

Scope

Kawasaki Heavy Industries Quarterly Newsletter

Special Feature

Reducing CO₂ Levels in the Ocean with LNG Fuel:

Verification Tests for the World's
First ME-GI Marine Engine and Gas Supply System

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To mark its 100th issue, *Scope* has been completely redesigned. We hope you will enjoy the new sections, as *Scope* continues to deliver the latest news from Kawasaki.

About The Cover
Manufacturing the Kawasaki Rexpeller at the Harima Works. See TechnoBox, page 10, for further details.



Photo: A test is conducted with a two-stroke test engine of about 3,300 kW, with a cylinder size equivalent to that used on an actual ship. Its height is 8.6 m; the photo only shows the top. The block-shaped component to the right of the brown part is the unit that injects the LNG fuel.

In order to reduce the CO₂ emitted by the ships plying the world's oceans, Kawasaki is developing a marine engine that uses LNG as fuel and a gas supply system. It is now working on verification tests, the first in the world to be undertaken by a shipbuilder and engine manufacturer, in order to move the technology into practice. The results of these tests will be the foundation for efforts to convince shipping companies to address environmental issues faster than before.

Reducing CO₂ Levels in the Ocean with LNG Fuel:

Verification Tests for the World's First ME-GI Marine Engine and Gas Supply System



1 and 2: When the LNG, held at low temperature in the cryogenic tank, passes through a pipe, frost forms instantly. 3: The LNG is then pressurized by a high-pressure pump. 4: The state of the system is monitored centrally in a control room, where data is continually collected.

New Efforts Underway to Reduce Emissions from Marine Vessels

The CO₂ emissions from all the merchant vessels traversing the globe constitute about 3% of all global emissions. Compared to the approximately 35% accounted for by power generation, this may not seem like a large portion of the environmental load. However, as the economies of emerging countries develop, marine transport and shipping tonnage are increasing. This means it will become more and more of an issue, and development of ships with smaller environmental footprints is urgently needed.

Kawasaki is thus working to develop an ME-GI engine that uses liquefied natural gas (LNG) as fuel and a supply system to deliver the gas to it. It is the first shipbuilder and engine manufacturer in the world to have long-term permanent test facilities, and has been conducting a variety of tests since December 2013.

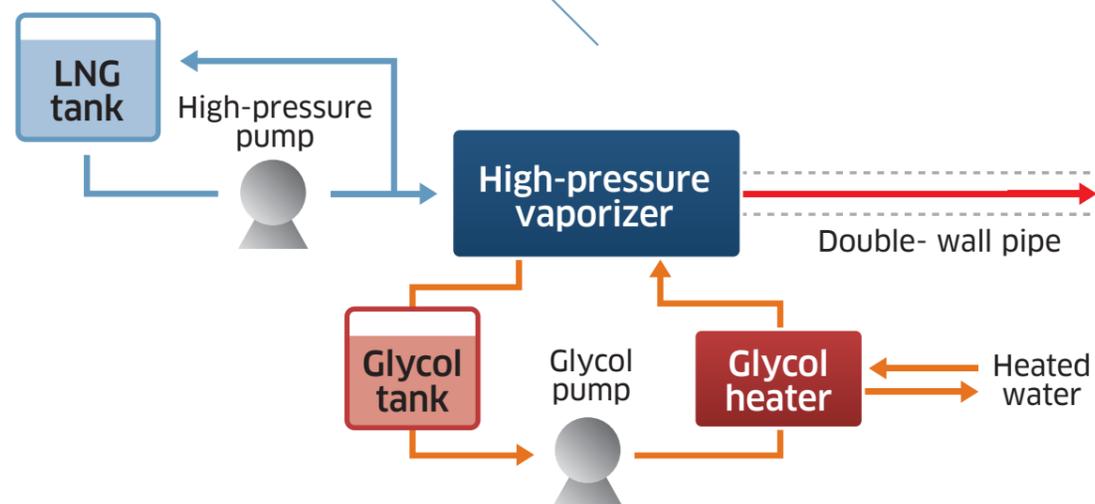
There are a number of different ideas for reducing the environmental load of ships, but there are two reasons why development of an LNG-fueled ME-GI engine is a particular focus: First, LNG can power two-stroke engines, which are the world standard for large marine

engines. Second, it is a cleaner-burning, lower-cost fuel. Compared to heavy fuel oil, for example, LNG can reduce CO₂ emissions by about 30% and NO_x by about 20%. Additionally, the start of shale gas production is dramatically expanding LNG supply.

