# ZERO CARBON

SHIPBUILDING IN JAPAN

2022

# JAPAN DECARBONIZE AND DIGITALIZE THE WORLD

**PUBLISHED BY**

Japan Ship Technology Research Association
The Shipbuilders' Association of Japan
The Cooperative Association of Japan Shipbuilders
Japan Ship Exporters' Association
Japan Ship Machinery and Equipment Association

**SUPPORTED BY**

The Nippon Foundation

**COOPERATED BY**

Maritime Bureau, Ministry of Land Infrastructure, Transport and Tourism

**PRODUCED BY**

Kaiji Press Co., Ltd.
Tosei Printing Co., Ltd.



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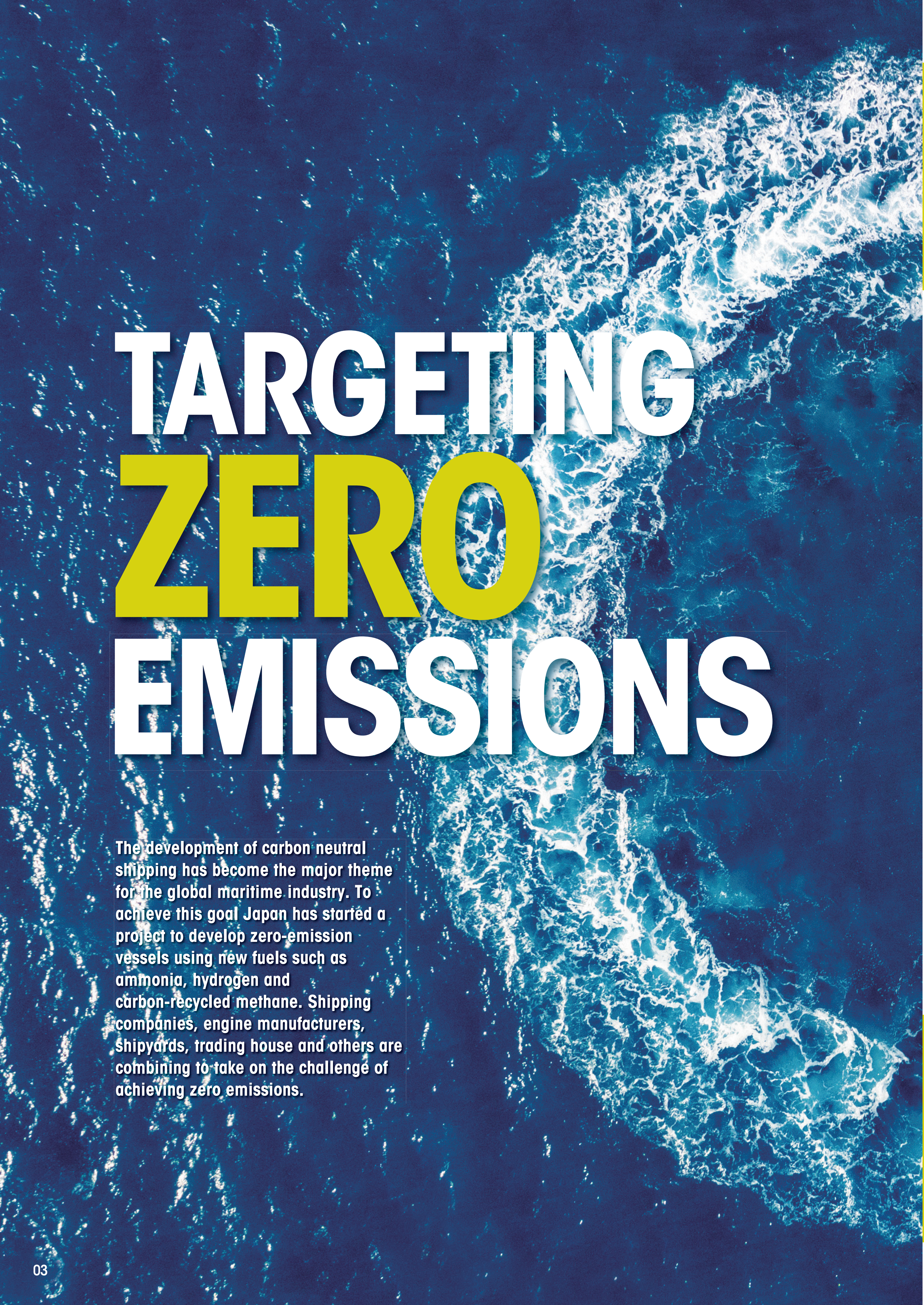
To help manufacturers develop and realise new products, Japan Ship Machinery and Equipment Association has received support from the Nippon Foundation and is now providing business assistance to them.



# TARGETING ZERO EMISSIONS

**The development of carbon neutral shipping has become the major theme for the global maritime industry. To achieve this goal Japan has started a project to develop zero-emission vessels using new fuels such as ammonia, hydrogen and carbon-recycled methane. Shipping companies, engine manufacturers, shipyards, trading house and others are combining to take on the challenge of achieving zero emissions.**

"As Japan aims to become carbon neutral by 2050 it has also set a carbon neutral target for total greenhouse gas (GHG) emissions from international shipping by 2050," said Ministry of Land, Infrastructure, Transport and Tourism Minister Saito Tetsuo on the 26 October 2021, as he announced the Japanese government's policy. The government plans to propose that the International Maritime Organization (IMO) set a common goal for the world and lead discussions on revising the goal by 2023. "We contribute to global decarbonization and strengthen the international competitiveness of Japan's shipping business. We will develop necessary technologies in cooperation with industry, and strongly promote carbon neutrality in international shipping," Saito said at a press conference.

On the same day, Japan Shipowners' Association president Junichiro Ikeda announced that the Japanese shipping industry would take on the challenge of achieving zero GHG emissions by 2050. "Through this challenge Japan's shipping industry will actively contribute toward addressing global environmental issues. The Japanese government and industry will work together to lead international shipping," he said. Japan will collaborate with industry, academia, the government and the public to achieve this goal.

To achieve carbon neutrality it is essential to switch to zero-emission vessels using new alternative fuels such as hydrogen, ammonia and carbon-recycled methane. However, Zero-emission ships are not expected to be fully deployed until the 2030s, and there is a doubt whether an international hydrogen and ammonia fuel supply infrastructure will be in place by then. There are two scenarios for the development of marine fuels by 2050: A scenario in which the supply of hydrogen and ammonia expands, and a scenario in which the supply of biomethane and carbon-recycled methane will expand in addition to LNG, without expanding the supply of hydrogen and ammonia. Whether hydrogen, ammonia, or methane (biomethane or carbon-recycled methane) will become the main alternative fuel is not known at present. So, it is necessary to promote the development of several different fuel options as candidates for zero-emission vessels. Therefore, Japan has decided to develop a hydrogen-fueled ship, commercialize an ammonia-fueled ship, and develop technologies to drastically reduce methane slip in LNG fuel.

To achieve carbon neutrality by 2050, not only in the maritime industry, but also in the energy and industrial sectors, the Japanese government established the Green Innovation Fund to accelerate innovation through structural and demand changes and encourage bold investment. Funding will be provided to the New Energy and Industrial Technology Development Organization (NEDO) to support research and development, demonstration and social implementation. Up to ¥35 billion has been budgeted for the Next Generation Vessel Development Project to realize zero-emission vessels. In October 2021, four themes and practitioners were decided. A total of 12 companies, including major shipping companies, shipyards, engine manufacturers and trading companies will cooperate in the project, which will also involve universities and shipping associations. The aim is to realize the commercial operation of zero-emission vessels earlier than 2028 when it was originally envisaged.

## HYDROGEN FUEL

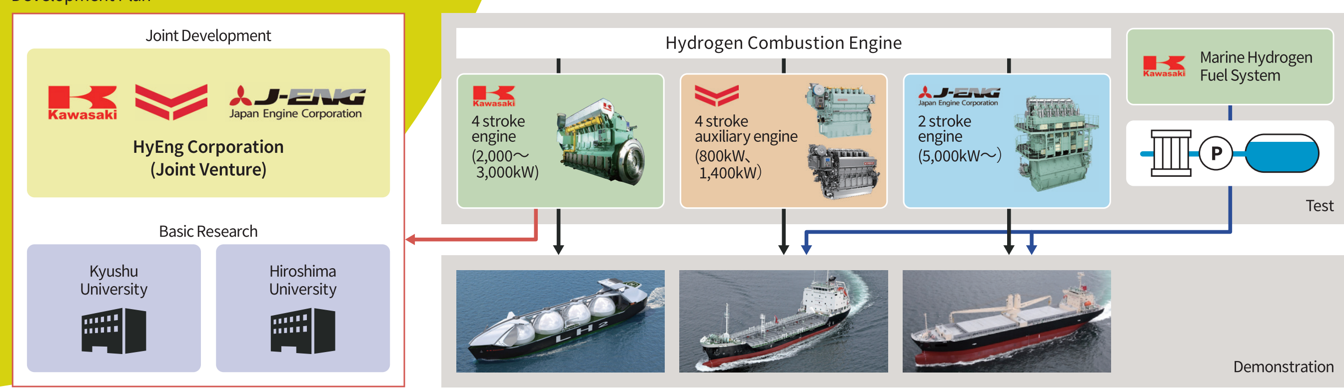
A consortium including Kawasaki Heavy Industries, Yanmar Power Technology and Japan Engine Corporation (J-ENG) will work to commercialize hydrogen fuel. Low-speed, medium-speed and high-speed engines using hydrogen as fuel will be simultaneously developed. By around 2026, a lineup of engines that can be used in a variety of applications is planned. A marine hydrogen fuel tank and a fuel supply system will also be developed. The project will cost about JPY 21.9 billion of which around JPY 21 billion will be made up of support from the Green Innovation Fund.

Kawasaki Heavy Industries will develop a medium-speed 4 stroke engine with a propulsion output of between 2,000kW and 3,000kW. Yanmar Power Technology will develop medium-speed and high-speed 4-stroke auxiliary equipment engine with an output of 800 kW and 1,400 kW. J-ENG will develop low-speed 2-stroke engines for propulsion with an output exceeding 5,000 kW. In addition, shipping companies and shipyards will cooperate to demonstrate the technology on actual ships ahead of social application. The medium-speed four-stroke engine will be demonstrated on a liquefied hydrogen carrier, the medium-speed and high-speed four-stroke engines on tankers, and the low-speed engine on a bulk carrier.

Kawasaki will also develop the Marine Hydrogen Fuel System (MHFS), consisting of a marine hydrogen fuel tank and a fuel supply system. The MHFS will be applied to the demonstration operation of medium and high-speed four-stroke engines, and two-stroke engines, after a land-based tests.

In August 2021, the 3 companies established the joint venture development company HyEng to become a world leader in commercializing hydrogen-fueled engines. HyEng will jointly develop common technical elements such as basic combustion analysis, the development of materials and sealing technology, and compliance with classification rules. Test facilities such as test engines will also be shared. Kyushu University and Hiroshima University will also be commissioned to undertake the basic test research. Kawasaki plans to link up with this project through the demonstration of a large liquefied hydrogen transport ship to commercialize the liquefied hydrogen supply chain.

