Future Visions of Japanese Maritime Industries

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Japanese zero-emission ships by 2028

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To help manufacturers develop and realise new products, Japan Ship Machinery and Equipment Association has received support from the Nippon Foundation and is now providing business assistance to them.

Future Vision 01

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In 2028 Japan will introduce the first-gene
Projects are underway to realize this using d
ammonia, batteri
This does not only invol
but also fuel supply and transportati
practical application rig

In October 2020 Japanese Prime Minister Yoshihide Suga, in his first policy address, made clear Japan's environmental targets in accelerating the movement toward decarbonization. He said: "I hereby declare that Japan will strive to become a carbon neutral society, with zero net emissions, by 2050."

Before this, in March 2020, the following policy was outlined for the Japanese maritime industries. "As the milestone of our challenge, we will endeavor to realize the first-generation "Zero Emission Ship" being introduced by 2028."

In 2018 shipping companies, shipbuilders, ship machinery manufacturers, research institutes, universities and government representatives gathered to establish the International Greenhouse Gas (GHG) Zero Emission Project. Over the next year and a half a general policy for the decarbonization of the Japanese maritime cluster was discussed. Movements in world energy and decarbonization were researched and the state of technical development was examined. Based on this discussion Japan's maritime industry announced decarbonization scenarios and a workplan to reduce GHG.

While the world maritime industries set an ambition to realize the zero-emission ship by 2030, Japan set its own target ahead of this by two years to realize commercial operation in 2028. Through this Japan demonstrated its own intention to move ahead of the rest of the world.

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Concept Design of
Zero-Emission Ships
"C-Zero Japan"

ration of emission-free ships to the world.
ecarbonization technology such as hydrogen,
es and CO_2 capture.
ve developing new ships,
on and taking a world lead in realizing
ht across the value chain.

In drawing up the zero-emission strategy different scenarios for the availability of fuels were presented. The International Maritime Organization (IMO) had announced a target for the international shipping industry to halve emissions by 2050. But, on average, as world trade continues to grow, by how much would ship efficiency have to improve to achieve this? Japan's calculation was that, on an individual ship basis, compared to 2008, a 78% improvement would be necessary.

Based on this a list of alternative fuels and emission reduction technology was drawn up, technologies were selected to achieve, by 2028, close to a 90% improvement in efficiency and two different of future scenarios were drawn up.

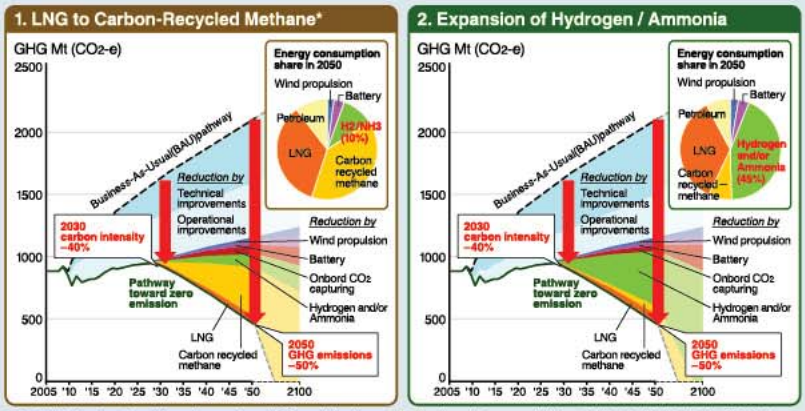
One scenario was a move toward synthetic methane produced from LNG as the main marine fuel. Synthetic methane has the same CO_2 emissions as LNG but, as it is refined from captured CO_2, it is expected to be regarded as a carbon neutral fuel. This scenario is promising because it allows future LNG fuel technologies and infrastructure to be used as they are.

If things develop in line with this scenario from now on, by shipowners investing directly in converting to LNG fuel, there is a high possibility that not only the 2030 target, but also the 2050 target can be achieved.

The other scenario is the establishment of hydrogen and ammonia as a marine fuel. Neither fuel produces any CO_2 at all when burned

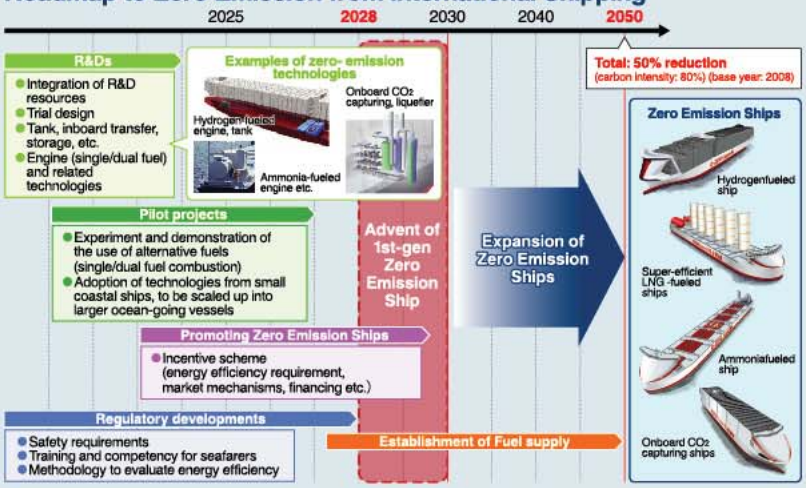
Emission pathways toward 2050 and beyond

Acknowledging uncertainties in future energy supply scenarios, two feasible emission reduction pathways, aligned with the GHG reduction targets set out in the IMO Strategy, are developed.



* Synthetic fuel produced from the captured CO_2 and Hydrogen. As its chemical property is basically identical to that of LNG, it can be dropped into existing LNG-fueled ships and LNG bunkering infrastructure.

Roadmap to Zero Emission from International Shipping



so zero emissions can be achieved. Ammonia has to downside of being toxic, with poor combustion characteristics, while hydrogen is difficult to handle and has other technical problems. But engine makers are hastening research and development and there is a high possibility these problems can be overcome.

Based on the use of both these fuels a simulation took place on achieving the target to reduce overall ship emissions by 50% in 2050. The result of the share of fuels adopted by ocean-going shipping is shown in the attached table.

Based on these assumed scenarios four concept designs were drawn up as basic zero-emission ships under the name C-Zero Japan series. *(See conceptual images of the four ships on the previous page.)*

There are two concepts based on the scenario that synthetic methane and LNG are the main marine fuels. One concept involved an all-inclusive energy saving vessel using LNG as a fuel along with existing technology including low-speed designs, wind propulsion, air lubrication and hybrid type contra-rotating propulsion systems. Based on this concept designs for an 80,000-dwt bulk carrier and 20,000-teu containership were drawn up and a reduction in carbon emissions was confirmed.

One other concept was for an onboard CO_2 capture and storage system from exhaust gasses used together with a methane-fueled propulsion system. A concept design for a 20,000-teu containership took place.

Also, for the use of liquid hydrogen and ammonia as the main marine fuel scenario, concepts were presented for a liquid hydrogen fueled ship and an ammonia fueled ship.

For the hydrogen-fueled ship two designs were created, an 80,000-dwt bulk carrier and 20,000-teu containership. The engine and fuel supply system, enlarged fuel tank, heat insulation and measures to prevent hydrogen leakage were based on the use of a duel-fuel reciprocating engine. Solutions were found to technical issues such as refueling.

For the ammonia fueled concept an 80,000-dwt bulk carrier concept design was created. To counter ammonia's poor combustion characteristics a pilot fuel was introduced to stabilize ignition. Even with that a 91.9% improvement in CO_2 emissions can be expected.

A road map for the use of these four ship types was drawn up toward realizing the zero-emission ship by 2028. For example, for hydrogen and ammonia fueled vessels, the process involves developing the engine by 2024, verification of the mixed combustion and installation on a coastal vessel by 2026 and the vessel entering into service by 2028.

In line with this road map the Japanese maritime industry players began collaborative research and development and technology verification. Projects to realize zero-emission ships are starting up around the world, but Japan's unique feature is that this not only involves just the development of ships, but is progressing a study of the fuel supply from the viewpoint of the full supply chain from upstream to transportation.

Japan is using it depth of its maritime cluster to take a lead in realizing the zero-emission ship.

Japan has started several projects involving the use of ammonia as a marine fuel. From the spring of 2020 six companies, Imabari

Joint R&D Starts for Ammonia-fueled Tugboat

© NYK Line

Shipbuilding and Mitusi E&S Machinery, ClassNK, Itochu Enex, Itochu Corporation and MAN Engine Solutions, began a joint-development project. Japan's largest shipbuilder and engine manufacturer combined in this project to develop the ship. In addition, the Itochu Group played a role in overseeing the integration of the project to include the development of areas in the establishment of ammonia as a marine fuel, including the vessel ownership and operation and preparation of the fuel supply infrastructure, while ClassNK will develop the guidelines.