Kawasaki is utilizing mature engine technology to innovate environmentally enhanced technology. This is happening now at the Kobe Works.

Overview of the High-Pressure Fuel-Gas Supply System

In the new propulsion system, the gas supply system works with the engine to use LNG as a fuel. Pressurized LNG is heated by a high-pressure vaporizer and led to the engine in a double-wall pipe for safety.



Applying Innovations to Mature Two-stroke Engine Technology

LNG has already been put into practical use as a marine fuel in steam turbines, for instance. However, it would do wonders for efficiency if Kawasaki had an ME-GI engine that used gas in a low-speed two-stroke diesel engine, the most efficient kind.

“ME-GI” refers to electronically controlled gas injection. Gasified fuel is injected directly into the cylinder, with the injection and other factors electronically controlled for energy-efficient operation. By combining this with existing technology for low-speed diesel engines, Kawasaki hopes to create a propulsion system that is efficient and eco-friendly. The purpose of the verification tests is to clarify the issues involved and their solutions.

There are two major focal points of the development process: the fuel-supply plant, which must smoothly supply gas in response to the engine's consumption and required pressure; and the engine itself, which requires control technology for optimal combustion.

The pressure required to gasify LNG for fuel injection is up to 30 MPa, which is similar to the pressure at 3,000 m below the ocean. In the verification tests, LNG liquefied at -163 °C is pressurized by a high-pressure pump and then heated to 45 °C by a high-pressure vaporizer. This puts the LNG into a supercritical state, neither liquid nor gas, ready for use as fuel for an ME-GI engine.

Right now, tests are being conducted to establish how to set pump pressure, overall system control methods and safety measures, among other things. The system may behave differently from what was anticipated in the

design stage, but that is exactly what is most useful about verification testing. More tests will be done in order to understand the system completely.

Meanwhile, on the engine side, validation is being conducted on control methods to achieve performance and operability equivalent to or better than conventional models after switching from oil to natural gas as fuel. The problem is the difficulty of igniting LNG. Kawasaki employed a fuel-oil injection valve as an auxiliary measure. The system is such that, when the piston raises the air pressure in the cylinder to a peak, the fuel oil is ignited and this ignites the natural gas.

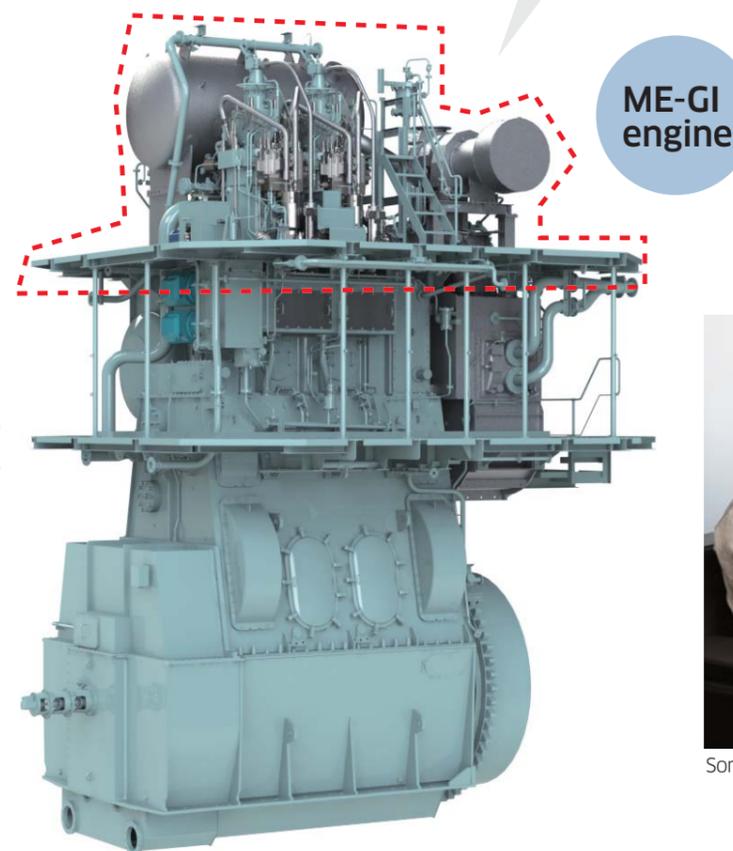
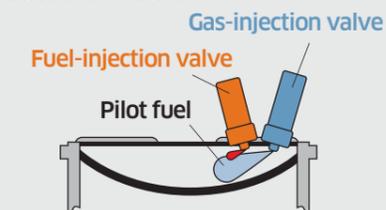
When ships travel, changes in sea conditions create load fluctuations on the engine. The engine must track these changes to continue to operate stably. To achieve utmost safety and efficiency, verification tests on technology to control fuel gas injection, gas pressure, fuel oil quantity and other factors are also being conducted.