Development Plan



# AMMONIA FUEL

There are two consortia working on a project to commercialize ammonia fuel for ships. The first is a consortium of four companies including NYK, Nihon Shipyard (NSY), J-ENG and IHI Power Systems. The development and operation of ammonia-fueled vessels will be carried out using a domestic tugboat and an ocean-going ammonia carrier. The tugboat is scheduled to be completed in 2024 and the ocean-going ship in 2026. Classification society ClassNK will also be involved.

NYK and IHI Power Systems will develop the ammonia-fueled tugboat. The companies will develop a 4-stroke engine of around 1,600 kW output, then design an ammonia-fueled tugboat considering safety and practicality, and then establish operation and maintenance methods. The aim is to achieve an ammonia fuel mixed combustion rate of 80% or higher. In the future, by using biofuels as pilot fuels, efforts will be made to improve the mixed combustion rate to achieve zero GHG emissions.

For the ocean-going ammonia carriers, NYK, J-ENG, IHI Power Systems and NSY will cooperate with ClassNK. A two-stroke ammonia fuel engine of around 8,000 kW will be developed as the main engine and a four-stroke ammonia-fueled engine of about 1,300 kW for the auxiliary equipment. The project will focus on developing the major ship types, ammonia fuel and cargo handling piping systems, operation sequences, the establishment of an onboard safety system against ammonia toxicity, and the establishment of operational and maintenance procedures. As ammonia will be transported as cargo the ship will use the cargo, and ammonia gas which is vaporized from the cargo, as fuel during the voyage. The ammonia mixed-combustion ratio should be a maximum of 95% for the main engine, and 80% or more for the auxiliary equipment.

The project is expected to cost about ¥12 billion, with a maximum of ¥8.4 billion in financial support.

Ammonia-fueled Ammonia Gas Carrier

Anmmonia Fuelled Tugboat

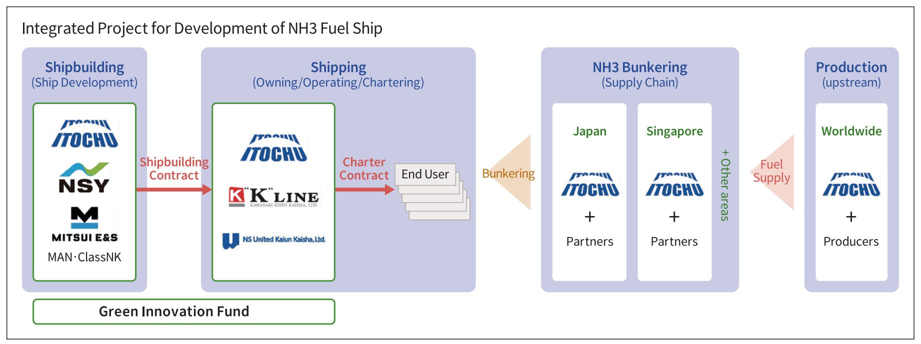
ClassNK Nippon Kaiji Kyokai: Safety assessment; Fundamental research for guidelines; Support for regulation clearance

A-Tug

| Item | Assignment | FY21 | FY22 | FY23 | FY24 | FY25 | FY26 | FY27 |
|---|---|---|---|---|---|---|---|---|
| Main Engine | 株式会社IHI原動機 IHI Power Systems Co., Ltd. IHI Power Systems | 4-stroke engine development & fabrication, shop trial etc. | | | Delivery | | | |
| Ship Design & Buildings | NYK LINE NIPPON YUSEN KAISHA NYK Line | Hull Design, buildings, sea trial etc. | | | | | | |
| Operation | NYK LINE NIPPON YUSEN KAISHA NYK Line | Regulation clearance, formulate operation manuals etc. | | | | Demonstration & Commercialization | | |

AFAGC

| Item | Assignment | FY21 | FY22 | FY23 | FY24 | FY25 | FY26 | FY27 |
|---|---|---|---|---|---|---|---|---|
| Main Engine | J-ENG Japan Engine Corporation Japan Engine Corporation | 2-stroke engine development & fabrication, shop trial etc. | | | | | Delivery | |
| Aux. Engine | 株式会社IHI原動機 IHI Power Systems Co., Ltd. IHI Power Systems | | 4-stroke engine development & fabrication, shop trial etc. | | | | | |
| Ship Design & Buildings | NSY Nihon Shipyard | | Hull Design, buildings, sea trial etc. | | | | | |
| Operation | NYK LINE NIPPON YUSEN KAISHA NYK Line | Regulation clearance, formulate operation manuals, business model evaluation etc. | | | | | | Demonstration & Commercialization |




The consortium behind the other project is Itochu, NSY, Mitsui E & S Machinery, Kawasaki Kisen and NS United Shipping.

A unique feature of the project is that it will involve the development of an ammonia fuel propulsion system and a hull, which will be owned and operated, as well as an integrated project covering the entire area of fuel production and the construction of fuel supply bases. The goal is to find a social application as soon as possible before 2028. The project will be worth JPY 3 billion, of which JPY 2 billion in financial support will be provided.

In the consortium, NSY and Mitsui E & S Machinery will be in charge of developing the vessels. Mitsui E & S Machinery will develop an ammonia fuel tank and a fuel supply system, develop technologies related to the ammonia fuel main engine, develop safety specific to ammonia fuel ships and conduct demonstration operations. NSY will develop a hull equipped with an ammonia fuel tank and verify the contents of the research and development through actual ship demonstration of an onboard ammonia fuel handling system and onboard safety system. MAN Energy Solutions and Class NK will also work in cooperation. Itochu, Kawasaki Kisen and NS United will test the actual ship.

In addition, Itochu will construct a supply chain from the production of marine ammonia fuel to the fuel supply to vessels. By acquiring the upstream interests of producers around the world, the company will develop a fuel procurement system and work with partners in Japan, Singapore and other regions to develop fuel supply bases.

The five companies established an international council to promote the use of ammonia as a marine fuel and have been cooperating with shipping companies and shippers around the world. Their work is accelerating the commercialization of ammonia-fueled vessels.

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# METHANE SLIP REDUCTION

Three companies, Hitachi Zosen, Yanmar Power Technology and Mitsui OSK Lines will jointly develop technology to reduce methane slip from LNG-fueled vessels.

When the supply of carbon recycled methane and biomethane is expanded in the future, LNG bunkering and onshore fuel supply infrastructure can be converted to handle the new fuels as they will contribute to the achievement of zero emissions. Even if hydrogen and ammonia become widely used as fuels, LNG and carbon-recycled methane are still expected to become one of the main fuels among international shipping's total energy consumption by 2050.

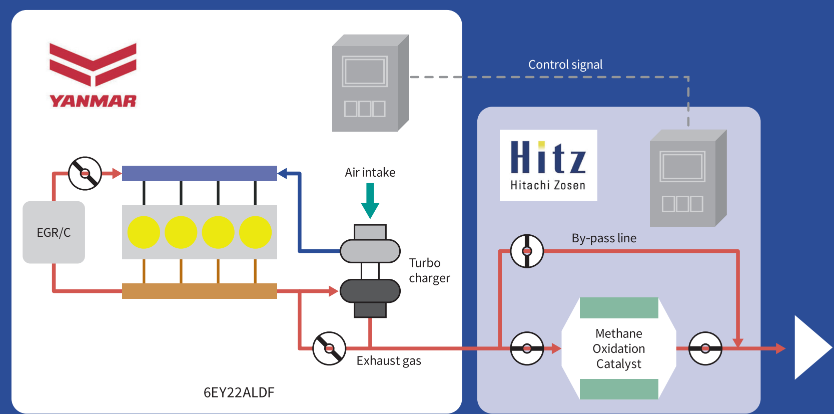
However, methane slip reduction is a major theme for LNG fuel, so the companies will develop catalytic technology and new engine systems with advanced methane slip reduction technology, and demonstrate them on a large coal carrier under construction by Mitsui OSK Lines. The goal is to achieve a methane slip reduction rate of 70% or more for LNG-fueled vessels by 2026.

The project will cost around JPY 1.1 billion, of which about JPY 600 million of financial support will be provided.

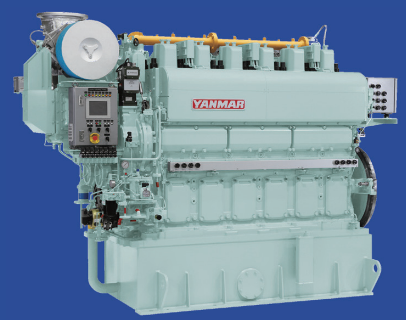
Catalytic technology is one of the keys to reducing methane. Hitachi Zosen will develop a methane oxidation catalyst that exhibits high methane slip reduction performance in engines during operation. The project will demonstrate Hitachi Zosen's technology as a unique manufacturer in the world, producing both catalysts and marine engines. In addition, that will be combined with Yanmar Power Technology's engine improvements. The project will establish innovative engine combustion technology, increase the reduction rate of methane oxidation catalyst, develop technology to reduce methane slip from the engine outlet, and based on these technologies, develop a new engine system.

The newly developed system will be installed on a large LNG-fueled coal carrier to be built by the Namura Shipbuilding for the Mitsui O.S.K. Lines. The company plans to establish a technology for installing methane reduction systems on actual ships and a method for operating them.

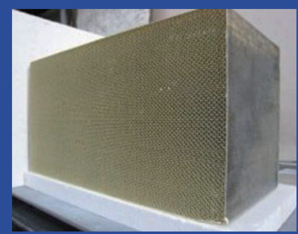
Methane slip reduction system (image)





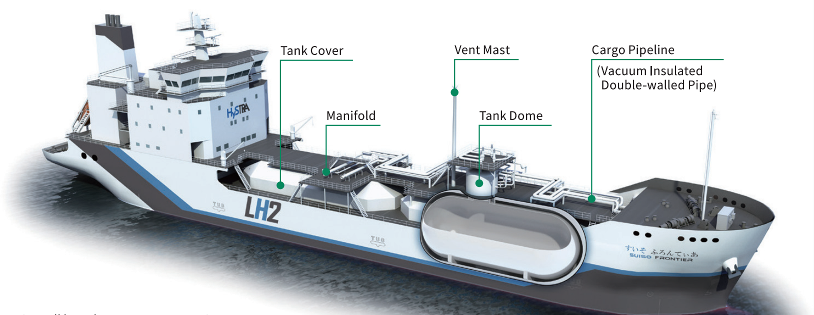


4 Stroke Gas Engine


Methane oxidation catalyst

# HYDROGEN TRANSPORTATION BEGINS

**The world's first liquefied hydrogen ($LH_2$) carrier *SUISO FRONTIER* has entered into operation for demonstration. Kawasaki Heavy Industries has taken on the challenge of developing and building a ship that can carry cargo at the unprecedented low temperatures of minus 253 degrees Celsius.**




Overall length : 116.0m
Overall width : 19.0m
Depth : 10.6m
Maximum crew : 25 persons
Gross tonnage : 8,000 tonnes
Vessel speed : 13 knots
Draft : 4.5m
Tank capacity : 1,250kl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Hydrogen is expected to be used in power plant and fuel cell vehicles as a clean energy source that does not produce greenhouse gases such as carbon dioxide during combustion. In 2016, Kawasaki Heavy Industries, Iwatani Corporation, Shell Japan and the Electric Power Development Co of Japan (J-Power) formed the $CO_2$-free Hydrogen Energy Supply-chain Technology Research Association (HySTRA), with the aim of realizing a society in which hydrogen can be widely used in the same way as oil and natural gas. After that, Marubeni, ENEOS and "K" Line joined the project. There are currently seven companies involved in technology development, through the support of the New Energy and Industrial Technology Development Organization (NEDO), with the aim of building an economic and stable supply chain to procure large amounts of hydrogen. The plan involves producing hydrogen from brown coal in Australia and exporting it to Japan as $LH_2$.