In parallel with this project Nippon Yusen Kaisha, Nihon Shipyard

(a joint venture between Imabari Shipbuilding and Japan Marine United) and ClassNK started a research and development project to develop a dedicated ammonia ship. The project is aiming to develop a vessel that would be the world's first ammonia-fueled dedicated liquified ammonia gas carrier in addition to an ammonia floating storage and regassification barge.

The project is not only looking at the use of ammonia as a marine fuel but also the establishment of methods for the high-volume transportation and supply of ammonia, from the perspective of the full ammonia supply chain, including the future use of ammonia at coal-fired power stations and on land.

Projects to develop the use of hydrogen fuel are also starting. Five companies including Nippon Yusen Kaisha, Toshiba Energy Systems, Kawasaki Heavy Industries, ClassNK and ENEOS have started a practical demonstration project aimed at realizing a vessel with a hydrogen fuel cell system.

The project aims to develop a high-powered marine fuel cell system for a medium-sized tourist vessel and to also construct a land based liquid hydrogen fuel supply system.

Image of NYK and NSY's ammonia-fueled ammonia gas carrie

The project will include verification right across the whole value chain from a feasibility study to research and development including the ship construction, developing the fuel supply chain, operational verification, safety standards and the approach to legal aspects. The plan is to demonstrate the vessel in operation at Yokohama port in 2024.

Namura Shipbuilding and others are also progressing a project to commercialize a hydrogen fuel cell ships. Together with Iwatani Sangyo, Tokyo University of Marine Science, Kansai Electric Power Company and the Development Bank of Japan the project is aiming at the commercialization of a hydrogen fuel cell powered ship and hydrogen station for shipping. The idea is to build a ship that in 2025 will operate between Osaka city centre and the site of the Osaka Expo2025. It is expected that the 30 metre-long hydrogen fuel cell ship will have to capacity to carry 100-150 people.

K Line and Mitsubishi Shipbuilding, along with ClassNK, have started the world's first onboard demonstration tests for an onboard CO_2 capture system. A small CO_2 capture demonstration plant will be produced and in financial year 2021 it will be installed on the K Line-operated 88,800-dwt coal carrier *Corona Utility*.

Conceptual drawing of the CO_2 recovery demo plant

Mitsubishi Shipbuilding will convert CO_2 capture systems designed for a land-based power plant to produce a demonstration plant for ships and, with the cooperation of ClassNK, a hazard identification (HazID) evaluation will be undertaken.

Onboard verification tests are planned within 2021. The expected amount of CO_2 recovery during the verification will be around 1/1,000 of total emission from the ship.

Japanese shipbuilders have decided to join forces for this type of zero emission ship development project. In October 2020 the leading nine shipbuilders, including Mitsubishi Shipbuilding and Japan Marine United, together set up a new organization to develop ships with advanced environmental performance called the Planning and Design Centre for Greener Ships (GSC). Each company contributes technology and people to jointly carry out product development and technical research for ammonia, hydrogen and battery fueled zero emission ship. It is expected that, based on the results of the GSC, each company will independently develop and market its own ship types, with the aim of basic new ship types coming onto the market from 2023.

The GSC representative director Hiroyuki Yamato said: "In the current situation the move toward zero carbon is revising the industrial map of the world and this is a great opportunity for us." JMU president Kotaro Chiba said: "To realize the zero-carbon ship, development of basic technologies, research on infrastructure, decision-making on investment strategies, and cooperation with other industries will be necessary. I would like to progress GSC as an all-Japan project."

Mitsubishi Shipbuilding president Toru Kitamura said: "The early realization of zero emissions will not be achieved by South Korea, China, or Europe but Japan, the country with the leading environmental technology. Japan can use land-based environmental technology systems developed for plant and other industries and build new shipbuilding technology. GSC is for that purpose, it is a place for shipyards to come together and combine their wisdom."

A new age in which Japan will take a world lead around the key word decarbonization has begun.

Japanese Zero-Emission ships by 2028


Members of Planning and Design Center for Greener Ships

Mitsui E&S Shipbuilding aims to commercialise autonomous ship navigation systems

© Mitsui E&S Shipbuilding

Future Vision 02

Japan is accelerating the realization of autonomous ships. In addition to its ambition to realize autonomous vessels ahead of the rest of the world by 2025 it has started a project with the new target that, by 2040, half Japan's coastal ships will be replaced with crewless vessels.

MEGURI2040 has been launched

Japan targets Autonomous

Sunflower Shiretoko

Mitsuyuki Unno, managing director of the Nippon Foundation, which is leading the project, said: "The realization of the operation of crewless vessels will dramatically innovate the logistic industry and show the world Japan's highly-advanced technology."

The name of the project is 'MEGURI2040'. The Japanese term 'Meguri' means 'circulation'. The name was chosen to symbolize the idea that if the automated ship is realized, the circulations of transport, cost and human will improve and become more beneficial. '2040' is the target year of the project. "We hope that 50% of the coastal ships in Japan will be crewless in 20 years," said Unno.

As a first step toward the implementation of crewless vessels, five types of demonstration will be conducted by the end of fiscal year 2021. More than 40 companies and organizations participate in the five business consortiums that will carry out the demonstrations. Adding to the maritime-related companies such as Japanese shipping companies, shipyards, trading companies and shipping equipment makers, local governments, universities and IT companies will also participate in these demonstrations.

Each consortium will verify the technologies necessary for crewless ships with various types of ships including large ferries, small passenger ships, container ships and amphibious vehicles. The focus of this project is the world's first demonstrations such as crewless navigation of large ferries and crewless navigation in congested sea areas.

In Japan, the government is drawing up a roadmap to gradually increase the level of vessel automation and to aim at the practical use of automated vessels by 2025.

After Phase I, in which the optimal routes will be proposed with using IoT, Phase II aims to realize the automation of vessels by 2025, in which the specific actions of the crew will be proposed.

The timeline of 'MEGURI2040' seems to be roughly the same as this. Through demonstrations, besides the clarification of necessary requirements for crewless navigation and acceleration of necessary technology development, in particular, it is hoped to increase the level of social acceptance of crewless navigation.

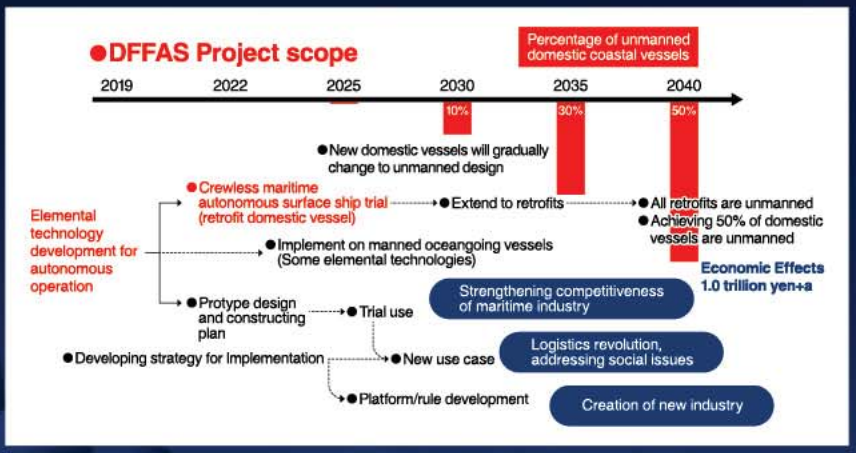
"It is necessary to develop social understanding to alleviate the public concern about whether the crewless ship is really safe. While the government will prepare systems and infrastructures, the Nippon Foundation will conduct demonstrations to deal with social awareness," explained Unno.

As part of the MEGURI 2040 Project, the Joint Technological Development Programme for the Demonstration of Crewless Ships is underway to demonstrate crewless vessels.

Among the adopted demonstration projects adopted under

MEGURI2040, one which has a strong intention to progress the introduction and establishment of crewless vessels, is Nippon Yusen Kaisha Group company Japan Marine Science Inc's Designing the Future of Full Autonomous Ship Project (DFFAS).

The consortium consists of 27 companies from a variety of fields including shipbuilders, navigational equipment makers, telecom companies, ship management companies, insurance companies, ICT start-up companies and so on. In total, more than 50 companies from all over the world, including classification societies and universities are cooperating in this project. In fiscal year 2020/2021 the open collaboration project will develop and demonstrate crewless ship technology.



The concept of the project is to draw up a grand design for the operation of crewless vessels. This will not be just from the technical perspective, but it will also create processes covering all aspects in the introduction and establishment of crewless vessels including legal, insurance, test implementation procedures, risk assessment and others. Through this the project aims to draw up international standards.

In 2022 demonstrations will take place on the 740-gt coastal containership *Suzaku*. The vessel will depart the port, sail on the planned route and, while detecting the surrounding vessels, take the necessary collision avoidance action, then arrive at its destination port.