The testing has yielded a variety of results that are useful for designing a practical ME-GI engine. For example, it has been confirmed that not only is the high-pressure gas supply system stable and reliable, but also, the engine is free of output limits on gas running, and the tracking when the load on the engine fluctuates is at the same level as when operating with fuel oil.

The environmental and economic performance of these features is a major boon to shipping companies that operate large ships and should accelerate efforts to address environmental problems.

ME-GI Combustion Method

Fuel oil is used to ignite fuel gas injected at a high pressure of 30 MPa. The amount of fuel oil injection and the timing of injecting fuel oil and gas are key.



Some participants of verification tests.

Marshalling Resources to Push ME-GI Engines Still Further

In verification tests, such unique Kawasaki technologies as water-emulsion fuel and exhaust gas recirculation (EGR) are applied.

Water-emulsion fuel is a type of fuel containing fine water particles. The water particles dispersed throughout the fuel capture ambient heat when they evaporate. This reduces the combustion temperature inside the cylinder, thereby decreasing the production of NOx. EGR recirculates some exhaust gas, which has a low oxygen concentration, into the cylinder, for low-oxygen combustion. This also reduces the maximum combustion temperature and decreases the production of NOx.

The development of an ME-GI engine that uses LNG as fuel and a gas supply system constitutes new technology leveraging Kawasaki's know-how in

shipbuilding and marine engines. The company aims to introduce it not only into LNG carriers, but also into general cargo ships such as container ships and car carriers.

The cost efficiency and environmental soundness thus produced are likely to spark further innovations in marine transport.

Many meticulous checks are conducted on a daily basis to ensure the safety of the system.



The supply system stands in an outdoor corner of the shipyard.



From the Project Team

By Kenji Nagamachi

Manager, Engine Planning Section, Basic Engineering Department
Research & Development Division, Ship & Offshore Structure Company
Kawasaki Heavy Industries, Ltd.

*We're confident about our efforts.
We only release the technology we believe in.*

The verification tests of the LNG-fueled ME-GI engine and gas supply system are designed to help realize the development. We are not testing this new technology to pursue some future dream, but rather under the assumption that the results will be applicable to a current ship. Existing engine technology is used as a base, to which we have added brand-new features to evolve it. In short, this offers an easy way to utilize the results of technological innovation.

The collaboration of our ship and engine business units is resulting in extremely meaningful test results. Their ease of application and low-cost advantages promise major reductions in CO₂ emissions from the world's oceans.

The next step for us is to leverage the advantages of this propulsion system throughout the ship, utilizing it for waste heat recovery and fusing it with other environmental technologies. However, at Kawasaki, we only release technology that we fully believe in. So we will continue working on these challenges.

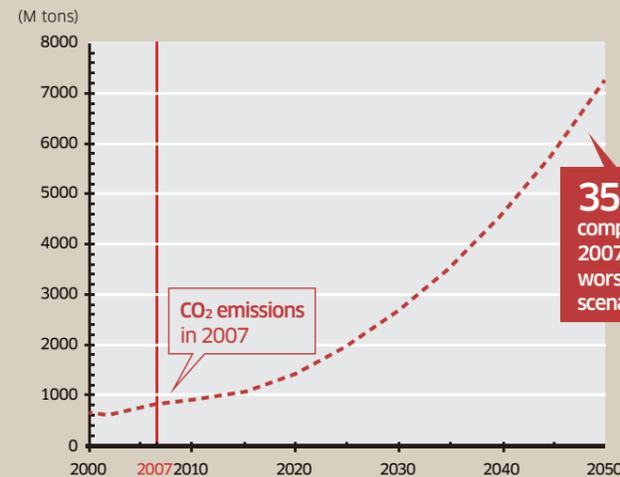


Future Vision



Global Shipping and Air Pollution

In July 2011, the International Maritime Organization (IMO) agreed on a framework to regulate CO₂ emissions from marine vessels, and in January 2013, this took effect. The framework will reduce CO₂ emissions by at least 20% by 2030.