At the very core of the project is the transportation of $LH_2$ by sea. Kawasaki Heavy Industries built a $LH_2$ transport pilot demonstration carrier named *SUISO FRONTIER*.

The most important issue in transporting $LH_2$ to prevent heat from the outside affecting the very low cargo temperature. There are three modes of heat transfer: conduction, convection and radiation. In order to reduce heat transfer Kawasaki Heavy Industries developed a vacuum insulated stainless steel tank as a Cargo Containment System (CCS) for liquified hydrogen. The double-shell-structure prevents heat transfer due to convection by creating a vacuum between the double shells. In order to prevent heat from being conducted from the outer shell through the supporting material in the inner shell, an excellent insulation material made of Glass Fiber Reinforced Plastics (GFRP), which is resistant to conducting heat, was adopted. To prevent heat transfer through radiation, a laminated heat insulating material was attached to the inner shell. Kawasaki also used a thermal protection panel on the outer shell, which it had developed for use on LNG carriers. *SUISO FRONTIER* is equipped with 1 tank with a 1,250 cbm capacity.

Hydrogen has a lower boiling point than oxygen. If the piping of $LH_2$ is not sufficiently insulated, the oxygen in the air will liquefy when it comes into contact with it, which could lead to a dangerous situation if it catches fire. The double-wall vacuum insulation system for the cargo piping was adopted to ensure high thermal insulation performance.

In cooperation with domestic and foreign manufacturers a variety of cargo equipment has also been developed for cryogenic use: cryogenic valves, cargo pumps, cargo compressors, thermometers, level gauges.

©HySTRA

Liquefied Hydrogen Terminal'*Hy touch Kobe*'


© Kawasaki Heavy Industries, Ltd.

Large $LH_2$ Carrier

If hydrogen becomes ignited, it will be difficult to see the flame even if it burns, so a special fire detection equipment was fitted.

Since this vessel was the first liquefied hydrogen carrier in the world it presented a big challenge even before the design stage. Hydrogen boils at minus 253 degrees Celsius and combusts easily, and its molecules are very small and easily diffuse, careful safety measures must be taken. As regulations for ships to ensure the safety of $LH_2$ have not yet been established, Kawasaki Heavy Industries designed the ship based on risk assessment methods such as HAZID and HAZOP. Kawasaki has a long record of using $LH_2$ storage tanks for rocket fuel. In this project the depth of technology Kawasaki Heavy Industries has as an industrial conglomerate were demonstrated.

Kawasaki Heavy Industries began work on the vessel at its Kobe shipyard in January 2019. Construction of the ship required higher quality and accuracy control than ordinary ships. For example, At minus 253 degrees Celsius, steel shrinks significantly, requiring high engineering precision to prevent stress concentration.

At the same time as the hull was under construction Kawasaki built the CCS at its Harima works. In March 2020 the hull of the *SUISO FRONTIER* was transported from the Kobe shipyard to the Harima works, and CCS was installed using a floating crane. As the CCS was completed, and construction at the Kobe shipyard entered its final phase, a new problem emerged - the spread of the COVID 19. Business trips and multi-person meetings were banned, and remote work increased. In addition, engineers from overseas were unable to enter the country and equipment could not be commissioned. With the timing of arrivals from aboard unknown, problems with production management continued.

As this was happening, the production site worked hard to prevent delays and took measures to stop the spread of coronavirus, such as wearing masks even in the hot summer, as they persevered to keep production going. In October 2020, Kawasaki Heavy Industries successfully completed the ship's official sea trials. The commissioning of cargo equipment, which was delayed at that time because foreign engineers were not allowed to enter the country, was later carried out and completed.

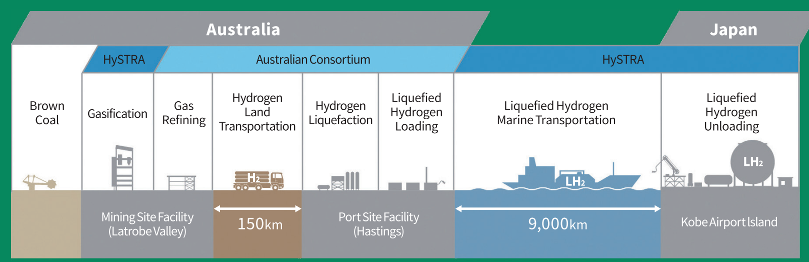
By October 2021, cargo handling and operation tests of various equipment using $LH_2$ were conducted at *Hy touch Kobe*, which is a demonstration terminal for $LH_2$ loading and unloading. A full load test voyage, of about 3 weeks, was completed around the Japanese coast with a cargo tank full of $LH_2$. In December, the ship was classified by ClassNK, and preparations for a large-scale ocean transport demonstration test were finally complete.

Aiming to commercialize the seaborn transportation of hydrogen in 2030, after the demonstration of the *SUISO FRONTIER*, Kawasaki Heavy Industries started to demonstrate the commercialization of a large ship. Utilizing the design, construction and safety technology learned in building the *SUISO FRONTIER*, with the support of NEDO, a system for large ships was studied, and a cargo storage facility with a new thermal insulation system was developed. In May 2021 a CCS with the world's largest capacity for use in large $LH_2$ carriers was received basic design approval (AiP) from ClassNK. A single cargo storage tank had a 40,000-cbm capacity which is equivalent to that of a large LNG carrier. The company plans to use four such tanks into a 160,000-cbm capacity ship ready to be demonstrated by the mid-2020s.

From 2021, Kawasaki Heavy Industries, ENEOS and Iwatani, with the support of NEDO, started a large-scale demonstration project, based on the assumption of a commercial application, involving sea transportation by a large-$LH_2$ carrier with a capacity of 160,000 cubic meters. The goal is to achieve the CIF price of 30 JPY/Nm3 by 2030, of this cost the marine transportation cost is expected to be reduced to 2.5 JPY/Nm3 through large scale transportation using a 160,000 cubic meters liquified hydrogen carrier.

$LH_2$ carriers are ready to sail into the world's oceans.

Hydrogen Energy Supply Chain Pilot Project

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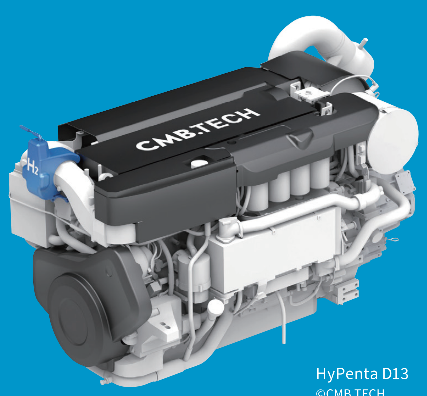
# AGE OF HYDROGEN FUEL

**Hydrogen is seen as a potential candidate to become a future fuel for ships in the decarbonization era. The 19-gt aluminum alloy passenger ship *Hydro BINGO*, with a mixed hydrogen gas and diesel combustion engine, is the world's first hydrogen fuel ferry and was made in Japan.**



HyPenta D13
©CMB.TECH

In the maritime world, research and development has begun to use hydrogen as a fuel. Belgian shipping giant CMB saw the potential of hydrogen fuel at an early stage and the company has been working toward the realization of hydrogen-fueled ships since around 2016.

CMB recognized Japan as the place to realize hydrogen-fueled ships. In 2017, Japan became the first country in the world to formulate a basic hydrogen strategy and raised the ambition of realizing a hydrogen society. It is the best country to explore the possibility of a hydrogen-fueled ship. TSUNEISHI FACILITIES & CRAFT (TFC), a company that builds passenger ships made of aluminum alloy, became CMB's partner in realizing the concept.

Since TFC developed Japan's first battery-powered electric propulsion ship in 2012, it has become a shipbuilder which has consistently pursued the possibility of reducing environmental impact. The company has built a series of small battery-powered ships and has been working on the challenge of zero-emission ships. However, conventional lead-acid batteries and lithium-ion batteries are not suitable for heavy-load ships, and from the viewpoint of speed and operating time, it is difficult to deploy them on passenger ships. TFC recognized the possibility of using hydrogen from early on in its search for alternative means of propulsion, and has been studying hydrogen fuel cell ships. Against this background the CMB Group's hydrogen-diesel dual fuel engine was evaluated as a realistic option toward a hydrogen society.

In 2019, CMB and TFC agreed to work toward developing the world's first hydrogen-powered ferry. A joint venture company, called Bingo Research Institute, was established to work together on building the ship. On 12 July 2021 the *Hydro BINGO* was completed.

The vessel is equipped with two hydrogen-diesel dual fuel engines "HyPenta D13-1000", manufactured by Volvo Penta on an OEM basis, as hydrogen-fuel internal combustion engines. The maximum continuous power output is 441 kW per unit.

A control system developed by CMB. TEC automatically adjusts the optimum mixed combustion ratio of gas, oil and hydrogen according to the rotational speed and power output. The actual mixed combustion rate of the engine is 0%-70%. This ship is scheduled to operate at 30%-50%. This reduces $CO_2$ emissions by up to 50% compared to conventional diesel engines.

Since it is a mixed combustion engine of hydrogen and diesel, it is possible to operate the ship using only diesel in sea areas where hydrogen fuel is not available. One of the merits of the system is its redundancy, which allows it to operate even if hydrogen fuel runs out or the hydrogen system fails. The hydrogen injection system was jointly developed by TFC and CMB.

A major issue when introducing new fuels is the fuel supply system. In order to supply new fuel to ships, it is necessary to establish the supply infrastructure, such as dedicated fuel supply ships and land facilities. In this regard, *Hydro BINGO* takes a unique approach to hydrogen supply. On the rear deck is a square box labeled "$H_2$" which is a storage tank for hydrogen fuel. Inside is hydrogen curdle, made up of a bundle of 30 compressed hydrogen cylinders. A fuel tank for diesel is also provided separately on the ship. In the system hydrogen and diesel oil are supplied to the engine through separate lines, and are then combusted together.