An automated system will be developed for this series of movements, and for the vessel to be operated while crewless. As rules and infrastructure problems require that the vessel is crewed, there will be crew onboard and the demonstration will take place while complying with the current regulations, but the real operation will be automated and take place following the planned route sent from the shoreside.

A long-distance route in congested water is planned. A comprehensive system including all the functions required for a crewless ship, which considers land-based-monitoring, analysis and evaluation, providing feedback to the vessel, as well as remote operations for an emergency, will be developed and demonstrated.

One of the special features of this project is the remote operation support center which is established on land for supporting a crewless ship. In the future it is foreseen that a land base will be necessary when crewless ships are in practical use. As well as observing the ship it will be structured to offer remote support for vessels in emergency situations. The plan is to set up a monitoring station somewhere in the Kanto region manned by two people which is equipped with a large-scale display screen.

As the project is set up with a view to introduce and establish the crewless vessel this is reflected in the form of the crewless operating system. To easily fit crewless functions to existing ships a container-type module has been adopted. Consideration has also been given to the introductory phase of the of the crewless ship. The crewless functions have been placed in a container as a unit giving it versatility to be easily introduced to any ship type.

There are also technical challenges. It is necessary to recognize other ships and take avoiding action. However, one technical development issue is the correct performance of this function in circumstances such as poor weather or ocean-going voyages. The technology required to realize crewless vessels will be taken from consortium members' independently developed technology and, if necessary, from outside.

It is not only an issue of crewless technology, progress will also be made on preparing for issues such as the development of rules aimed the introduction of crewless vessels, the sharing of responsibility, insurance and cyber security measures.

The second consortium, in which Mitsui OSK Lines plays a central role, is aimed at the establishment of an automated ship operation system from unberthing to berthing operations. A feature is its use on two ship types: a long-distance coastal ferry and a coastal containership. Highly versatile technology is required for the establishment of the crewless ship.

The demonstration is taking place on two ship types with very different characteristics in terms of size, type of hull form and unique physical properties, which will help to establish the versatility of the technology.

One of the demonstration vessels is the MOL Ferry's approx 11,000-gt car ferry *Sunflower Shiretoko*. The demonstration will take place on the Tomakomai to Oarai route in 2021. The challenge is to conduct the demonstration on an existing route. The other demonstration on a container vessel is taking place on a domestic route using a highly versatile 749-gt type vessel. Imoto Corporation is supplying its coastal container vessel *Mikage* for the experimental voyage between Tsuruga and Sakai which is planned to take place sometime between 2021 and 2022.

The verification trials will include a demonstration of automated berthing and unberthing and automated operation, mooring support and land-based observation support.

The technology required for independent ship operation can be split into three main areas. First there is recognition of the situation surrounding the vessel (recognition) then, based on the recognition, there is judgement (judgement) on how to avoid collision and, from that judgement, there is the actual rudder

Marubeni consortium to demonstrate on small ship

Japan targets Autonomous

© Nippon Foundation

control or (ship operation).

In this demonstration functions will be established that can maintain a watch without mistake and "recognize" the situation around the vessel in fog or at night, make a "decision" which can evaluate the danger from oncoming vessels and conducts "ship operation" with appropriate avoidance action.

Furuno will use technology which recognizes the situation around the vessel. Mitsui E&S Shipbuilding will be in charge of the "judgement" and "ship operation" technology. The automated functions will be verified through simulation by Mitsui E&S Shipbuilding and MOL Marine and, based on that, the challenge of verification in a real sea area is planned.

One more feature of the project is the demonstration of the use of drones in mooring support. Mooring operations are highly dependent on human activity and automation of this area is a major issue to achieve the full automation in shipping.

The first major step is for drones to replace humans in the laying out the heaving line. Using a newly developed drone a heaving line will be automatically picked up from a containership and dropped near to the quay. In containerships, as berthing and unberthing and mooring operations are labor intensive, the aim is to lighten this workload.

Another challenge that will be taken on is the use of augmented reality (AR) in land-based observation. Technology will be developed for the land-based side to see the situation on the automated ship as if it were actually onboard the vessel.

Mitsubishi Shipbuilding and Shin Nihonkai Ferry, as part of the development of a smart ferry, will demonstrate autonomous vessel technology on a large-size car ferry. A 16,000-gt car ferry under construction at Mitsubishi Shipbuilding for Shin Nihonkai Ferry will be used. There are many demonstrations of autonomous ship technology but there is no case of such technology development for a large-size long distance ferry. After the vessel is delivered in June 2021 the demonstration will take place over several times until February 2022.

While continuously ensuring safety, autonomous operations with crew watch are planned to take place on the route between Yokosuka and Shin-Moji.

The planned demonstration involves continuous automated ship operations from unberthing to the voyage, collision and grounding avoidance and berthing.

Also, technology for the improved monitoring of the engine room and land high-level security technology to be applied by a land-based monitoring system is being developed.

During the automated operation monitoring of the condition of the ship operation and engine room will take place from a land base, along with a diagnosis of the engine room machinery.

An important point is the monitoring of the engine room. A barrier to the future development of fully autonomous ship operation is said to be current diesel engines. In this demonstration importance is being placed on strengthening monitoring during operations, technology will be developed to detect oil leaks, analysis and diagnostics related to data collection and predicting breakdowns. By strengthening the monitoring of the engine room it will be possible to detect indications of breakdown and, when the vessel is at berth, through preemptive maintenance of the appropriate part, it will be possible to avoid breakdown during operations.

In the consortium Mitsubishi Shipbuilding has the role of coordinator and is leading the integration of the whole system. As for the automation of ship operations group company MHI Marine Engineering, which is experienced in coastal vessels, is developing the navigation support system "Super Bridge-X". It has experience in fitting automated ship operation systems on the Oshima Shipbuilding-built battery powered ship *e-Oshima*.

In addition, it will also take responsibility for the development of the engine room monitoring system. The idea is that a large-scale engine remote diagnostics technology developed by Mitsubishi Shipbuilding will be applied to the ship engine room and verification trials of the crewless ship as a comprehensive plant system will take place, leading to the promotion of technological development.

In a separate demonstration, coordinated by trading house Marubeni, an autonomous control module developed by Mitsui E&S Shipbuilding will be fitted to a small boat and, on a route of around 1.7km, a demonstration test of crewless ship operation will take place by March 2022. The aim is to develop automated technology that can cheaply and quickly be fitted to existing small ships and applied to a wide range of small ship types.

Development of Smart Ferry

© Shin Nihonkai Ferry

In another demonstration, represented by IT Book Holdings, a Japanese amphibious vehicle will be automatically driven using a dam as the test area. One feature is that it will use the general-purpose automated driving software known as "Autoware".

Competition to develop ship automation as a solution to a shortage of seafarers and preventing maritime accidents due to human error is developing around the world.

Japan is a world leader in developing core technologies, such as sensors and visual analytics, which are the essential to realize the automated vessel. Japan also boats a top-class fleet and, one of its strong points, is that it can use feedback from the site of ship operations in technology development.

The companies which have these technologies and know how, by jointly developing technology, can dramatically progress the technology required for the crewless vessel.

Alternative Fuels support Eco

Japanese shipyards are highly regarded around the world for building advanced energy saving Ecoships. The Japanese Ecoship is now being developed further by combining it with decarbonized fuels.

Future Vision 03

The International Maritime Organization (IMO) has set the target of halving international shipping's greenhouse gas (GHG) emissions by 2050.

The use of LNG as a marine fuel is positioned as a transitional "bridge" solution on the way to realizing the emission-free ship of the future.

LNG-fueled ships are continuing to increase in number and many Japanese shipyards are involved in developing LNG as a fuel in newbuilding projects for all ship types and designs.

Among them bulk carrier projects are attracting a lot of attention. Bulk carriers built in Japan have a reputation for their usability and easy maintenance. In addition, Japanese shipyards' advanced ship development capability is well known for producing ships which can demonstrate a high propulsion performance even in real sea operating conditions.

The main trend is for the world to move toward LNG fueled ships, but Japanese-built ships are not just looking to reduce GHG by switching fuel. Through the addition of high-performance propulsion systems a greater reduction in GHG, and further real improvements in fuel economy, can be achieved.

Namura Shipbuilding and Oshima Shipbuilding are constructing the world's first LNG-fueled dedicated coal carriers, each building one ship in the series. After delivery in 2023 the vessels will be operated by Mitsui OSK Lines and NYK Line in transporting coal to power plants operated by Kyushu Electric Power Company.

Both shipyards have innovated by locating the LNG fuel tank behind the accommodation unit to minimize the reduction in cargo space.

Namura Shipbuilding, in cooperation with Mitsui OSK Lines, began research into an LNG-fueled dedicated coal carrier at an early stage.

In addition, in 2019, in collaboration with K Line, it developed a 250,000-dwt ore carrier which was accredited with an Approval in Principle (AIP) by classification society DNV GL.