IMO CO₂ Rise Forecast

The IMO has prepared multiple forecast scenarios regarding CO₂ emissions from international shipping, but even if certain efforts are made to reduce emissions, by 2050 they will have increased several fold compared to 2007.

Japan Leads the Global Discussion on Regulations

There are approximately 104,300 ships in the world with a gross tonnage of 100 t or greater, and their CO₂ emissions are estimated at approximately 870 million tons per year (2007). This accounts for 3% of total global emissions and is equivalent to the total emissions of Germany alone, by way of comparison. The IMO decreed that newly built ships (ships with construction contracts dating January 2013 or later, which are delivered after the end of June 2015) with a gross tonnage of 400 t or greater which travel through exclusive economic zones must limit their CO₂ emissions to a certain standard. Japan led the discussion on new emission standards. From its position as one of the world's few shipping and shipbuilding heavyweights, Japan offered a range of proposals based on its excellent environmental technology and helped to achieve an international agreement. (Data from the IMO and the Japanese Shipowners' Association)





Ninja

Since its debut 30 years ago, the Ninja has remained true to its roots as a standard-bearer of innovation.

In the 1970s and 1980s, manufacturers around the world were engaged in a fierce competition to develop more powerful motorcycles with larger displacements. In 1984, one motorcycle entered the scene and made history—the Ninja (the Japanese GPz900R). It was loaded with cutting-edge technologies, including such notable features as Kawasaki's groundbreaking 908 cc liquid-cooled in-line four DOHC 16-valve engine, mounted on a light, compact chassis, as well as side cam chains and a diamond frame.

These lavish technological features, coupled with the Ninja's unique, aerodynamically superior styling, completely redefined the norm for motorcycles and made it an instant global success. The Ninja/GPz900R was a best-selling model for 20 years, and still has many fans around the world. The Ninja became Kawasaki's flagship brand, and its name has been inherited by the numerous models that came after it. The ideal motorcycle for Kawasaki is one that offers a safe ride and the utmost joy for all riders, whether on the circuit,

highway, city streets or winding roads. The Ninja has continually challenged the accepted wisdom for 30 years to become the standard-bearer of innovation in motorcycles. This lineage of challenge, so to speak, continues to the present day as an inherent quality of each Ninja.



Ninja/GPz900R

The Ninja marked a stunning debut. It came with a state-of-the-art 908 cc liquid-cooled in-line four DOHC 16-valve engine mounted on a light, compact chassis, with astonishing power and incredible handling. It was named the Motorcycle of the Year around the world.



Ninja ZX-7R Ninja ZX-7RR

This model took circuits around the world by storm with its newly designed aluminum perimeter frame and short-stroke, high-rpm engine. Its brilliant performance on the circuit left a lasting mark.



Ninja ZX-10R

This model came equipped with a powerful engine yet had a body weight of less than 170 kg. Boasting an astonishing power-to-weight ratio, its performance on the circuit was equally outstanding.



Ninja ZX-10R

This is a best-in-class supersport model loaded with the latest in technology. Its superior quality was demonstrated when it won the series champion title in the 2013 World Superbike Championship.



Ninja 250SL

This latest ultra-lightweight sport model features a slim, compact body and a newly designed trellis frame, encasing a high-rpm, liquid-cooled single-cylinder DOHC four-valve engine.



1984

1990

1996

2000

2004

2008

from 2011

from 2012

from 2014



Ninja ZX-11/ZZ-R1100

Featuring a 1,052 cc high power engine, this flagship model became the first commercial motorcycle to adopt a ram-air system. This cutting-edge system, combined with excellent aerodynamic properties, made it the world's fastest motorcycle at the time.



Ninja ZX-12R

This was the first production model to adopt a monocoque aluminum frame. An innovative machine featuring an engine with amazing power, it also introduced many new technologies.



Ninja 250R

This model featured a liquid-cooled parallel twin DOHC 8-valve engine on a compact chassis. It became a favorite among riders around the world, both as an entry model in developed markets and a high-end model in emerging countries.