One unique feature is that the hydrogen tank is kept on a portable trailer. Under the system the empty trailer is towed off the ship onto the roadway and taken to a factory on land, where it is refilled, before being once again loaded onto the vessel. The concept is that refueling is carried out by replacing the entire tank. By this method, it is not necessary to install a dedicated hydrogen fueling facility at the quay, and transportation and installation of equipment for supplying hydrogen becomes easy. The tank carries about 100 kg of hydrogen. Its gross vehicle weight is around 3,500 kg or less, and it complies with the high-pressure gas safety and the road transportation vehicle laws.

In order to secure space for the hydrogen tank trailer on the aft deck, the vessel is designed as a catamaran type and hull is made of lightweight aluminum alloy.

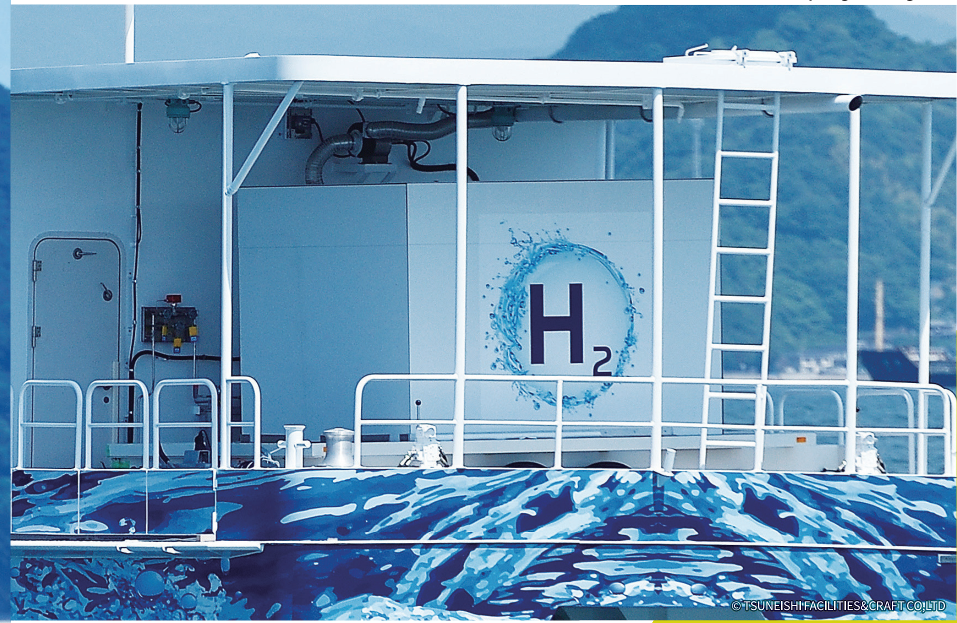
As the first hydrogen-fueled ship to be built in Japan, careful measures were taken during the design and construction to ensure safety. The design is in accordance with the Safety Guidelines for Hydrogen Fuel Cell Ships, developed in line with the functional requirements of the IGF Code and the particularities of hydrogen fuel. TFC, in cooperation with external research institutions, established a "Risk Assessment Committee" to reflect expert knowledge in design, and to set up various facilities, while discussing measures to further ensure safety. The design work was also advanced through consultation with an approval organization.

The CMB and the TSUNEISHI Group will further strengthen their partnership to promote hydrogen. CMB and KAMBARA KISEN increased the capital of Bingo Research Institute, renamed as "JPNH₂YDRO" in 2021,a joint venture company established to develop *Hydro BINGO*, which now includes the participation of three companies. Following on from the *Hydro BINGO*, the company also decided to build a hydrogen-powered tugboat at TSUNEISHI SHIPBUILDING in 2024. Utilizing the know-how gained from the construction of the *Hydro BINGO*, the company has taken on the challenge of realizing a hydrogen-powered tugboat which requires high power and the installation and operation of large hydrogen engines.

On the 10 August, 2021 TFC and CMB held a ceremony to mark the completion of *Hydro BINGO*. Local children also took part in the ceremony. TFC President Jun Kambara said in his greeting: "This ship, powered by a new fuel called hydrogen, was developed with the aim of reducing $CO_2$ emissions. I hope that children will be interested in new ships and new technologies, and that they will work in ways that will benefit society in the future." CMB Chief Executive Alexander Saverys, in a welcome video message addressing the children, said: "You are the future of this society. Hydrogen also holds great potential for the future, and that future starts here today.".

The future of a hydrogen society starts with *Hydro BINGO*.

Movable hydrogen storage tank



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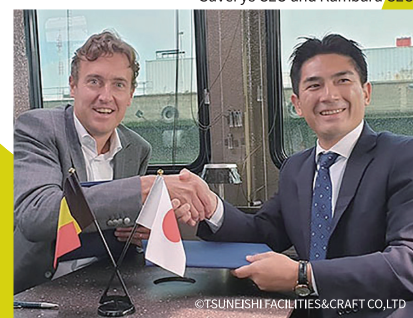
Saverys CEO and Kambara CEO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# JMU MAKES HULL MONITORING BREAKTHROUGH

**By fitting an advanced hull monitoring system to one of its capesize bulk carriers Japan Marine United is taking on the challenge of revealing the stresses that occur to the hull in actual sea conditions.**


| | | | |
|---|---|---|---|
| Overall length | :299.99m | Gross tonnage | :108,903 tonnes |
| Width | :50.00m | Deadweight | :212,078 tonnes |
| Depth | :25.00m | Speed | :14.50 knots |
| Draft | :18.40m | Class | :NK |



On the 28 July 2021 the 210,000-dwt bulk carrier *DREAM CLOVER* was launched from JMU's Tsu plant. A feature of the ship is the installation of a monitoring system to measure and record stresses on the ship's hull.

What is the significance of such a hull monitoring system?

The previously unknown condition of a ship during a voyage has now been made clearer through the advancement of monitoring technology. For example, the capture of data on the engine and sea conditions through monitoring allows analysis of each voyage to be carried out to see how the ship is performing. It is also possible to verify whether the performance calculated in tank trials is realized in actual sea conditions. JMU is now collecting and analyzing operational data from the ships it has built to provide a feedback loop which will inform the next series of ships it is builds. Even though it has now become possible to see the propulsion performance of the ship in real sea conditions, there is still one thing which cannot be viewed, the true condition of stresses on the hull.

In recent years the bulk carriers and containerships have grown rapidly in terms of size and shape. While at sea the ship's hull can quickly become exposed to intense forces because of heavy weather or sudden changes in the sea condition. Depending on the environment in which the ship is used it is possible that ageing of the hull will accelerate due to corrosion or fatigue. For this reason, to ensure safety, it is necessary to as much as possible, accurately understand the real condition of the ship at sea and, in addition, to evaluate the structural strength of the hull and establish the appropriate operational support technology for crew.

Between 2016 to 2020, together with Nippon Yusen Kaisha and MTI, and with the support of the Ministry of Land Infrastructure Transport and Tourism, JMU completed the "Study on Monitoring the Structural Health of Vessel Hulls for Very Large Containerships." Under this research sensors were attached throughout the hull of a 14,000-teu containership to collect data on the stresses occurring on the hull in sea conditions, to try to clarify how it impacts on the strength of the hull and attempt to develop a system that would be beneficial for both ship design verification and safe navigation.

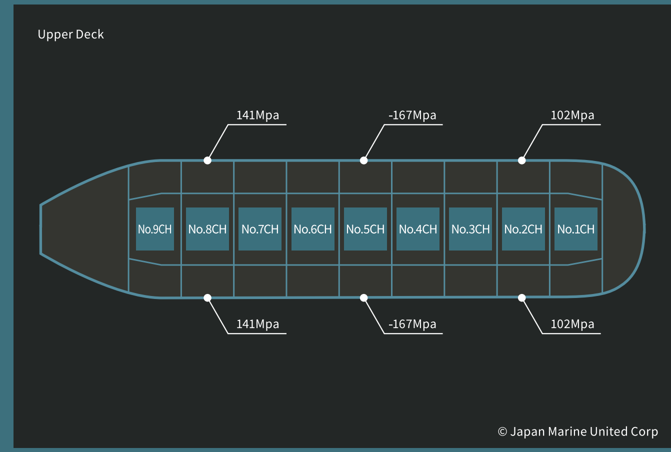
Following these advances in monitoring technology, another joint project was launched in Japan. The Japan Ship Research Association started the "Research and Development of the Highly Accurate Digital Twin Models for Ship Hull Structures" in 2018 with the support of the Nippon Foundation. Six shipbuilding companies, including JMU, as well as universities,shipping companies, National Maritime Research Institute and ClassNK are participating in the project to establish digital twin technology that can replicate the behavior of a ship's hull, in actual sea areas, in cyberspace. Work began in 2020 toward the practical application of this technology, involving acquiring various data using a monitoring system on ships in operation. The data is then used to trying to reproduce the structural response of the entire hull digitally. It was decided to fit a monitoring system on the *DREAM CLOVER*.

The *DREAM CLOVER* ship's hull structure monitoring system is made up of 26 strain gauges installed on the ship, an accelerometer attached to the bow and personal computer on the bridge. The strain gauge attached to the structure measures the longitudinal bending stress of the hull, while the accelerometer measures the acceleration generated in the hull. The data will be stored in a personal computer onboard the ship and in JMU's Sea-Navi 2.0® integrated ship operation support platform. The system estimates the response and safety of the hull structure to external forces, such as waves and cargo loads, based on monitoring data on the strain and acceleration of the hull structure. The data showing the condition of the hull structure can be confirmed in near real time from either the ship, or land, through the cloud.

Sensor On Deck



Stress Display






There are several ways to use this data. One is to support safe operation. By accurately grasping the actual condition of the hull, and analyzing it together with the navigation data, it can be used as a reference when determining the speed and course of a vessel under way. For example, while operating in heavy weather, if it is understood from the data that the stress on the hull exceeds, or is about to exceed, the allowable range, it can be confirmed that the stress on the hull can be reduced by lowering the ship speed or changing course.

Hull maintenance support can also be expected. Fatigue strength can be estimated from the historical data on previous stress, and on conditions such as degradation with age, so that the inspection locations can be narrowed down, and appropriate maintenance times can be estimated.

The aim is to also to feed data from the actual sea conditions into the hull's structural design. By collecting data on the forces exerted on the hull during operation, it also becomes possible to obtain new knowledge and develop a more rational hull structure.

*DREAM CLOVER* was certified as a ship equipped with hull monitoring. The ship is the first in ClassNK registry with its new notation "DSS (HM (F + LS, O))" representing the ship has the latest hull monitoring system.