Oshima's LNG-fueled coal carrier

Imabari's LPG-fueled capesize bulker

As well as using LNG as a fuel, additional CO_2 reduction technology was also researched, including the incorporation of a shaft generator, a binary generator and a lithium battery power storage which was also considered.

Bulk carrier specialist Oshima Shipbuilding also started to look at the energy transition to LNG at an early stage.

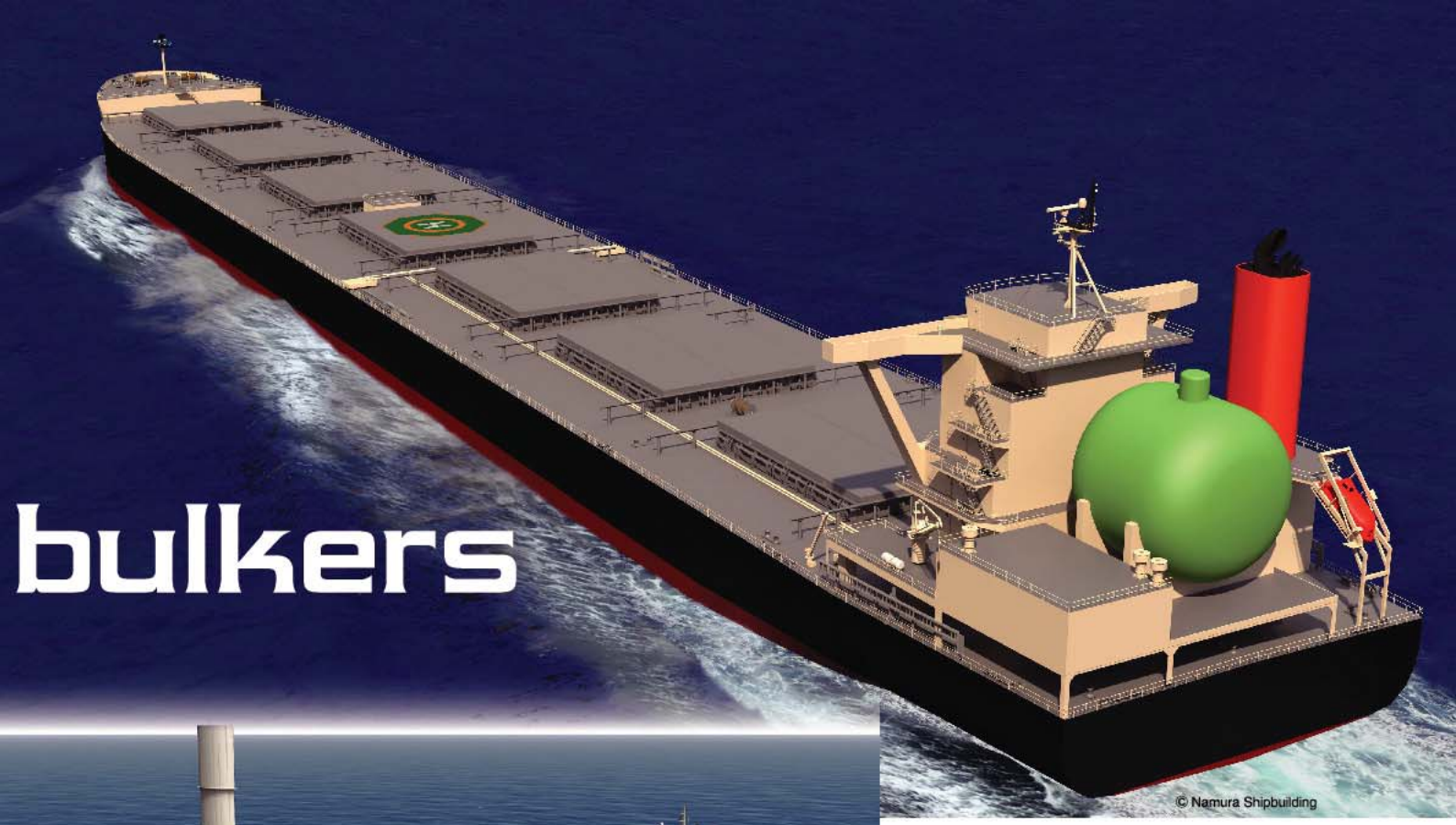
In 2015 it developed a Kamsarmax bulk carrier with the LNG fuel tank located behind the accommodation unit. The design was accredited with an AIP by DNV GL. From an early stage it has also been developing an LNG fueled post-panamax bulk carrier with NYK Line.

After LNG both shipbuilders are now looking toward developing zero-emission ships. Namura Shipbuilding is involved in a hydrogen battery-powered small passenger ship newbuilding project. The ship is scheduled for delivery in 2025.

In 2019 Oshima Shipbuilding launched the passengership "e-Oshima," with a battery powered propulsion system. This type of technology is being now considered for application to ocean-going vessels in the future.

Many shipyards in Japan have developed designs for LNG-fueled large size bulk carriers. Japan Marine United,

bulkers



Namura's LNG-fueled coal carrier

Wind Challenger

Imabari Shipbuilding and Kawasaki Heavy Industries have all completed basic designs.

Among these Imabari Shipbuilding is also looking at LPG as a marine fuel. In 2020 it developed the world's first 180,000-dwt LPG-fueled bulk carrier and received an AIP from classification society ClassNK.

LPG has a high environmental performance and there is a world-wide LPG fuel infrastructure already in place, allowing for flexible global ship operation. This came to the attention of Imabari Shipbuilding which, with the cooperation of Mitsubishi Heavy Industries, came up with a basic design.

Compared to LNG, LPG is cost effective because it does not require the use of low temperature materials or cryogenic insulation. The design specifies LPG fuel is handled at normal temperature, and at high pressure, so there is no need to give special consideration to boil off gas and onboard operations become easier.

The design also positions the LPG fuel tank behind the ship's bridge and provides enough fuel for a continuous return journey from Japan to Australia, one of the main capesize bulk carrier routes.

A risk assessment was also carried out considering the unique physical properties and characteristics of LPG.

Work is also progressing on low-carbon fuels for specialist ship types, which are a strength of Japanese shipyards. In 2019 Sanoyas Shipbuilding (Shin Kurushima Sanoyas Shipbuilding) completed a concept design for a 430,000-cbft woodchip carrier and received an AIP from ClassNK.

In the design the LNG fuel tank is located on the stern side of the accommodation unit, maintaining the cargo space, which is an important factor in the woodchip carrier market.

The design also effectively uses the space available on woodchip carriers and places the LNG fuel supply system around the engine room area.

In December 2020 Higaki Shipbuilding launched the *ISE Maru*, Japan's first coastal cargo ship to use LNG as a fuel. The ship is engaged in transporting coal in Japanese waters for power company JERA.

The next generation post-LNG bulk carriers are also being developed. The E5Lab project, involving the cooperation of Mitsubishi Shipbuilding and others, has completed a concept model for electric-powered ocean-going vessels. The plan is to start with an 86,000-dwt kamsarmax bulk carrier. The project has established three stages to achieve the complete emission-free vessel.

The first is to use a small-capacity lithium battery and a diesel generator using fuel oil to create emission free operations within the harbor and port. The second stage is to use a large-capacity lithium battery together with an LNG and fuel oil powered diesel generator and hydrogen fuel cell to achieve zero emission operations in territorial waters between 2025 and 2030. The final stage is to aim at completely emission free operations through the use of a large capacity lithium battery with an ammonia and bio-fuel powered diesel generator with a hydrogen fuel cell.

In addition, bulkers which use wind power, which are drawing attention as a renewable energy source, are being introduced. Mitsui OSK Lines and Tohoku Electric Power Company are building a 99,000-dwt coal carrier at Oshima Shipbuilding which includes hard sail wind power propulsion system called "Wind Challenger." The ship will begin operations in 2022.

Wind Challenger is a telescoping hard sail that converts wind energy into propulsion force. It is Japan's first large cargo ship with "sail" that has been developed in a joint industry and academic research project which began more than 10 years ago. Japanese bulk carriers are progressing from LNG and LPG fuel to battery and sail propulsion.

Sanoyas is ready to build LNG fuelled wood chip carrier

© Shinkurushima Sanoyas Shipbuilding

AR for Fut aut

Augmented Reality

The number of ships crossing paths on the world's ocean increases each day and the seas are becoming increasingly congested. The size of ships is also increasing, so it is becoming ever more important to be aware of the situation surrounding the vessel from the ship's bridge to improve the safety and security during operation. Furuno has taken on this challenge. It has created a system to support seafarers' visual perception during operations using Augmented Reality (AR) technology which will also be the first step toward the automated ship of the future.

Future Vision 04

Kazuma Waimatsu, Director

© Furuno

Furuno is involved in providing marine electronic equipment and services to the commercial shipping, fishing and pleasure boat industries. Established in 1948 it first developed equipment to detect fish before expanding into the commercial shipping and pleasure boat business. It has since developed a full product line and expanded into the global market. It currently has a 41% share of the global radar market for commercial shipping.