Ninja ZX-14R

This model, Kawasaki's latest flagship, strikes an optimum balance between awe-inspiring power and handling and comes loaded with state-of-the-art technologies.



The Rexpeller Azimuth Thruster

By Hiroyuki Yamazaki

Senior Staff Officer, Basic Engineering Section
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A Solution that Satisfies All Needs

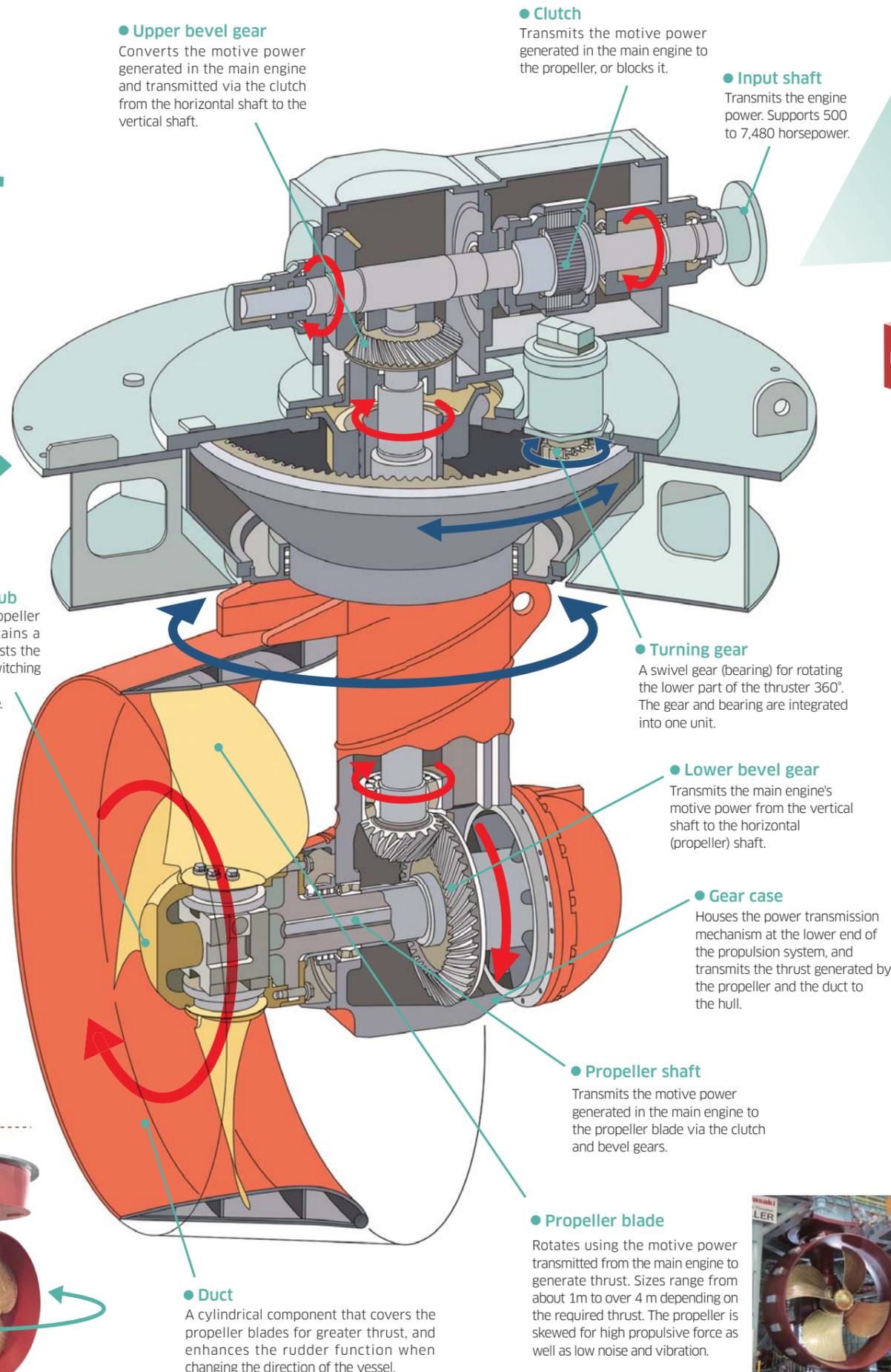
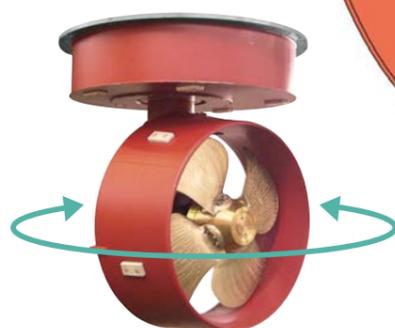
Azimuth thrusters are a configuration of marine propellers in pods that can be rotated to any horizontal angle ("azimuth"), making a rudder unnecessary and giving ships better maneuverability than a conventional propeller and rudder system. In the 30 years since production started in 1983, 900 Kawasaki Rexpellers have been delivered.