Until now, it has been difficult to verify the structural response of ships in operation to wave load in actual sea areas. Usually rule calculations are based on past experience, various analyses, and experimental results. Ships operate within the range of external forces which are assumed at the time of design to maintain structural strength and ensure safe operation. With the monitoring system, the stress generated in the hull can be understood simultaneously with actual data, such as the sea conditions. Then the gap that exists between the estimation of external force, and strength which is assumed at the time of design, and the reality, becomes clear. This will lead to safe operation and proper maintenance, as well as provide new knowledge on hull structure, which can be utilized in ship design. Eventually in the future it is expected to lead to the proposal of new rules.

In addition, the joint digital twin hull structure project, involving tests on the *DREAM CLOVER*, aims to digitally reproduce the structural response of the entire hull based on monitoring data. By bringing together the simulations, not only of the measurement sites, but also areas that are unmeasured, or are physically impossible to measure, it is taking on the challenge to estimate the structural response of the whole ship. In addition, it is taking on the challenge of estimating hull stresses from advanced weather forecast data indicate navigational safety.

*DREAM CLOVER* is the first step toward a new era of ship hull structure.

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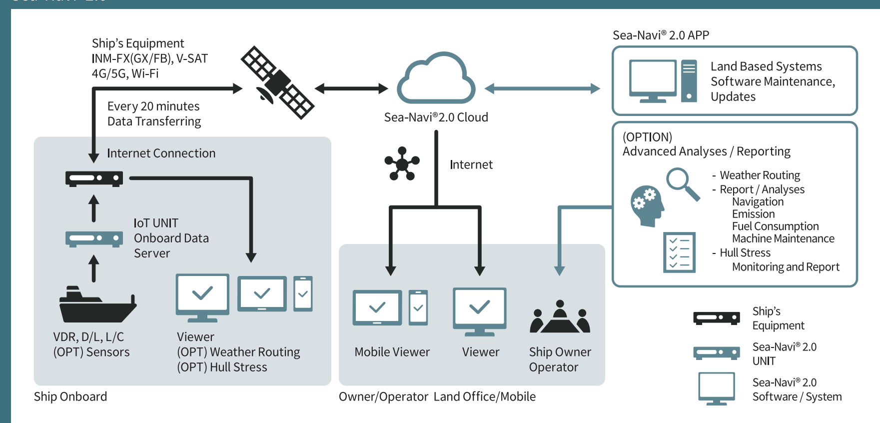
Sea-Navi®2.0



Remote Control Console

# GRAND DESIGN FOR AN AUTONOMOUS SHIP

Under The Nippon Foundation MEGURI2040 Fully Autonomous Ship Program, the Japanese maritime industry has taken on the challenge of a project called Designing the Future of a Full Autonomous Ship (DFFAS) project. To achieve The Nippon Foundation's target of implementing autonomous shipping by 2025, the project is aiming to successfully demonstrate the world's first fully autonomous operation.

SHIPBUILDING IN JAPAN 2022

With NYK Line's Japan Marine Science Inc. acting as project leader, this project, through the spread of fully autonomous operation, aims to bring about a logistics revolution, and show to the world Japan's strength. In addition, though the results of this technical development, it also aims to achieve safety and environmental protection, and solve the labour shortage in the coastal shipping industry. As well as bringing together Japanese know how, it also hopes to utilize foreign knowledge and knowledge from other industry areas.

The DFFAS project consortium is made up of 30 Japanese companies representing different sectors such as shipping, shipbuilding, ship machinery, communication, ship management, insurance, IT and other think tank bodies. In addition, including cooperating companies such as classification societies, research bodies and all types of makers, there are around 60 domestic companies involved in the challenge of this open innovation project.

This project not only involves the automation of berthing and unberthing, sailing according to the voyage plan and collision avoidance, but also the development and demonstration of a comprehensive system, that includes functions which support autonomous operations, such as observation from land, situational assessment and on shore operations during an emergency. In February 2022 using the 749-gt containership *SUZAKU*, a demonstration project was carried out between in congested waters between Tokyo Bay and Ise Bay. Under current regulations fully crewless operations are not permitted, so the crewless operations were simulated with crew onboard.

Before the voyage, a voyage plan is automatically generated by land side based on the vessel's information, speed and other conditions, and shared with the ship. The ship's side confirms that the plan is safe. The ship unberths according to the plan, monitors the location of nearby vessels, and other conditions in the area, and operates accordingly, before berthing. As this demonstration did not include the automation of berthing and de-berthing, the captain of the ship operated the vessel within about 70 metres from the quay, but the system that has been developed automates all operations, including berthing and un-berthing.

The automated system on the ship side is packaged in a 40ft container as a unit. As retrofitting a ship to accommodate a fully autonomous system would be costly and time-consuming, it was decided that the most effective way would be to mount this container on the ship and link it to the ship-side system considering the social realization.

The heart of the project will be the fleet operation center in Makuhari near Tokyo. The operation of *SUZAKU* will be monitored and supported by a marine engineer.

The operation center will collect all data connected with the voyage, such as weather and sea conditions. Under the voyage plan a safety policy, including information on the ship, its draught and distance from other vessels will be formed. In line with the operator's intention, such as to "prioritise the fastest route" or "prioritise fuel consumption," based on standard routes, an optimal route will be planned. Normally route planning which is carried out by hand can take several hours, but using this system it can be completed in a matter of five minutes. After safety checks and authorizations have been completed, the voyage plan will sent to the ship and, in line with the plan, automated operation takes place. During the voyage land-based operations have full knowledge of the location of the ship and how decisions are being made on collision avoidance. The condition of all the functions of the autonomous operation system can be automatically monitored and, according to conditions, the ship can be operated remotely from land as well as automatically at sea.

All technology related to the autonomous operation will be collected at the Fleet Operation Center. Japan Radio has developed equipment to display information captured by each sensor together with weather information and to analyze the collected data, assessing the ships safety and economic efficiency. Furuno Electonics has have developed an emergency response system to allow the remote operation of the ship in an emergency situation. It has also developed a system that supports the ship's operational plan while assessing the situation around the vessel.

The concept of DFFAS is to create a grand design of the Japanese automated ship using a variety of experts. It is not only to clear the technical hurdles but to address all the full range of legal, responsibility, insurance, risk assessment issues around the introduction and establishment of the fully autonomous ship. Both these areas will be indispensable to socially realize the autonomous ship.

This project's unique feature was the use of high-level simulation in developing the automated system. Simulation was used to test if different specialist manufacturers systems could be linked and combined to achieve the intended function. It is a method which allows system checking and improvements to be made before the demonstration is carried out. This is a development method that can be used in response to the increasing complexity and technological sophistication of ships.

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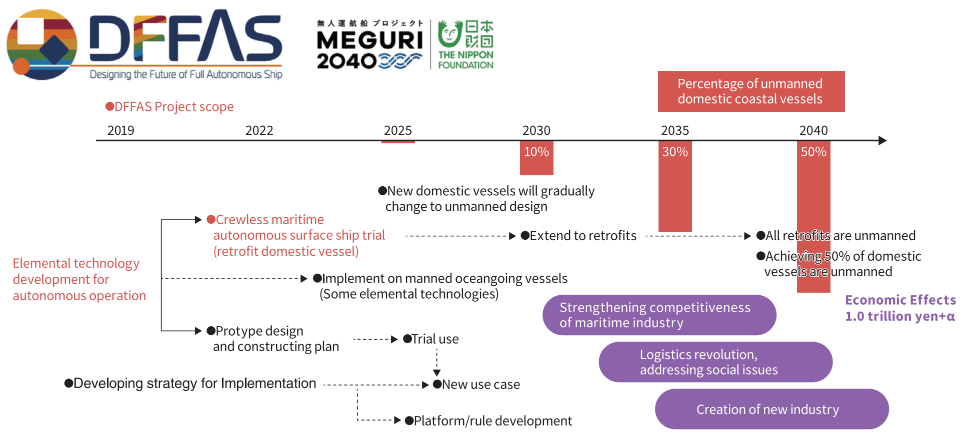
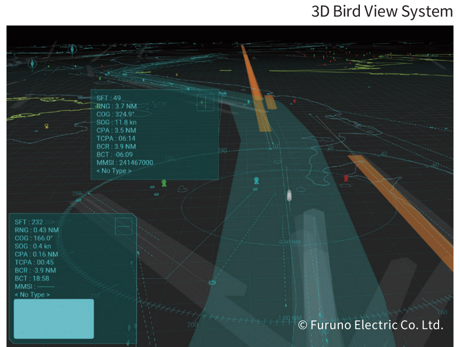
Fleet Support System Console



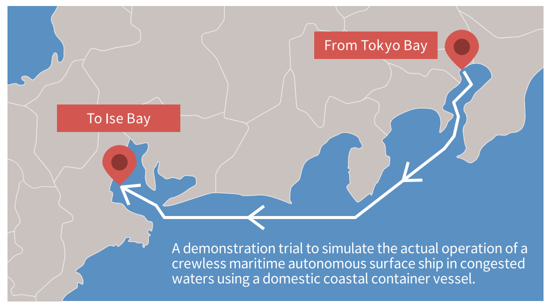

Companies participating
Japan Marine Science Inc. (project leader); MTI Co., Ltd.; Kinkai Yusen Kaisha Ltd.; SKY Perfect JSAT Corporation; Tokio Marine & Nichido Fire Insurance Co. Japan Radio Co., Ltd.; Mitsubishi Research Institute Inc.; Sunflame Co., Ltd.; Suzuyo Marine Co., Ltd.; Furuno Electric Co. Ltd.; Japan Hamworthy Co., Ltd.; Japan Marine United Corporation; Nabtesco Corporation; Nippon Shipping Co. Inc.; Honda Heavy Industries Co., Ltd.; Miura Co., Ltd.; Nihon Shipyard Co.

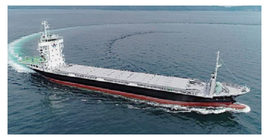

The participants verified the system many times through simulations

3D Bird View System




Demonstration Trial





A container equipped with the DFFAS system was installed on Suzaku, a 749 GT container vessel in a demonstration trial.

# DIGITALIZATION MAKES COASTAL SHIPPING SMARTER



**Smart Assist Ship, a next generation energy efficient coastal vessel, which fully utilizes digital technology, has been born. Solutions to the problems faced in coastal shipping have now been found by adapting technology used on large ocean-going vessels for use on small coastal ships.**


Steering Stand

In the Japanese coastal shipping industry labour shortages, and an ageing workforce, are a problem and so the reduction of manual workload has become a major issue. The 199-gt type dedicated liquid soda carrier *RYUTO* was developed to take on this challenge.

There were three main points. The first was to reduce cargo handling and cleaning work, the second was to reduce highly skilled work required of crew in berthing and unberthing operations, while improving safety, and the third was to reduce the main engine room workload. Shipowner Fuji Kisen said it wanted to build a ship which could fulfil these three points, and consulted with Hongawara Shipbuilding, which is known for its advanced coastal vessels. "We received a strong request from the owners, and selected equipment and technology which could attain these themes and began development," said Hongawara Shipbuilding president Makoto Hongawara.

To solve the three problems a new system was developed which included a "Centralized Remote Cargo Handling System," "Berthing and Unberthing Support System" and "Remote Management System."