Furuno took on the challenge of developing a navigational support system for large vessels using AR technology. (Furuno ENVISION AR Navigation (AR 100M Type))

Until now seafarers have had to keep in their heads a variety of navigational information including radar, Automatic Identification System (AIS), Electronic Chart Display and Information System (ECDIS), chart, route and visual information. But, by overlaying all these information sources in a camera image display, the AR-100M allows the easy recognition of the surrounding sea area and the sharing of information in one simple system.

Basically, actual images take by a camera of the ship's forward section, overlayed with ship operational data presented through AR technology, can be used as an auxiliary operational decision support function for risk avoidance and safe navigation. The combined data which is displayed includes the ship's position, route, speed and heading information gyro compass, in addition to AIS and radar tracking information, the route set by ECDIS and chart information. It visually supports stress-free operation by recognizing other ships and obstacles in visually challenging circumstances such as at night and in poor weather.

The project was triggered by Furuno's research and development department which had posed the question "Can AR be used in shipping?"

AR technology had already been widely used in cars and in gaming but there were not many cases of it being used in shipping. Furuno quickly came up with a concept and introduced it at a maritime exhibition.

It soon attracted interest from a number of companies. Mitsui OSK Lines showed a

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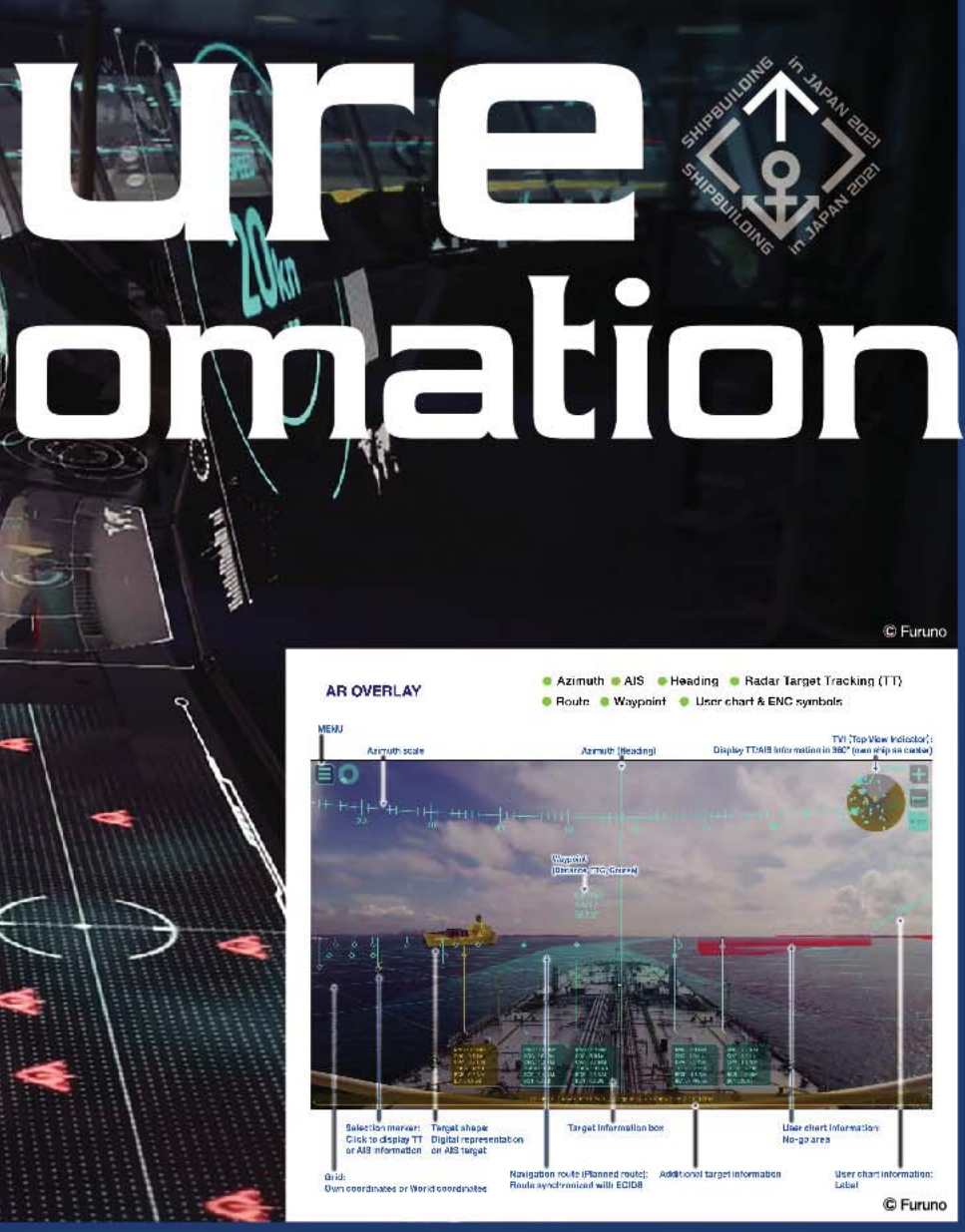

particularly strong interest and said: "We would really like to try out this technology." Furuno then embarked on a joint development project.

In the development one area of difficulty was deciding on what type of information and in what style it should be configured. Another issue was how to display real time data in a way that is stable and easy to see when the ship in a state of rolling or pitching movement.

Also, the further forward the camera was placed the more distorted the image became. With the picture distortion Furuno struggled to clearly overlay the pictures and information. But in overcoming these difficulties Furuno succeeded in developing the product.

A prototype was installed on two vessels and further improved following feedback from navigation officers. After one and a half years of product development it was launched in May 2019.

As a joint development project with MOL it was decided to deploy AR Navigation on 21 VLCCs operated by the company. From the start of 2020 the system was offered to shipping companies around the world. AR Navigation is just the first step and Furuno intends to develop various additional solutions under the Furuno ENVISION Series as a visual support to navigating and watch crew.

AR Navigation is also the first step toward the realization of the automated ship. Since January 2021 Furuno established an autonomous navigation technology development department with the aim of quickly developing sensors for automated operations and navigation instrument products to realize the fully automated ship by 2025. Researchers and developers came together to tackle this project.

In Japan in 2020, under the sponsorship of the Nippon Foundation, MEGURI2040, a joint project to develop a crewless ship, also began. Furuno had an important role in this project. Furuno was tasked with using its expertise in sensor technology to detect the area around a ship.

Until now the ship's master has had a to carry out recognition, decision making and operational tasks but Furuno's system could take on the role of recognition. It is aiming to develop a series of technologies that could correctly assess the situation around the vessel and, while avoiding collision with other vessels, navigate independently.

Furuno sees three stages in the route toward the realization of autonomous vessel operation. Firstly "cognitive support" supports the recognition of the surrounding situation, the "decision support" which connects the recognized information with the "judgment" of how to operate the vessel, and finally "ship operational support" connects the judgment with the actual operation of the vessel. AR Navigation is the technology behind the "cognitive support" that is the first step along that path.

AR Navigation is not the final end product. Based on mutual requests and recommendations from clients Furuno will install the equipment and, based on feedback and evaluation, aims to develop the product further.

For example, at present AR Navigation is restricted to images from the front of the ship, but from now on research and development is planned so that images from all directions can be seen.

To be able to have simultaneous images from all directions, without any blind spots, the study of where and how many cameras need to be placed is necessary. There are other technical issues such as how to simultaneously combine images from multiple cameras.

It will not be easy but Furuno intends to take on these technical challenges with the cooperation of clients.

Behind the development of AR Navigation is Furuno's passionate desire to realize safe navigation.

Kazuma Waimatsu, director of the Marine Electronic Products Division, says: "We have the grand ambition to achieve zero accidents. This does not only apply to automated ships, but is also the same for manned ships."

"The first step is to have clients recognise the situation around the vessel in a way which is more precise and easy to understand. For this reason we want to supply new products and new functions."

Furuno's voyage to realize ship safety and security will continue.

Usuki innovates with Stainless steel

Chemical tanker construction is a specialty of Japanese shipbuilders. Usuki Shipyard has developed the world's first cargo tank using duplex stainless solid steel and clad steel together in a chemical tanker. Usuki Shipyard is now building these ships as its main product. Compared to chemical tankers built up to now it has improved strength and resistance to corrosion.

A chemical tanker has around 20 different cargo tanks and numerous pipes which run across the deck. Chemical tanker construction involves a complex outfitting process and, in addition, when stainless steel is used the difficulty of the welding and other construction processes is quite high.

Because chemical tankers are involved in the transportation of corrosive materials welding quality control is an important factor. Japanese shipbuilders are using their experience and technical ability for the consecutive production of chemical tankers. Japanese shipbuilders have a leading presence in the world market for chemical tankers.