With repeat customers around the world, the Rexpeller lineup showcases the best of Kawasaki's technologies, including the hydraulic technology that controls the rotation of the propeller and the azimuth rotation of the thruster, and the control technology that provides highly accurate control of the entire propulsion system.

In recent years, demand for vessels related to offshore oil and gas production has been increasing. These include drillships, shuttle tankers for transporting the extracted oil and gas, and supply ships for carrying supplies to offshore bases. Expectations for the Rexpeller have been growing due to its excellent positional accuracy and stability, even under strong winds and currents or other hostile ocean conditions. With Kawasaki's superior custom development capabilities ensuring every need is met, the Rexpeller is carving out an ever-larger share of the global market.

360° Azimuth-Steerable "King" of Propellers

Since the propeller rotates 360 degrees around its vertical axis, the thruster can perform double duty, propelling as well as steering a vessel. Rex means "king" in Latin, and the name Rexpeller conveys Kawasaki's commitment to continue developing the best propeller products available.



Possible Maneuvers with Two Rexpeller Units



Pivot turning



Zigzag



Extensive Lineup Includes Retractable and Swing-up Models

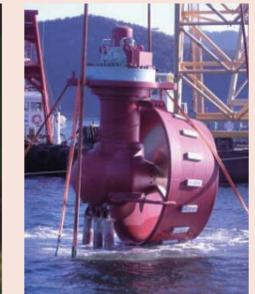
The Rexpeller comes in a wide variety of models, including a one that can be retracted into the hull when not in use to reduce drag, one that can be pivoted up when docking, and an underwater-mounting model designed for large vessels that cannot enter the dock.



Retractable Rexpeller



Swing-up Rexpeller



Underwater Mounting Rexpeller

Applications

The Rexpeller is mainly used on vessels that require both stability and fine positioning control, including tugboats, drillships, shuttle tankers, research vessels, workboats and accommodation vessels.



©IODP/JAMSTEC

Chikyu deep-sea drilling vessel

The first vessel that can drill into the earth's mantle, the *Chikyu* is capable of maintaining the same position for up to 1 year, under wind speeds of up to 23 m/s, 4.5 m waves and a 3-4 knot current, using the Rexpeller and GPS sensors.



Offshore vessels

Vessels that carry supplies to offshore oil platforms and deep-sea mining facilities, as well as perform other tasks, these include shuttle tankers for transporting oil and gas. The Rexpeller ensures these vessels can securely access offshore facilities even in rough seas.



Tugboat

Tugboats help large vessels dock and undock, which requires an ability to freely maneuver in any direction. The Rexpeller's outstanding maneuverability and powerful thrust ensure the vessels are safely handled.



Since they were young boys, the Yoshida brothers have won countless awards in national tsugaru shamisen competitions. With skills perfected to a master's level, these pioneers have revolutionized the genre by fusing Japanese tradition with Western music, helping bring the banjo-like tsugaru shamisen to the world stage. Let's take a look at the challenges faced by these young pioneers, who believed in the infinite possibilities of traditional music.

Staying True to Their Own Style

"It's been over 25 years since I started playing tsugaru shamisen, but even today, I still come across new sounds. It just goes to show the infinite possibilities that this traditional instrument offers," says Kenichi, the younger of the two.

The brothers started playing the shamisen at the age of five, at their father's suggestion. When they were 10 and 12, they began studying in earnest under a master of tsugaru shamisen. They had been playing the slow, feminine style of minyo shamisen and were blown away by the quick, muscular sound of tsugaru. They went on to win numerous national competitions, earning fame around the country. In 1999, about a decade after they started learning tsugaru and just 19 and 21 years old, the Yoshida Brothers released a debut CD.

