural integrity. HD HHI has successfully optimized the shape of the liquefied gas tank, effectively reducing the sloshing effect and enhancing stability. This significantly mitigates the risk of accidents and potential disasters during transportation. Furthermore, the innovative tank design incorporates an improved layout, leading to enhanced work efficiency and productivity. The newly developed tank shape exemplifies cutting-edge technology that combines improved safety measures, increased productivity, and efficient sloshing reduction techniques.

HD HHI plans to expand the application of the new tanks to various liquefied gas carriers and propulsion ships in the future. It is expected that HD HHI will continue to strengthen its competitiveness in the liquefied cargo carrier shipbuilding market, including LNG, by providing safe and reliable solutions to customers.

KR is committed to actively collaborating with the technology development of new tank types, including Hi-ICON. As a leading classification society, KR will provide comprehensive technical support to facilitate the development of next-generation eco-friendly ships, further promoting the advancement of maritime industry.

MOU with Hyundai Mipo Dockyard for Joint Development of CSOV

On 24 July, KR signed a Memorandum of Understanding (MoU) agreement with Hyundai Mipo Dockyard (HMD) for the joint development of a commissioning service operation vessel (CSOV). The signing ceremony took place at HD Hyundai's Global R&D Center in Korea.

CSOVs play a pivotal role in the operation and maintenance of offshore wind power structures. As the global trend toward renewable energy expansion gains momentum, the offshore wind power market is set for growth. This trend resonates in Korea, where ambitious large-scale offshore wind power projects are being championed in Ulsan, Donghae, and Jeju.

To proactively respond to this demand, the two companies have agreed to join forces to develop their own CSOV design while promoting cooperation to localize offshore wind farm operation technology.

A key technological element of CSOVs is the ability to maintain the stable underwater position of a vessel, taking into account the surrounding maritime environment. To achieve this, a dynamic positioning system leveraging propellers and rudders is employed. This enables the vessel to withstand external forces—like wind, waves, and water flow—ensuring stability during offshore work.

Considering the unique maritime environment of these domestic and foreign wind farms, HMD will develop an optimal linear design to ensure the dynamic positioning performance, and at the same time apply a hybrid electric propulsion system to the design. In addition, HMD will ensure market competitiveness by systematizing various equipment such as cranes and gangways capable of motion control to enable stable work performance.

KR plans to review domestic and international regulations for this CSOV design and verify its stability and suitability. Once this technology development is completed, it is expected to be able to operate and maintain domestic offshore wind farms in Korea.

The process of localizing this CSOV technology is ongoing, and KR remains steadfast in its commitment to offering unwavering technical support. This collaboration with domestic shipyards, who have world-class shipbuilding prowess, emphasizes KR's dedication to furthering technological localization efforts.

KR Launches 'SeaTrust-FOWT' Solution

On 25 July, KR unveiled the 「SeaTrust Floating Offshore Wind Turbine (FOWT) solution」 a new addition to the SeaTrust series—a suite of KR technical software designed to enable direct structural analysis evaluation of floating offshore wind platforms and related guidelines.

The KR SeaTrust software series has been released in various versions focusing on detailed functions, such as ship structural analysis and safety inspection based on direct analysis. The solution has gained a wide range of users in the shipbuilding and shipping industries internationally and is highly valued by maritime stakeholders.

The newly released KR SeaTrust-FOWT has been developed to meet the technical requirements of KR customers. With the expansion of the floating offshore wind power market and the promotion of large-scale offshore wind power projects in Korea, the structural analysis requirements for floating offshore wind power platform design and structural safety verification are expected to rise.

Due to the nature of the offshore environment, it is essential to perform integrated load analysis and simulation to verify the structural safety of FOWT platform structures, as wind loads caused by time-varying wind speed, direction, and type are transferred to the lower portion of the wind turbine blades and towers.

In order to evaluate the safety and performance of this platform, it is necessary to comply with the international IEC 61400 standard. Major classification societies, including KR, have formulated their own rules and guidelines for FOWT evaluation based on this standard, assuring safety.

Nonetheless, challenges arise in conducting these evaluations within tight timelines, notably in meeting the integrated load analysis criteria dictated by IEC. Addressing this, KR collaborated with Front Energies in the United States, harnessing open-source tool OpenFAST to overcome these difficulties.