Usuki Shipyard based in Oita Prefecture is one of Japan's chemical tanker shipbuilders. It specializes in the construction of ships between 10,000-dwt and 20,000-dwt and, along with ferries and small tankers, produces between four and five ships a year. Since 2018 it has been a part of the Fukuoka Shipbuilding Group.

Ahead of the rest of the world Usuki Shipyard has developed an innovative chemical tanker with full use of duplex stainless steel throughout the cargo tanks.

The types of stainless steel plate used in the cargo tanks of chemical tankers include austenitic and duplex and for each type there is solid and clad steel. Clad steel is mild steel with 3mm of stainless steel added to the surface and made into a single steel plate. Compared to solid steel plate it is less expensive and has excellent coating properties.

Until now stainless steel ocean-going chemical tankers built in Japan mainly used a combination of austenitic stainless solid steel plate (316LN Solid Steel) in the bulkhead and austenitic clad steel plate (316L clad steel) in the side bulkhead and top of the tank.

On the other hand, duplex stainless steel (UNS S32205) is a duplex of austenite and ferrite and, compared to the austenitic stainless steel used up to now, is twice as strong and has significantly improved corrosive resistant properties.

In overseas shipyards duplex stainless steel (UNS S32205) is generally used in the cargo tank but, as only duplex stainless solid steel is used, the material cost is high and there are problems with paint adhesion in the ballast tank and other demerits.

In 2013, to develop the use of duplex stainless steel plate, Usuki Shipyard, with the support of ClassNK, started to work together with Nippon Steel & Sumitomo Stainless steel (now Nippon Steel Stainless Steel) and JFE Steel to develop duplex stainless-steel plate for use in ships. As at the time there was no production method established for duplex stainless clad steel plate, a "hybrid tank type" was developed which used duplex stainless solid steel plate in the bulkhead and austenitic stainless clad steel plate in the side bulkhead and tank top and, in

Stainless Steel Used in Chemical Tankers and Charastaristics

	Conventional	Hybrid	Full Duplex
Bulkheads Adjacent	Clad Austenitic	Clad Austenitic	Clad Duplex
Bulkheads	Austenitic	Duplex	Duplex
Corrosive Resistance	○	○	◎
Strength	○	○	○
Coating quality of ballast tank	◎	◎	◎

2014, a 12,500-dwt hybrid type chemical tanker was constructed.

Then JFE Steel developed duplex stainless clad steel plate which made it possible to use duplex stainless throughout the cargo tank while ensuring paintability. In 2017 Usuki Shipyard completed the development of the world's first all duplex stainless cargo tank chemical tanker using a combination of solid steel and clad steel together. This was first used on the 12,500-dwt chemical tanker *Sun Jupiter* for Shokuyu Tanker. In addition, the same type was also used on the second in the series the *Sun Iris* delivered to Shokuyu Tanker in 2020.

Between 2016 and 2017, towards the development of the construction of an all-duplex stainless cargo tank type chemical tankers, Usuki Shipyard, together with stainless steel makers, universities and welding material manufacturers made progress to evaluate the materials and establish the construction method. In performance tests the corrosion resistance, strength of the weld connection, weldability, fatigue strength of the weld joint and other aspects were verified.

Percentage of Major Components of Stainless Steel

	Chrome	Nickel	Molybdenum
Duplex Stainless Steel (UNS S32205)	21.00～24.00%	4.50～ 6.50%	2.50～3.50%
Austenitic Stainless Steel (SUS316L)	16.50～18.50%	10.50～14.50%	2.00～3.00%

In the study of corrosion resistance, the duplex stainless clad steel plate was superior to the conventional austenitic stainless clad steel plate in pitting corrosion resistance, intergranular corrosion resistance, general corrosion resistance, corrosion resistance to phosphoric acid, as well as in concentrated sulfuric acid corrosion resistance and strength properties. In terms of performance, duplex stainless steel proved to be superior to conventional austenitic stainless steel.

As well as the performance aspects the weld strength and construction method were also carefully confirmed. Compared to austenitic stainless, duplex stainless requires detailed management and construction of aspects such as the weld heat.

Through this verification it became possible to come up with an optimal design that applied the suitable strength limit.

Also, the conventional duplex stainless solid plate that was previously used caused problems with the quality of the coatings and was the cause of disruption in the construction process, but through the use of duplex stainless clad steel plate the same coatings quality could be achieved as with the conventional clad plate, solving one technical concern.

The price and cost of chemical tankers that use stainless steel in the cargo tanks is strongly influenced by the price of nickel contained in stainless steel. Austenitic stainless steel contains around 12% nickel but duplex stainless steel contains only between 5% to 6% nickel. The lower level of nickel content reduces the impact on price and has the merit of reducing the risk of changes in material costs.

In addition to the all-duplex stainless cargo tank type 12,500-dwt chemical tanker's *Sun Jupiter* and *Sun Iris*, Usuki Shipyard has also delivered two 16,000-dwt chemical tankers and two 19,000-dwt chemical tankers, making it six in total.

It has also developed an 8,900-dwt chemical tanker completing a full line up of new chemical tankers applying all-duplex stainless steel across the main sizes ranging from 9,000-dwt to 20,000-dwt.

Much attention will be drawn to whether from now on the chemical tanker has advanced to a new stage in which the all-duplex stainless steel type will become the world standard.

Future Vision 05

The manufacture of cranes with a capacity to carry over 150 tons cargo load until now has been limited to four European companies. To gain entry into that market marine crane manufacturer Manabe Zoki embarked on the development of a heavy lift crane with a lifting capacity of 500 tons. As the first Japanese company to take on the challenge there were many difficulties awaiting but Manabe Zoki pulled together to overcome the rough seas.

Manabe enters Heavy lift market

Manabe Zoki was established as a marine cast steel maker in 1960. Based in Imabari City, known as Japan's largest maritime city, it focused two main products: winches and cranes. As well as its Japanese operations it also signed contracts for the establishment of after sales service representative offices in 30 countries around the world.

Although it celebrated its 60th birthday in 2020, it still has the character of a "challenger" that is ready to directly take on new business areas.

Generally, cranes with a lifting capacity of over 150 tons are known as heavy lift cranes. There are more than 200 heavy lift vessels and multi-purpose ships in operation around the world which are equipped with heavy lift cranes.

On the other hand, heavy lift ships may only use the capacity of heavy lift cranes just a few times a year. Most cargo handling is generally light work that requires speed compared to heavy lift operations. Until now heavy lift cranes, which specialized in heavy cargoes, did not adequately meet that requirement.

So Manabe Zoki, which originally manufactured large scale cranes, embarked on the development of a heavy lift crane with 500-ton lifting capacity that could lift both heavy cargo and general cargo with high efficiency and low energy.

While specializing as a large-scale crane manufacturing the company had built cranes with a maximum lifting capacity of 150 tons. So why did it decide to develop a heavy lift crane with 500 tons lifting capacity? Company president Masayuki Manabe said: "The turning point in developing a new type of crane came when we received an inquiry about supplying a heavy lift crane," he remembers of the lead up to the development project.

The capacity of marine cranes has been gradually increasing to meet the demand for more efficient cargo handling. On the other hand the shipping and shipbuilding industries place an importance on performance.

Future Vision 06

Loading efficiency

Ex) 433 pieces of 30TON cargo for 13,000DWT multi purpose vessel

[Conventional crane]	[Our heavy crane]
729.2 sec/loading	**517.6 sec/loading**

30% reduction

Total 25 hours reduction

Calculation basis

	Manabe's Heavy crane	Conventional Heavy crane
Hoisting up	38m/min	35m/min
Luffing time	235sec (10.5~36m)	360sec (10.5~36m)
Slewing speed	0.39rpm	Austenitic

President Manabe commented: "We wanted to avoid a situation where we could not participate in commercial negotiations." So the company set the target of coming up with Japan's first heavy lift crane product.

The project to develop a heavy lift crane began in April 2017 with the support of the Nippon Foundation. Among the objectives was to develop a lighter product that also improved cargo handling efficiency and energy performance during idling.

The main themes were to construct an optimal oil pressure system, develop a high oil pressure system to achieve a smaller size, and use high-tensile steel to reduce weight.

The challenge of developing a 500-ton heavy lift crane was far from easy. To realize a lighter weight a major revision of the basic design was undertaken while, during the project, torrential rain hit Western Japan causing a natural disaster and also brought manufacturing delays.

The newly developed crane used Manabe Zoki's open-circuit bulb control system rather than the closed-circuit pump control system used by European manufacturers. By using a simple hydraulic circuit cargo handling efficiency and energy use during idling improved, while an improvement in safety during starting and stopping operations was also achieved.

To enable slow handling operations a precise control of the hydraulic flow rate was made possible and, in addition, energy efficiency during idling was improved by 19.6% in comparison to the company's own products.

Compared to European manufacturers, which set the benchmark, a 30% improvement in cargo handling efficiency was achieved. The target of reducing weight below 320 tons was not achieved but, by revising the construction of the jib and optimizing shape of each component, the company thinks that it will be possible.