"Before our debut," says Ryoichiro, "I went up to Tokyo alone and spent some years

playing in folk music bars in Asakusa. The audience there wanted to hear a standard, traditional type of performance, and I sometimes found myself losing sight of my own playing style. Faced with that doubt, I realized I wanted to stay true to my own style of playing, rocking back and forth as I strummed emotionally on the shamisen, a style I cultivated back when I was in Hokkaido. That was probably when I made up my mind to go my own way as a pioneer."

The younger of the siblings, who was living in their hometown in Hokkaido, spending much of his time writing original songs, responded to the impassioned call of his brother. They had no idea what the correct answer was. But they knew one thing for sure: staying where they were would not take them anywhere. After their debut, they started cultivating a new style that involved Western music, and in 2003, they made their debut in the United States, a path no one had yet attempted in this genre.

Helping Other Musicians Earn Recognition outside Japan

"It was a huge challenge for us to put our work in the hands of American producers who knew nothing about tsugaru shamisen, but it was far more productive than we had expected," Kenichi recalls. "I guess we had some fixed ideas about how things should be done, which we weren't able to completely let go of. But they tore them all down. They



▲Kenichi (left) and Ryoichiro

would say things like, 'Let's do Bach.' They are just so incredibly creative."

Then came the brothers' tour in Los Angeles and New York. As they started strumming powerful chords on their tsugaru shamisen in a dimly lit live music club, the vibe of the audience visibly changed. For the audience, it was a completely new experience, one in which East and West blended in exquisite harmony. The audience may have been skeptical, but once the performance started it was alive with enthusiasm. This is what is great about performing live overseas.

"Tsugaru shamisen has been around for only 150 years or so," says Ryoichiro. "Because of its relatively short history, it can capture the essence of the present as it evolves. To bring this amazing Japanese tradition to the audience of the world, we have to keep searching for a better way to deliver our music, and keep changing."

After spending over a decade performing across the globe, the Yoshida Brothers find themselves being drawn toward traditional Japanese sounds once again. While continuing to perform together, they have also been actively pursuing individual projects with other traditional Japanese musicians.

"Our biggest focus now is on fostering the next generation of performers. We want to create an environment where young people who are interested in tsugaru shamisen or any other traditional Japanese instrument can pursue their interest. That is one of the goals of our new projects. We hope this will lead to more Japanese people going out into the world and earning recognition. We, too, will continue taking on more challenges."

Yoshida Brothers

"Traditions keep evolving, so we never stop taking on new challenges."



Performing at Otakon on July 30, 2010 (Baltimore Convention Center)

Yoshida Brothers

Ryoichiro (born 1977) & Kenichi (born 1979)
Tsugaru shamisen performers born in Hokkaido, they released their debut album *Ibuki* in 1999. After their U.S. debut in 2003, the duo went on to perform on stages around the world. In recent years, they have also pursued individual projects. Ryoichiro has formed a new group called Wasabi, which consists entirely of traditional Japanese instruments – shakuhachi, koto, taiko and shamisen. Kenichi has produced a group called Hayate, formed with tsugaru shamisen performers from various schools.

364 MRT Cars for New Singapore Line

Kawasaki was recently awarded a 60 billion yen contract along with Kawasaki Heavy Industries (Singapore) Pte. Ltd. (KHI-SIN) and CSR Qingdao Sifang Co., Ltd (Sifang) from the Land Transport Authority (LTA) of Singapore. The three companies will work together to supply 364 Mass Rapid Transit (MRT) train cars for the new Thomson and Eastern Region Lines of the MRT system.

Kawasaki will be responsible for the overall project management, design, manufacturing of bogies and procurement of

major components. Sifang will be in charge of manufacturing, final fitting and assembly of complete MRT trains, factory tests and off-site integration tests. KHI-SIN will be responsible for the delivery of complete MRT trains to the depot and on-site testing and commissioning. The new MRT trains are scheduled to be delivered to Singapore beginning in 2018. LTA is implementing a master plan to double its rail network from 178 km to 360 km by 2030, and is extending and adding more trains on existing lines.

The Thomson and Eastern Region Lines will be fully underground and will run north-south, serving housing estates, and east, connecting the city and the Marina Bay area, providing greater accessibility and significant improvement of travel time for commuters.