Firstly, the Centralized Remote Cargo Handling system linked all the cargo handling and ballast functions, including pumps, valves and deck machines, under a remote centralized operating system. Until now cargo handling operations took place in three places: the pump room, on the deck and in the cargo office, and it also involved three or four people. The deck operations took place in extreme heat during the summer, and in freezing cold in the winter, making it dangerous work. With the newly developed centralized remote system, only the first stage, the hose connection, is carried out manually. After that all the work is carried out from one place, the operations room, where the operation can be carried out remotely. Along with relieving crew from deck responsibilities, through centralized monitoring, accidents during cargo operations and human error are prevented, safety is improved, and labor saved. Under the Japan Ship Machinery and Equipment Association's new product development project, Hongawara Shipbuilding received support from the Nippon Foundation.

Until now such cargo handling operations had only been installed on large vessels. But digitalization led to the development of smaller equipment and, along with some innovation, a system which could be installed on the smallest class of tanker was realized. A remotely operated valve which can be used on a small chemical tanker was realized through software developed by Musasino Machinery. The development of the valve was handled by Misuzu Machinery. The cargo pump remote operation and monitoring was realized with the cooperation of Taiko.

The second newly developed system was the berthing and unberthing support system. Berthing and unberthing operations require skill from the crew and leads to a great deal of tension.

To support this, through the remote operation and linking of thrusters and winches, and by monitoring the distance between the wharf and surrounding areas, easy and safe berthing and unberthing is possible even in narrow water passages.

The thrusters are positioned in the ship's bow and stern. The bow and stern thrusters are able to be operated independently and, in addition, through a one lever joystick the main engine can connect both thrusters making parallel and turning movement possible.

Also, in the bow and stern a new Drum in Motor Winch (DIMW), developed by SK Winch, including the Smart Digital Winch, were installed for the first time. As well as being able to operate the winch remotely from the wheelhouse, it can also detect and display the mooring line tension. Through a newly developed remote centralized operation integrated panel, called the Mirai Panel, the thruster and the winch can be linked and controlled in an integrated manner.

The distance between the wharf and the ship is measured with a ship to shore distance sensor with a radar wave calibrated in millimeters, and displayed on the Mirai Panel. Safe berthing and unberthing operations can take place by matching images from live cameras located throughout the ship to check the surrounding situation.

Digital Electric Winch

Mirai Panel

Onboard Live Camera Display

Upper Deck

The third new system is the remote observation system. It is a system which allows the remote observation of main engine operation and other machinery, and makes possible the collection of operational data. Onboard the vessel there is a server compliant with the international standard ISO19847 for onboard data, and ISO19848, for ship data formats. The main engine and auxiliary engines are fitted with a data logger, which records operational data such as temperature and pressure, and sends it to the server for collection, and then displays the information in one on a monitor in the wheelhouse. Also, data from the centralized remote cargo handling system, and the berthing and unberthing support system, are also sent to the server for storage.

Through ship to shore communication, data from the vessel's cargo handling pump and engine can be monitored on a land-based PC or tablet. Based on this, cargo handling and operational information, which land based staff could not access until now, can be shared. If the staff have experience in being a chief engineer, then appropriate instructions can be given to the ship, based on monitoring at engine data on a land-based monitor. Safer and more precise cargo handling and engine monitoring become possible.

The ISO data server was constructed with the cooperation of BEMAC. By making the browsing and storage of data to ISO standards possible, the number of digital devises could be reduced, making the installation more compact and enabling it to be installed on a small coastal tanker. Many cargo handling and operational control devises could then be fitted to the ship.

The Future Study Group of Coastal Shipping group, involving more than 40 Japanese coastal shipping shipowners, engine manufacturers and design companies, and played a big part in the development of the Smart Assist Ship. This research group was established in 2019 to find a solution the coastal shipping industries' problems of an ageing workforce and labor shortage, improving working conditions and greenhouse gas emissions reduction. Centered on remote operations, electrification and automation to improve onboard operations numerous research and development projects are being advanced. The Smart Assist Ship is the result of its work in the year since it was established.

Through this system, for small coastal tankers, there has been a reduction in the number of crew required, centered mainly on cargo handling work, and the workload has been widely reduced.

From now on the idea is to see the system used more widely. The Smart Assist Ship concept will become a cornerstone for solving the problems of Japan's coastal shipping industry.

Supported by THE NIPPON FOUNDATION

**The first large size LNG-fueled ship in Japan is the 7,000 vehicle capacity car carrier *SAKURA LEADER*. It is also fitted with many advanced digital technologies and has become a flag ship for environmental protection and digitalization.**



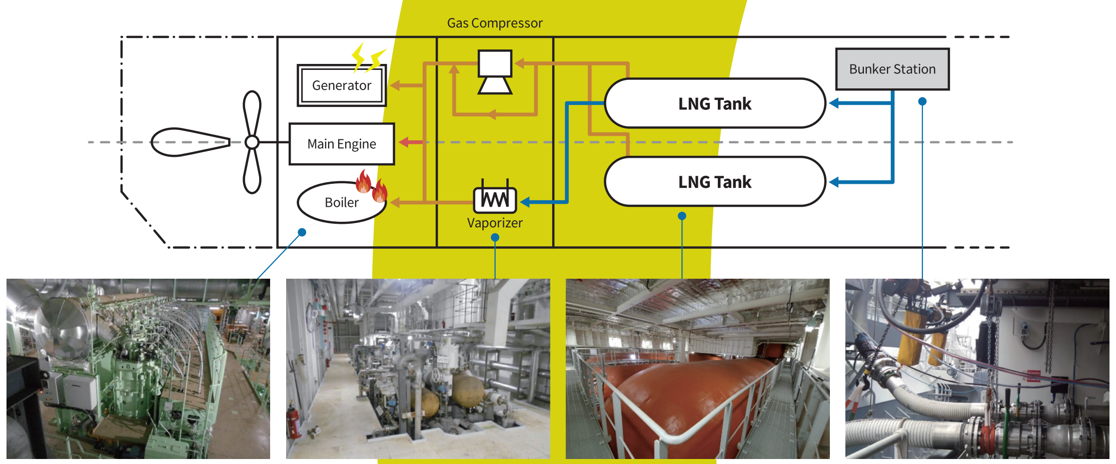
# LNG AND DIGITALIZATION ACHIEVE DECARBONIZATION

© Central LNG Marine Fuel

Around 2015, LNG began to attract serious attention as a next-generation fuel for deep-sea shipping in the world, and accumulating technology and knowledge on LNG fuel for large ships became a major challenge in Japan. At the time, Japanese "Challenge 4 Zero" team was established to share opinions and information on the future challenge of achieving zero emissions. Taking part were a total of eight companies. These included NYK Group, which had taken a lead in switching to LNG-fueled vessels in Japan, leading car carrier shipbuilder Shin Kurushima Dockyard, LNG specialist Mitsubishi Shipbuilding, engine maker IHI Power Systems, generator manufacturer Daihatsu Diesel, combustion technology specialist Sunflame, marine electrical system company Terasaki Electrical Systems and classification society ClassNK. Challenge 4 Zero team decided to build the first LNG-fueled large size car carrier.

The number 4 has a key meaning in the team name. Firstly, there is the involvement of the “four pillars” of the maritime industry: the shipping company, shipbuilder, machinery and equipment manufacturer and classification society. Then there is the aim to reduce $CO_2$ emissions by “40%”. In addition, by the time ship becomes old in “2040”, the aim was to make sure the vessel still had a high level of






environmental performance.

The main engine is an IHI Power Systems' low speed two stroke dual fuel 8X52DF engine. Then first dual fuel 6DE28DF model auxiliary engine, developed by Daihatsu Diesel, was also installed on the ship. Sunflame's Rotary Cup Burner was adapted for LNG and used as the burner for the boiler. Mitsubishi Shipbuilding provided the Fuel Gas Supply System. Mitsubishi Shipbuilding developed the system from its experience in LNG and gas handling technology used in LNG carrier. Mitsubishi Shipbuilding also supported the shipyard by providing the relevant engineering services and technical support relating to the gas handling, as well as dispatching experienced engineers for a part of installation work and the gas testing. Shin Kurushima Dockyard group shipyard Shin Kurushima Toyohashi Shipbuilding was selected to build the ship. It is the shipyard with the largest construction record for car carriers and it brought together all these new technologies and products in taking on the challenge of constructing its first LNG-fueled vessel. This led to the delivery of the *SAKURA LEADER* in 2020.

The use of LNG fuel was not the only method to reduce greenhouse gas emissions in the project. In the ship's stern products developed by Shin Kurushima Dockyard such as the energy saving device "A.S Finn" and "Turbo Ring", and the highly-efficient K3 propellor were also used. In the ship's bow the "Areodynamic Screen" was installed to reduce wind resistance.

The pump for cooling seawater was controlled by an inverter, while energy saving paint was used on the hull bottom. Also, within the ship in cargo holds, accommodation unit and throughout the engine room, LED lighting was used. Energy saving technology was comprehensively introduced.

This energy saving machinery, in addition to the large size of the vessel, cleared the Challenge 4 Zero target of a 40% reduction in $CO_2$ emissions per unit of cargo transported.

*SAKURA LEADER* is not just an LNG fueled ship. It has another face as a Smart Ship that represents the pursuit of digitalization. It employs several advanced technologies which collect and utilize data from onboard machinery. One is, in support of safe navigation, technology to prevent trouble developing in equipment at an early stage.

ClassNK's total support platform CMAXS LC-A was introduced to perform automated and remote diagnostics based on operational data collected from ship machinery. This system's analytical method is to use machine learning algorithms and the manufacturers know how together to automatically detect abnormality in engine and machinery performance based on data.

In addition, it also has a trouble shooting function which automatically displays instruction on recovery procedures and information on maintenance management.

It is the first time this system has been applied to an LNG fuel engine. By sharing the LNG-fueled vessels operational data the Challenge 4 Zero members can aim to deepen their knowledge of gas related machinery, accumulate learned data from the diagnostic system, and aim to improve technology.

The NYK-developed onboard data collection and sharing system, Ship Information Management System (SIMS), was also installed with a new function developed to make it compatible with the LNG-fueled ship. During the voyage all types of data are collected and, together with the experience of the chief engineer and trouble diagnostic logic, based on artificial intelligence, contribute to safe navigation, while also providing real time visual analysis of the ship's energy performance.