As a basic concept the heavy lift crane is designed with after sales service in mind and it does not use special equipment such as hydraulic machinery. On the other hand, as it is more than three times larger than the cranes it previously manufactured some special materials, including forged metal products, were imported from Europe.

Also, the factory design has been changed and a 400-ton capacity jib crane and large-size CNC broking and milling machines were introduced. A manufacturing system that could handle increased production of deck cranes and heavy lift cranes was established.

Having successfully developed a 500-ton heavy lift crane the company is now receiving enquiries for 250-ton heavy lift cranes and large size winches. President Manabe said: "A 500-ton crane is not a product for which we will receive numerous orders, but if every few years we receive one order then that is a success."

The strategy now is to line up a product range of 250-ton, 300-ton and 400-ton heavy lift cranes. Manabe Zoki will utilize its own unique technology to develop further new products.

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Future Vision 07

Japan yards support ODA

Official Development Assistance

Japanese shipbuilders have abundant experience in building government vessels such as patrol vessels, fishery patrol vessels and ferries. From 2013 to 2020, Japan has provided 38 vessels to 13 countries (95.7 billion yen) under the Official Development Assistance (ODA) program. In recent years, under the vision for "Free and Open Indo-Pacific", Japan has been promoting international cooperation to commit peace and stability. Across the world, there is a mounting expectation to the Japanese shipbuilding technologies for the improvement of maritime safety capability as well as regional public transportation and other maritime services.

On the 19 December 2020 a Japanese-built Oceanographic and Fishery Research vessel sailed out from Okayama prefecture. Its destination was the port of Agadir in the Kingdom of Morocco where the ship will be used in realization of scientific research for sustainable marine fishery resources.

Morocco is one of the African continent's major fishing nations. Fishing is an important economic and social activity which represents around 3.1% of its gross domestic product. However, since 2000, due to climate change and marine pollution rising across oceans, the marine ecosystem has been affected and the fish catch has become unstable. This can badly compromise the lives of the people working in the fishing industry.

For Morocco to realize sustainable activity in its fisheries industry, it was necessary to improve the capability of its scientific marine and fishery research. So, Morocco planned to build a new fishery research vessel and asked Japan for cooperation.

The construction of an state-of-the-art Oceanographic and Fishery Research Vessel was decided in what was Morocco's first Japanese ODA loan agreement under the Japan International Cooperation Agency's (JICA) Special Terms for Economic Partnership.

In 2018, Mitsui E&S Shipbuilding (MES-S) took part in this project as shipbuilder for construction of the vessel for the National Institute of Fisheries Research (Institut National de Recherche Halieutique) which is the institution in charge for providing scientific knowledge to the Ministry of Agriculture, Fisheries, Rural Development, Water and Forests of the Kingdom of Morocco.

MES-S is known for constructing bulk carriers and tankers, but in Japan it has also built many special purpose ships such as fishing training vessels and fish research vessels, etc. The company uses its expertise to perform this vessel with ultra-modern technology which will contribute to Morocco's fisheries and oceanography development.

This research vessel is 48.50 meters length and 11.80 meters beam, and has several unique features. For example, in order to reduce underwater acoustic noise during its observation of the ocean, hull form was developed and adapted, anti-vibration measures were taken in main engine and generator engine, and propeller which suppresses water cavitation was also installed.

Installed Fishing equipments allow the continuous efficient fish trawling surveys. To allow a high-level oceanographic surveys the latest research equipment, such as scanning sonars for fish finding, multifrequency echo sonders for marine organisms detecting, multi-beam echo sounder for seabed mapping, and currents measuring sensors were equipped.

After delivery of the vessel, Morocco will acquire the ablility to conduct onboard its own surveys of fishery resources, marine organisms and marine environment. Morocco will improve its system to make assessment of marine reserves and marine environment within an Integrated monitoring approach. In addition, the vessel is expected to have an active role not only in Morocco, but also in neighboring countries of the Northwest Africa region.

MES-S also cooperated in training crew in the handling of equipment and other functions related to the ship's operation since the vessel has been built, and supported Morocco both in the hard and soft aspects of the project.

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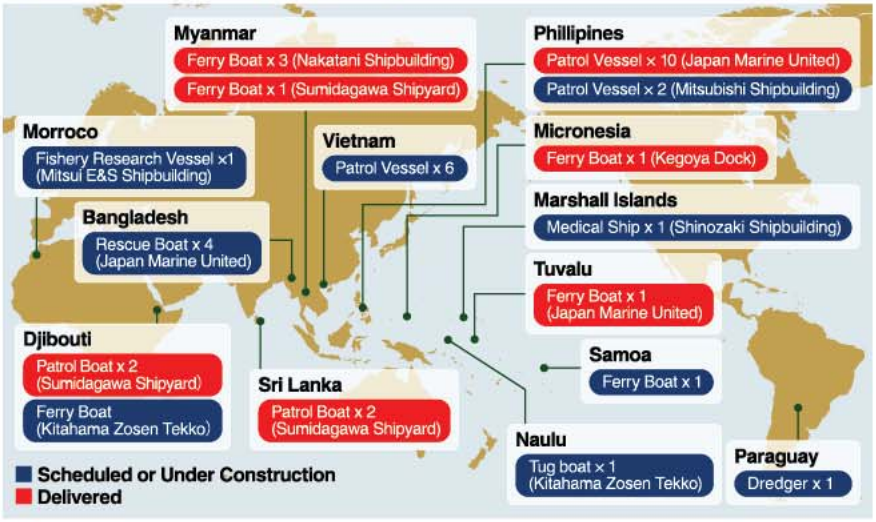
Fishery Research Vessel for Morocco

Japan's Ship Provision through ODA (2013-)



Japan has been providing patrol vessels to the Philippines to strengthen the capability of the Philippines Coast Guard (PCG). Japan first supplied 10, 40 metre-class multi-role response vessels. From 2016 to 2019, the vessels were built at Japan Marine United (JMU). Then in February 2020, a contract to build two large-size multi-role response vessels was signed with Mitsubishi Shipbuilding. The large vessels are 94-metre length with a maximum speed of over 24 knots and a continuous sailing range of 4,000 nautical miles. They were fitted with equipment to respond quickly to maritime casualties and crime, including communication equipment with the capability to monitor the Exclusive Economic Zone, a helicopter landing deck, a remote-controlled unmanned submarine and high-speed boat.

In 2020, Japan signed ODA Loan Agreement of six patrol vessels with Vietnam, which has a long coastline running from North to South. In the South China Sea, there is a high risk of maritime casualties due to rough sea by typhoons. Strengthening measures against maritime crime is also an important issue in the region.

Japan will also provide a vessel to Marshall Islands. The Marshall Islands is a country made up of 29 atolls. A medical ship periodically tours the islands where there is no doctor or nurses present. But at present, there is only one medical ship and it is currently only able to make one trip a year. To manage the health of local residents and to improve medical health services, Japan decided to grant a medical ship to Ministry of Health. In August 2020, it was decided to build the vessel at Shinozaki Shipbuilding.

In 2020, Ministry of Land, Infrastructure, Transport and Tourism (MLIT) revised The Action Plan for the Overseas Development of Infrastructure Systems, and added the maritime sector as one of the most important fields. It contains the plan to strengthen its efforts to contribute to the improvement of maritime capability of the developing countries through providing efficient and quality vessels made in Japan as well as training and technical cooperation programs.

Patrol Boat for Djibouti

Mitsubishi-Philippines MRRV signing ceremony

Meiyo Electric is taking Hydrogen's temperature

Future Vision 08

RESISTANCE BULB Pt1000
[TYPE/R-35IS-13A]

RESISTANCE BULB Pt1000
[TYPE/R-35IS-14B]

The world is starting to become a hydrogen society. An energy carrier that can transport large volumes of hydrogen will become necessary and, in some cases, liquid hydrogen will be transported at an extremely low temperature of minus 253 degrees Celsius. Marine measurement equipment maker Meiyo Electric has taken on the challenge of developing a high-precision temperature sensor that can measure the temperature of liquid hydrogen.

Meiyo Electric, established in 1936, has its headquarters Shizuoka Prefecture, the location of Mount Fuji. It is involved in the manufacture, sales and export of measurement and control equipment. Its main products are temperature sensors for the areas around marine engines and pressure sensors. It boasts a leading share of the market for LNG temperature sensors for the marine market.

The trigger for the development of a new type of temperature sensor came at a lecture held in 2013 where Meiyo Electric became aware of a project to transport and store hydrogen. With its specialist sensor technology it thought it could contribute to the coming age of hydrogen. But, even as the leading company in the field of LNG temperature measurement, it thought "As things stand the technology to measure liquid hydrogen at a temperature of minus 253 degrees Celsius is inadequate." It was then that Meiyo Electric decided to take on the challenge of developing a sensor that could measure extreme low temperatures.