The new trains will be designed and operated as a fully-automated four-car driverless trains with new features such as five doors on each side of each car and advanced train travel information systems, operating at a maximum speed at 90 km/h.

This is the third joint contract for Kawasaki and Sifang in the overseas market outside Japan and China. The history of cooperation between the two companies dates back to 1985, when they signed a friendship agreement. Since then, they have built a solid track record within China, including joint contracts for linear motor MRT trains for Guangzhou Metro Lines 4 and 5 and for high-speed trains from the Ministry of Railways of China.

Including joint contracts with other companies, Kawasaki is the No. 1 supplier of trains on Singapore's North-South and East-West Lines. The first train delivery was for the inauguration fleet of 66 six-car trains (396 cars) in 1986. Subsequently, additional fleets of 21 and 22 six-car trains (126 cars and 132 cars) were delivered in 1999 and 2011. Kawasaki is currently delivering 13 six-car trains (78 cars) and a further 28 six-car trains (168 cars) to Singapore from 2016.

Kawasaki will continue to expand its rolling stock business in Asia as well as other global markets.



Participation in Development and Production of Boeing 777X

In June, Kawasaki, Mitsubishi Heavy Industries, Ltd. (MHI), Fuji Heavy Industries Ltd. (FHI), ShinMaywa Industries, Ltd. (SMIC), NIPPI Corporation (NIPPI) and the Japan Aircraft Development Corporation (JADC) signed a Memorandum of Agreement to participate in the project to develop and produce The Boeing Company's next-generation large-size passenger jet, the Boeing 777X.

In this project, Kawasaki will be in charge of forward and center fuselages, main landing gear wheel wells, cargo doors and pressure bulkheads; and Kawasaki Group's NIPPI, wing components.

The 777X will be a successor to Boeing's 777 series of large-size twin-engine passenger jets, which have been well received by passengers, enabling them to play a leading role within the air transportation market. Two

models will be offered: the 777-8X and 777-9X. Currently, the 777-9X is under development, with plans calling for commencement of production in 2017 and delivery of the first aircraft in 2020.



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New Directors Team Starts

At the General Meeting of Shareholders held on June 26, Managing Executive Officers Munenori Ishikawa, Kazuo Hida, Shigehiko Kiyama and Kenji Tomida were elected to the Board of Directors, and were each subsequently appointed as a Senior Vice President at the meeting of the Board of Directors that followed.

* Representative Director + Executive Officer



Shigeru Murayama *+
President



Kyohei Matsuoka *+
Senior Executive Vice President



Hiroshi Takata *+
Senior Executive Vice President



Joji Iki *+
President
Gas Turbine & Machinery Company



Eiji Inoue *+
President
Plant & Infrastructure Company



Yoshinori Kanehana *+
President
Rolling Stock Company



Minoru Makimura +
General Manager
Corporate Technology Division



Akio Murakami *+
President
Ship & Offshore Structure Company



Munenori Ishikawa *+
President
Aerospace Company



Kazuo Hida *+
President
Precision Machinery Company



Shigehiko Kiyama *+
President
Motorcycle & Engine Company



Kenji Tomida +
General Manager
Corporate Planning Division



Yoshihiko Morita
Outside director

Yoake Project Part II:

Project K and Inside K Released

Part II of the popular Yoake Project series is now viewable on the website (see below). Two new videos introduce Kawasaki's Gas Turbine Division from the perspectives of development and manufacturing.

Project K documents the challenges faced during the development of the 30 MW L30A gas turbine. The video includes an interview with a key project team member from Daicel Corporation, which collaborated on the joint development.

Inside K provides a look inside the Akashi Works, Seishin Works and Kawasaki

Gas Turbine Asia Sdn. Bhd. (an overhaul base in Malaysia), which comprise the Gas Turbine Division. Viewers can see the actual work sites where Kawasaki's high-quality, high-performance products are created.

Please visit the project website for a look at these new videos as well as other content, including the Yoake Flight Malaysia video.

Kawasaki Yoake Project

<http://www.khi.co.jp/english/yoake/>
Or search "Kawasaki Yoake"





Powering your potential

The Kawasaki Group Mission is to be a "Global Kawasaki," working as one for the good of the planet; the Kawasaki brand is about paving the way to new possibilities for customers and society; to sum it up, "Powering your potential."

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