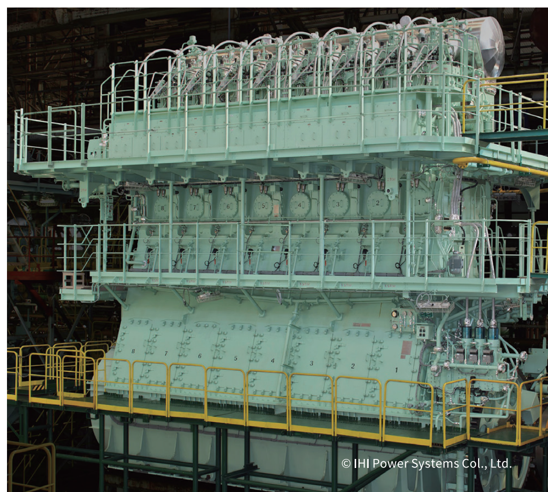
The data infrastructure of the *SAKURA LEADER* is more comprehensive than conventional vessels. There are numerous sensors of all types installed on the vessel. On standard vessels there are around 500 data points but on the *SAKURA LEADER* the number has been increased to 2,800. In addition, by combining Terasaki Electrical System's Integrated Control and Monitoring System with the onboard data platform, it is possible to process all types of data on the ship's internal LAN network. Onboard data can be saved every second and the collected data can be used in simulations for the development of next generation engines.

ClassNK awarded the vessel the Digital Smart Ship (DSS) notation. DSS recognizes ships with innovative digital technology and was newly established by ClassNK in 2020. The *SAKURA LEADER* is the first ship to be awarded the notation. The ship also has the DSS EE notation, which certifies that it is equipped with a high-level energy efficiency analysis function, and DSS MM, certifying it has an engine monitoring function. Finally, it also has a DSS CNS notation recognizing the onboard ship data handling and ship to shore data transmission function. It is acknowledged as the world's first ship to realize advanced digital technology, not just in the concept design stage, but during actual operation.

Applications for Safe Navigation


©NYK Line

8X52DF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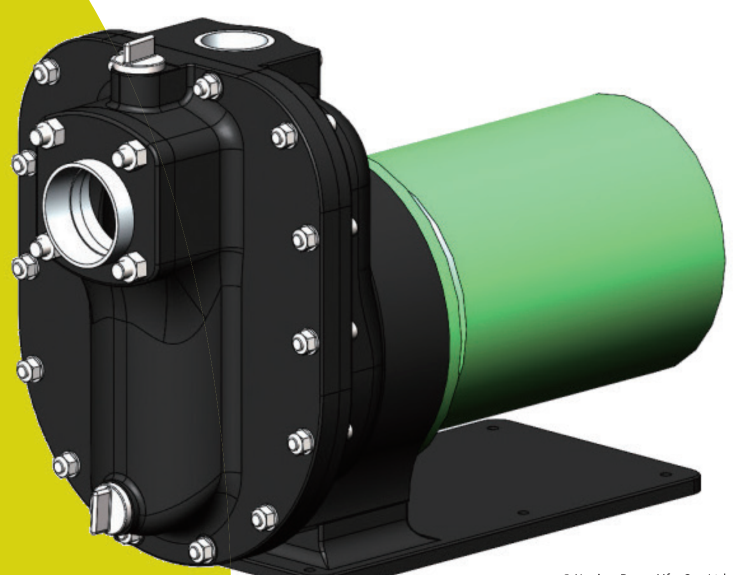
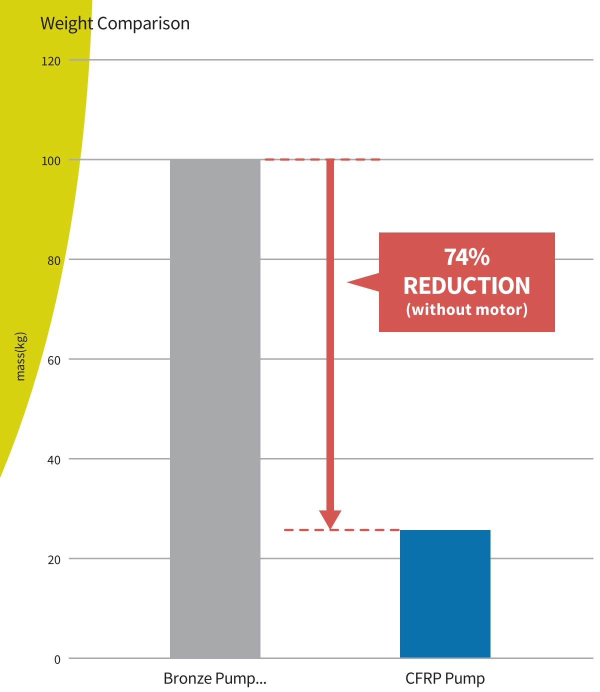
# NANIWA MAKES FRP PUMP POSSIBLE








**The pump is one of the most important pieces of equipment installed on a ship. For that purpose, the main material used is bronze. On the other hand, reserves of bronze are limited and, from the sustainability point of view, there is a need for an alternative to be found. Specialist of marine pump maker Naniwa pump took on the challenge of finding an alternative material and developing a new pump. As a result, it successfully developed the world's first pump made from fiber reinforced plastic (FRP) which is lighter, and more durable, than existing bronze pumps.**

Naniwa Pump was established in 1921. Its headquarters are in the manufacturing city of Osaka which is Japan's so-called "business town." Naniwa Pump mainly manufactures and sells a variety of pumps including centrifugal, gear, piston and screw pumps. Each year it produces around 15,000 units.

In 2014 Naniwa Pump, with the support of the Nippon Foundation and the Japanese Ship Machinery and Equipment Association, began research and development into FRP pump to replace the conventional bronze pump. Over the first year a feasibility study was carried out based on a centrifugal pump looking at combining fiber and resin materials and using a molding method. The selected materials were used to begin design and production in 2015.

Aiming at making a more efficient and lighter pump by two types of pump, a vertical and horizontal pump, were prototyped. The result was efficiency improvements of 5% for the horizontal pump, and 7% for the vertical pump, compared to existing bronze pumps, were confirmed. As far as weight was concerned the horizontal pump was 78% lighter, a reduction of 14 kg, and the vertical pump was 66% lighter, representing an 80 kg decrease.

After the Naniwa Pump FRP pump production process was established, in 2017 the new pump was introduced at the Bari Ship exhibition held at the maritime city of Imabari. There Kawasaki Heavy Industries showed its interest. "We would like to use an advanced marine pump which is lighter and more durable on our Jetfoil," Kawasaki Heavy Industries said.

The Jetfoil is Kawasaki Heavy Industries' fully submerged hydrofoil. As a hydrofoil raises up from the sea, and travels at a speed of over 80 km/h, a light hull is essential. Jetfoils had used light aluminum pumps, but focused on lighter and low-maintenance FRP pumps instead.

In 2017 Naniwa Pump started to develop pumps for the Jetfoil. Previously Glass Fiber Reinforced Plastic Pumps (GFRP) had been designed, but to achieve the strength and lightness for the Jetfoil it was decided to use Carbon Fiber Reinforced Plastic (CFRP).

For general metal materials mechanical property values are set by the Japan Industrial Standards (JIS), but the physical properties of FRP vary depending on the material used and production method. So, Naniwa Pump began the element testing of materials using a combination of resin and fiber. To determine the strength tests were carried out on its tensile and bending properties. Also, verification tests were carried out on Interlaminar Shear, which is unique to FRP, and does not apply to metals. It occurs when resin and fiber layers begin to peel off when a certain strength is applied to the material. The physical properties determined by the tests were used to design and build a prototype pump, pressure and durability tests were carried out, and the product was completed. The FRP pump was fitted to *SEVEN ISLAND YUI* which was the first JETFOIL Kawasaki Heavy Industries had built in 25 years. Through this project Naniwa Pump successfully completed the development of the world's first CFRP marine pump.

During product development structural analysis was carried out more than 20 times, and more than 30 performance analysis were carried out to achieve the required specifications. Through this product successful CFRP pump product development, compared to conventional pumps, the weight of the main body had been reduced by around 70% from 100kg to 26 kg.

In the development of this new type of pump, in contrast to conventional metals, the use of a material for which there was no existing regulation became a major issue. There are a variety of fibers used in FRP, and an unlimited number of ways in which fibers are knitted together, the thickness of each fiber, and the way fiber sheets are combined. Shigeki Kitano, general manager of the technical division and the man responsible for the development of the FRP pump, remembered: "We carried out structural and performance analysis again and again, and the repeated a process of trial and error was really hard."



*SEVEN ISLANDS YUI*

The main advantage of a FRP pump over a metal pump is not just its strength and weight. The lightness of the pump also makes improves its maintainability. Also, FRP pump has a longer life because it does not suffer from corrosion. Since the surface is smooth compared to the metal material, a friction loss of fluid is reduced and there is advantage pump efficiency is improved. Tomonori Inoue, manager of the Research & Development Team explained: "A reduction in vibration and noise is a feature of this product. Also, the FRP pump requires less heat in the whole production process, so $CO_2$ emissions can be reduced throughout the product's life."

There are also merits for the cargo loading capacity. Kitano said: "In the case of a large ship there are numerous pumps located in the engine room. By reducing that weight, if a piece of environmental equipment is fitted later, then the cargo load can remain the same." Also, FRP pumps are different from metal materials in that there are no existing fixed standards. Without the data on the physical characteristics compiled by Naniwa Pump through repeated tests it would not be possible to make similar products. Taking measures against counterfeit products also becomes possible.

From now on, an area for improvement is to establish a design which avoids Interlaminar Shear. The original design of CFRP pump for the Jetfoil had to be changed several times to address interlaminar shear. For future product development the approach will be to give more consideration to Interlaminar Shear. "The establishment of a design which eliminates Interlaminar Shear will continue to be the main issue. I want to establish an approach that can allow us to improve this," Kitano said.

For future development other high-speed passenger ships and other ship types which call for lighter products are being examined. In developing other products using pump technology, products used for environmental energy such as pump reversing turbines are being looked at. "Manufacturing the product takes time because it is a manual process, but we would like to take orders for, or dispatch, about one or two units a month," said Kitano.

The development of FRP pumps is just one part of Naniwa Pumps company-wide environmental protection activities. "An FRP pump, through its lifecycle, is a product which is useful for the environment. From now on we will work hard to develop such products and want to supply in the world," said Kitano. Inoue enthused: "The features of the FRP material is not yet fully known, so that clients understand its advanced performance we would like to promote its characteristics to society."