This effectively improved the analysis time and H/W resource issues found in the existing engineering tool. In addition, procedures and systems have been established that can efficiently evaluate structural stability according to the requirements set by IEC and various classification societies.

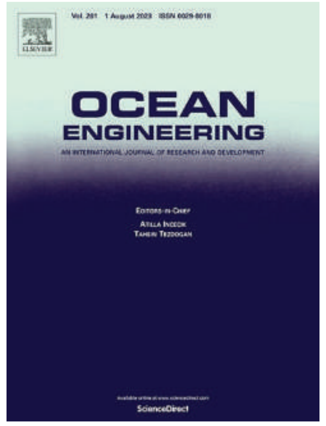
KR has also developed "Guidelines for Direct Structural Analysis of FOWT Platform." This comprehensive resource not only contains detailed technical insights but also showcases FOWT integrated load analysis scenarios, optimizing user accessibility and convenience.

Preceding the formal launch, on July 18, KR organized a technical conference in Seoul, Korea, to introduce the solution and highlight the technological merits underpinning SeaTrust-FOWT.

This conference served as an opportunity for KR to present the outcomes of software verification for the FOWT platform from the user's perspective. It delved into the practical application of each module, showcasing the strong potential for real-world utilization.

With the significant interest and positive response from shipbuilding, shipping, and academic stakeholders, KR is committed to further improving and expanding our customer-focused technical services.

Paper proposing effective implementation of CII published in international journal Ocean Engineering

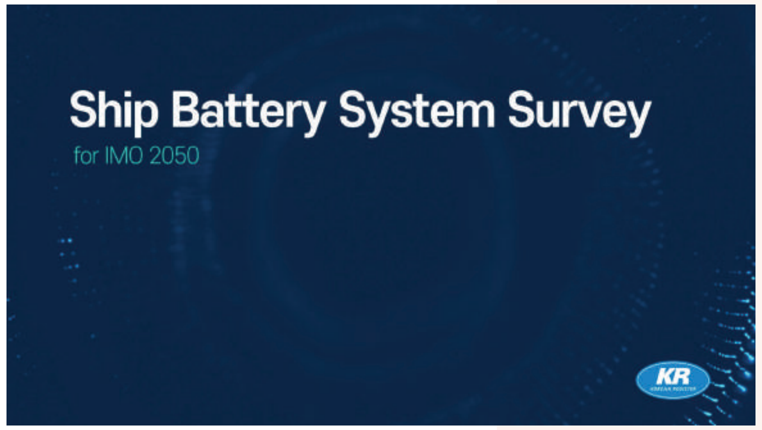


KR is proud to announce that a paper entitled 'Proposal and analysis for effective implementation of new measures to reduce the operational carbon intensity of ships' by KIM Hoijun, Principal Surveyor of KR Statutory Division, has been published in Ocean Engineering Volume 280, 15 July 2023.

Ocean Engineering is a world-class academic and research organization based in the UK, focusing on marine and offshore renewable energy and the development of devices to reduce air pollution and greenhouse gases, and is a prestigious international academic organization in the marine field, with a journal impact factor in the top 5% of international journals.

The paper analyzes the impact on the industry of the IMO's implementation of Carbon Intensity Indicator (CII), one of the IMO's short-term GHG reduction measures, and minimizes the negative impact on the maritime industry by providing a technically complete methodology for calculating the GHG emissions of international shipping. It is expected to be a useful guide for the maritime industry, including shipping companies and classification societies, in the implementation of the CII Regulation. The findings were shared with Member States during the IMO MEPC 80, which Mr. Kim attended as a South Korean delegate.

Ship Battery System Survey in Response to IMO 2050



The greatest challenge facing the international shipping industry is decarbonization. The IMO has set out a phased strategy to reduce greenhouse gas emissions from shipping by at least 40% by 2030 compared to 2008, and to reach net-zero by or around 2050, and the shipping industry is taking a multi-pronged approach to achieve this goal.

An electric propulsion ship is one of the options. Battery systems that can efficiently store and manage large amounts of electrical energy are a key technology for green electric ships. The ability to store more energy in a smaller space with safety guarantees it is an essential part of the system.

KR provides a comprehensive inspection and testing process for battery systems, ensuring its proper function and compliance with industry standards. Our Ship Battery System Survey for IMO 2050 video content is available on our YouTube channel.

[View the Ship Battery System Survey for IMO 2050 here.]

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.

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Korean Register

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