In 2015 it received support from the Nippon Foundation and, as a New Product Development Support Business under the Japan Ship Machinery and Equipment Association, began a project to develop technology for a liquified hydrogen temperature sensor and monitoring system.

At the start, as the company had little knowledge of liquid hydrogen, it took on the challenge with the cooperation of the National Institute of Advanced Industrial Science and Technology, the National Maritime Research Institute and two companies which are familiar with temperature measurement.

Importance was placed on the precision of the temperature sensor. In general LNG temperature measurement is on a scale of plus or minus 0.2 degrees Celsius, but Meiyo Electric took on the considerably more difficult challenge of achieving four times the precision of 0.05 degrees Celsius.

At the start it was thought that temperature measurement could take place using existing methods. However, at a temperature of minus 253 degrees Celsius, when the sensor and module are connected it became clear that, because of the environment in the area between the equipment, slight errors were occurring. If the level of precision for general measurement was applied the errors could be ignored but, when a precision of 0.05 degrees Celsius is being targeted, the small errors make a big difference.

As a solution the sensitivity of the temperature sensor was improved. Normally, a Pt 100 sensor (100 Ω/0 ° C) is used as the temperature sensor, but when measuring minus 253 degrees Celsius, the change in resistance becomes small, and the configuration of the measuring circuit becomes difficult. By adopting a Pt 1000 sensor with a sensitivity of 10 times, it succeeded in improving the variation of resistance even in the temperature range of liquid hydrogen.

The new temperature sensor measured temperatures from minus 253 degrees Celsius to room temperature, covering a range of 300 degrees Celsius. However, a module that evenly measures such a wide range of temperatures cannot achieve a precision of 0.05 degrees Celsius. So the degree of decomposition on the module side was increased and limited to the temperature region of liquid hydrogen.

Design department manager Keiichiro Ohtsuka described the path to overcoming these issues as "cut and try."

He said: "I thought of a new method, combined it, and repeatedly applied it to a temperature of minus 253 degrees Celsius."

Generally, the minus 253 degrees Celsius condition of liquid hydrogen can be replicated in a cryogenic refrigerator but there was a preference for the real liquid condition of liquid hydrogen in the experiments.

One of the unique specialties of Meiyo Electrics was demonstrated in the technology development. Generally, temperature sensors and modules are designed independently, then combined in the final product. But, for high precision measurement in an extreme cold environment to be realized, it is not enough to just improve the technology separately. One of the strengths of Meiyo Electric is that it has the technology for both sensors and modules and was able to pursue a mutual performance which compensated for the shortfalls and enhanced the strong points of each product.

Director Noboru Kobayashi recalled: "As our company has both sensor and module sections it was easy to carry out communication and collaboration. I think this was a factor in the success of the project."

Senior engineer Masanori Sekiya said: "The final stage for each department was combining both technologies. It was a good opportunity to for the company to break down barriers between departments and work toward a single goal."

In total it took a five-year project between 2015 and 2019, including the two years as a New Product Development Support Business, to realize the extreme low temperature sensor for liquid hydrogen.

Talking about future developments Design department manager Ohtsuka said: "We want find solutions to various issues that come out following installation on a ship. Through this challenge we would like to contribute toward Japan's lead in realizing a hydrogen society."

Meiyo Electric director Kobayashi enthusiastically added: "The theme from now on is the development of technology for mass production ahead of installation on ships. We would like to aim at production development by 2030 when the liquid hydrogen transport ship is expected to go into operation."

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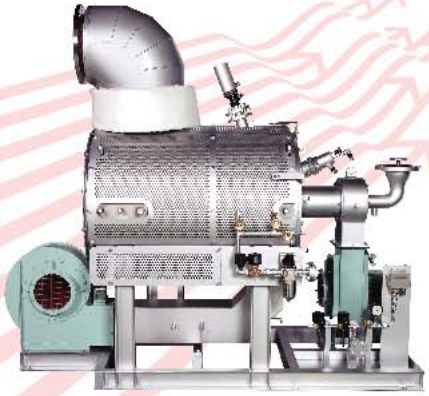
LH2 MEASUREMENT SYSTEM & MODULE



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Future Vision 09

Volcano solves LNG's methane problem

The age of LNG as a fuel has arrived. The disposal of boil off gas (BOG) which occurs inside the fuel tank has been a major issue in the use of LNG as a fuel but, combustion technology specialist Volcano is presenting a solution through its own simultaneous mixed combustion technology.

LNG is a clean energy with low CO_2 emissions during combustion but, its main component, methane, has a global warming potential 25 times that of CO_2. The BOG in the LNG tanks of LNG fueled ships and LNG bunkering vessels is mainly composed of methane and the handling of this is a major concern for LNG fueled vessels. So, Volcano took on the challenge of finding a solution.

Established in 1928 Osaka-headquartered Volcano has a long history as a manufacturing company. It produces combustion equipment including burners for ship boilers, factories, public facilities and waste disposal units. For handling BOG it developed the Gas Combustion Unit (GCU) (MECS-GCU). It burns BOG created in LNG fuel tanks and BOG mixed with inert gas which is used for gas free operations and during ship bunkering and maintenance operations. Through this BOG is not released into the atmosphere but fully combusted which contributes to reducing its environmental impact.

The turning point for the development of the GCU was the delivery of the tugboat *Sakigake*, Japan's first LNG-fueled vessel. When bunkering took place, by truck to ship transfer, there was a concern over the leakage of methane gas residue from the truck's hose into the atmosphere. So, Volcano took on the challenge of developing a small-scale GCU to combust the methane gas fully.

At the time there were no international rules established related to LNG, like the current International Code for Safety of Ships using Gases or other Low Flash Point Fuels (IGF Code). So, Volcano took guidance from classification society ClassNK into consideration and, with that, progressed with the development of a GCU and completed the first product.

After *Sakigake* installed the first version of MECS GCU, the following March, Volcano started selling the GCU. Kenji Sato, Senior Manager of the marine equipment section, who was involved in the development, said: "At the time the intention was to use it only for truck to ship operations, but after that we managed to broaden its application to bunkering and gas free operations."

Then, in 2019, a GCU was newly developed for Japan's second LNG-fueled tugboat *Ishin*.

Ishin was the first Japanese vessel to be built under the International Maritime Organization's (IMO) IGF Code so Volcano's new type GCU was also fully compliant with both the IGF code and the International Gases in Bulk (IGC) code.

After that, to meet calls from clients requiring larger capacity, the size of the product was increased. The previous maximum BOG combustion rate was increased from 173kg per hour to 1,000kg per hour. As LNG newbuilding plans increased the product was developed to handle a wider range of LNG-fueled ship types, including bunker vessels. It was also developed to cope with a wider range of sizes, and models with a combustion rate between 25kg per hour to 1,000kg per hour were made available. One feature of the product is the size range was intended not to overlap with European and other manufacturers.

Another factor that is important in the treatment of BOG is making sure that methane gas, which is mixed with inert gas, also does not escape into the atmosphere.

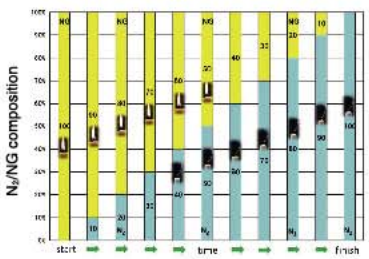
For example, in gas free operations, flammable gasses are replaced by inert gases such as nitrogen but burners, which can burn only gas or oil, cannot fully burn the methane gas, which is mixed with the inert gas, and it escapes into the atmosphere.

Volcano's solution is to use a Gas/Oil simultaneous mixed combustion DF burner. With Volcano's DF burner, even if the gas becomes difficult to burn, by combining it with oil combustion, it becomes possible to burn with gas and oil at the same time. All the methane contained in the gas escaping from the tank can be burned with the heat of just a small amount of oil.

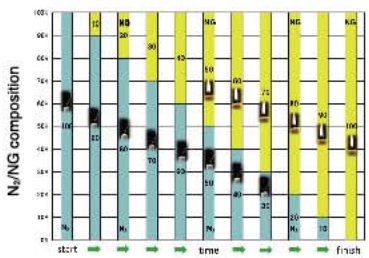
The stable burning of gas and oil together, whatever the ratio, is extremely difficult technology. But Volcano was able to make use of the technology it has cultivated over many years in burning gas and oil in combination. It does not matter whatever the ratio of the mix of gas and oil stable combustion can be achieved.

From now on in the marine field a wider variety of fuels is expected to be used. Hirofumi Yasuda, Executive Officer of Volcano's Research and Development department, said: "Our new technologies such as GCU and others, aimed mostly at LNG, will become a bridge over to new fuels."

The number of ships using LNG as a fuel is expected to increase over the coming years but Volcano will be moving ahead of other companies and looking beyond the use of LNG as a fuel.



Various composition of gas in Fuel tank at Gas-freeing



Various composition of gas in Fuel tank at Gassing-up

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