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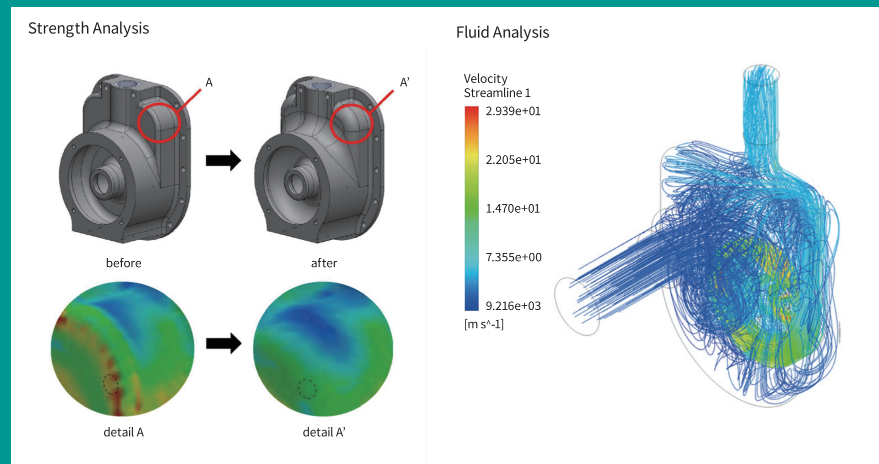
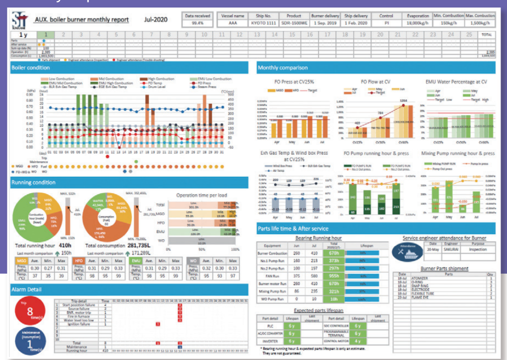


# DATA DRIVEN MACHINERY MAINTENANCE

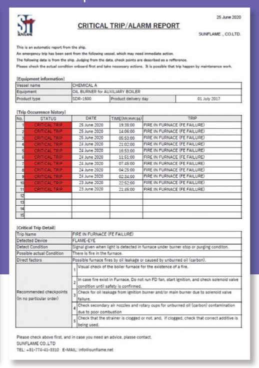
SHIPBUILDING IN JAPAN 2022

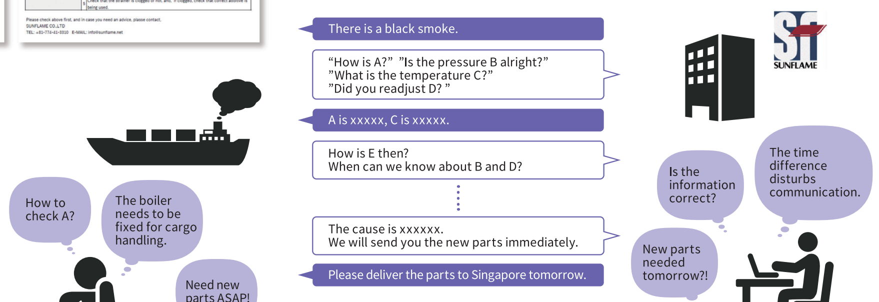
**In the marine industry, there has been an increase in data utilization to address machinery maintenance, to improve fuel efficiency and to reduce greenhouse gas emissions. Sunflame, a marine combustion equipment developer and manufacturer, is building a data analysis system to monitor the condition and to analyze performance of its combustion equipment.**

Monthly Report



Critical Report






Time cannot be wasted in an emergency.
Additional time and human resources are needed for troubleshooting.

Established in 1968, Sunflame has its office in Japan's old capital of Kyoto. As a manufacturer of burners and incinerators for marine boilers, the company developed the *Sunflame Smart Support System* to provide clients with feedback by analyzing the operational performance data of its products.

The function of this system is to first visualize the equipment's operational condition. Data collected through sensor devices aboard ships are sent to shore through communication panels, which are then stored in the company's internal server. Using its expertise, Sunflame then analyzes the same data into daily/monthly reports for its clients in order to disclose the hourly and daily operational trends of their marine equipment. Additionally, it provides clients with critical reports including instructions for dealing with equipment failures which may cause serious accidents. Using the results from the data analysis, clients can be given advice regarding optimal operation to prevent trouble and reduce the amount of fuel consumption, and when to replace spare parts. The communication system is not exclusive to Sunflame products to connect with the hub system; also works as a network gateway for other onboard machinery.

Sunflame had previously recorded its history of spare parts sales and after-service engineer dispatchment in its internal database. After 2000, Sunflame started to create individual data files based on their data accumulation. These individual data files are now combined with real time operational data to provide clients with advices and proposals for improvement.

In April 2021, the system was approved as an innovative technology under ClassNK's Innovation Endorsement for Products and Solutions. Sunflame is the first marine equipment manufacturer to acquire this recognition.

This system was born from the desire to rapidly resolve its clients' issues through improved task productivity. Around 2008, when Company Managing Director and President Tatsuo Tanaka arrived at the office one morning, he noticed a sales department employee dealing with a client's trouble inquiry. The communication between the parties had been taking two, three days of endless exchanges. When President Tanaka investigated what took so long, he found that there were factors causing inefficiency such as time difference, language barriers as well as the communication infrastructure on the ship.

Customarily, skilled engineers on ships repaired equipment themselves as they occurred. In recent years, due to ship crew shortages, there has been a decrease in sufficiently experienced ship crew. In the midst of this situation, the company decided to build a system that could, based on data, check equipment condition from its office.

Starting in 2012, data logger functions were installed in Sunflame's own equipment in anticipation of a robust communication infrastructure on ships. The function was initially installed in high-end models, and then on all models from 2019.

Data reception tests began in 2015 with shipowners' cooperation. Under the rapid development of marine communication technology, the new system was released in 2019.

"We were able to work together to install the equipment thanks to the shipowners," recalled the Sales Department's Sayuri Inoue. Their endorsement also helped Sunflame's data analysis process. Generally, manufacturers are unaware of how their equipment is operated on the ships after delivery. Therefore, the crews' insight was also essential for understanding data regarding equipment performance. DX Project Team's Keisuke Nakamura commented, "It is thanks to the crew's erudition that we were able to provide our clients with data utilization strategies that would truly benefit them. We were able to resolve their issues through close communication with the users of our products."

Sunflame is currently figuring out what the raw data indicates. The data that have been accumulated is being compiled to identify logical patterns through the "findings" to understand the equipment's condition. "It would be great to see a future where users and manufacturers work together to maintain equipment through data utilization," said Nakamura.

President Tanaka remarked, "The Sunflame Smart Support System aims to be the system that prevents our products from malfunction and error. Based on actual data, we can reach out to our clients to offer repair work and provide advice for maintenance. That is what we are striving for."



# NEW COATING BOOSTS EFFICIENCY

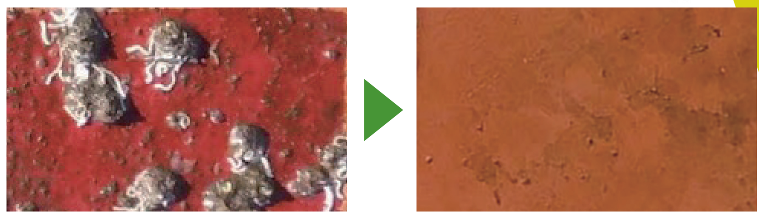
SHIPBUILDING IN JAPAN 2022

**From 2023 the IMO's Energy Efficiency Existing Ship Index (EEXI) and Carbon Intensity Indicator (CII) regulations will begin, and improvements to the ship's performance through the condition of the hull bottom will become even more important. Chugoku Marine Paints (CMP) is proposing a new technological approach to preventing fouling of hull bottom caused by marine organisms.**

Static performance

Test period : 5 months March to August 2019 (Tokyo bay)

Conventional AF → SEAFLO NEO M1 PLUS



Antifouling performance during outfitting period

Antifouling performance

Last drydocking / Conventional AF → SEAFLO NEO M1 PLUS (Prototype) / After 24 months

SEAFLO NEO M1 PLUS can reduce a risk of barnacle fouling in static condition and low activity operation.

The impact of climate change on increasing sea temperatures has made marine organisms more active and, as a result, has increased the risk of hull fouling. Damage caused by barnacles to the hull bottom especially is one of the factors which has a large impact on fuel consumption. The appearance of barnacles in seawaters which previously did not cause barnacles is a big problem. In the case of newbuildings, vessels like LNG carriers, which have a long outfitting time, can be affected by barnacles if the construction coincides with the summer season when barnacles become more active. With the moves to reduce greenhouse gas emissions the need to improve the condition of the hull bottom, for ships in operation and newbuildings undergoing outfitting, is becoming increasingly important.

CMP, a marine paint manufacturer, has until now developed the ultra-low friction antifouling series SEAFLO NEO. To improve the performance further, focus has been put on preventing the attachment of barnacles itself to reduce the risk of fouling to the underside of the hull to the maximum, and CMP used the antifouling agent, Selektope® (Medetomidine), which was developed by a Swedish biotech company. Medetomidine itself is a veterinary drug used as a tranquilizer for animals such as cats and dogs. However, if Selektope® is used as antifouling agent on a hull bottom, even in small amounts, the barnacle larvae become hyperactive and unable to attach to the surface of the hull. This is the first time in the paint industry to use an antifouling agent developed through a pharmaceutical approach, and CMP has succeeded in developing a low friction hydrolysis antifouling, using Selektope®, which will help both environmental and economic performance of ships.

Barnacles attach to the hull in the following way. Initially barnacle larvae attach themselves to the hull using cement secreted from their tentacles. After that, when the ship is stationary for an extended period, the body grows from just a few millimeters to a few centimeters. Selektope® affects the barnacle larvae and, before the larvae can attach itself, Selektope® triggers its swimming behaviour, which allows it to swim and escape. It is an approach which does not kill the barnacle but prevents it from attaching. Selektope® has received approval under the European Biocidal Products Regulation.

Since 2008 CMP has been working together with the Swedish company in joint research to maximize the performance of Selektope® in developing an antifouling and has received a patent.

The potential of Selektope® had already been confirmed, but it took about 10 years of actual verification tests before it could be used in paints for ocean-going vessels. Masaya Hata, CMP's Manager of the Marketing Group, said: "We have finally succeeded in developing the optimum antifouling paints containing Selektope®, and has now proven 5 years' track records with spectacular antifouling performance, fuel savings and reduction of $CO_2$ emissions." Until today Selektope® containing antifouling paint has been used on over 700 vessels.

This time, a new product "SEAFLO NEO M1 PLUS" was added to the series of SEAFLO NEO and launched for large-size commercial vessels. By using the antifouling agent cuprous oxide together with Selektope®, it extends the ship's operation period. It is also suitable for preventing the growth of barnacles on ships which are stationary for a long time, in areas with warm sea temperatures, and also for newbuildings which are being outfitted in a static environment.

The paint is not only effective in preventing the growth of barnacles. Its unique technology creates a very smooth coating surface which reduces hull friction resistance, and improves fuel consumption. Through the independently developed FIR (friction increase ratio) analysis, the effectiveness of the paint could be measured, making it possible to design the optimum coating film. Also, based on hydrolysis polymer technology, stable surface renewal could be realized and, even after long term operation, antifouling performance could be stably maintained. In addition, the content of volatile organic compound in this paint is 15% lower compared to that in existing products.

The new paint is not only being supplied in Japan but also to newbuildings and repair ships outside the country. "The paint can be applied to all types of ocean-going vessels. A selection can be made after observing the condition of the ship," Masaya Hata said. The antifouling paint is a suitable solution for ships to play a part in the reduction of greenhouse gasses from ship operation.