Contents By Builder By Ship Type

Proposal by KHI, YPT, J-ENG Adopted as NEDO's Green Innovative Fund Project

Step Taken Forward to Realize Zero-Emission Ships 82

A joint proposal made by Kawasaki Heavy Industries, Ltd. (KHI), Yanmar Power Technology Co, Ltd. (YPT) and Japan Engine Corp. (J-ENG) has been adopted by the New Energy and Industrial Technology Development Organization (NEDO) for its Green Innovation Fund Projects*1 and Next-Generation Ship Development.

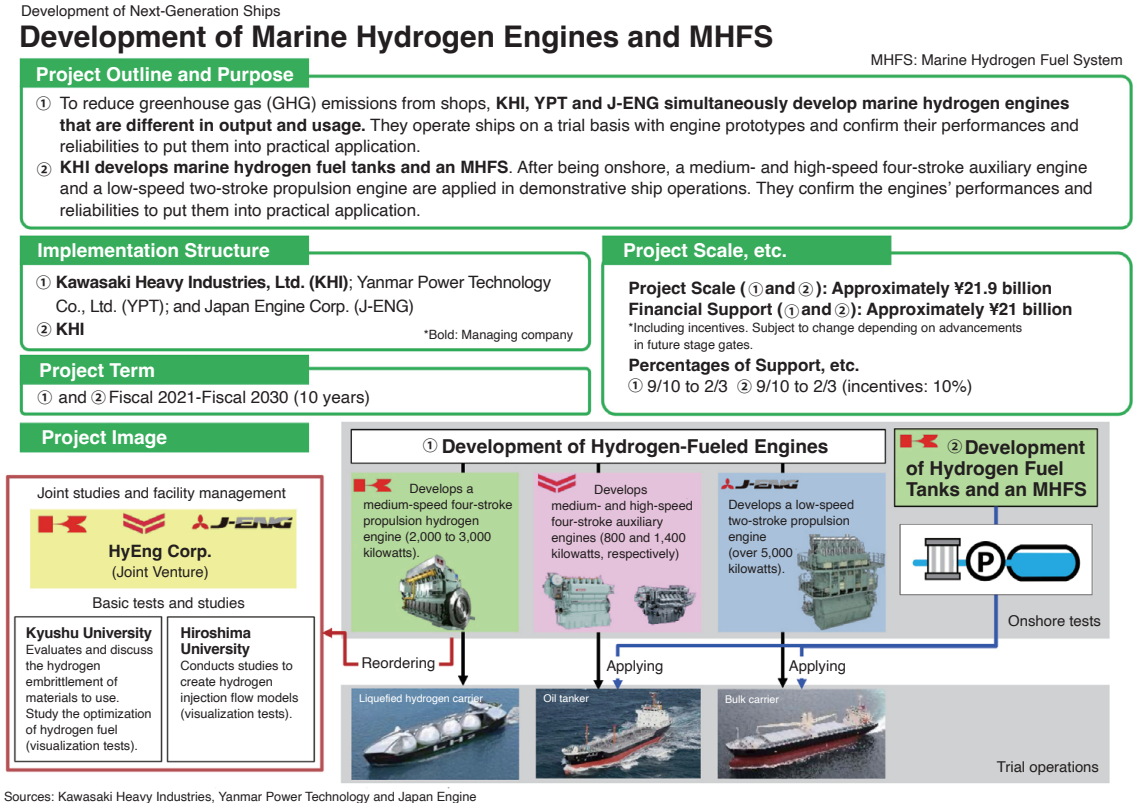
The proposal, the development of marine hydrogen engines and a marine hydrogen fuel system (MHFS), was made to contribute to realizing the Virtuous Cycle of Environment and Economy, an initiative to bring about innovative industrial structure and socioeconomic changes to accomplish further growth by taking active measure to global warming. The initiative is set forth in the Green Growth Strategy through Achieving Carbon Neutrality in 2050, which was formulated by the Ministry of Economy, Trade and Industry (METI) and other relevant governmental organizations on Dec. 25, 2020.

KHI, YPT and J-ENG will simultaneously develop medium-speed four-stroke, medium- and high-speed four-stroke and low-speed two-stroke engines, respectively, aiming to complete a lineup of engines for a wide variety of purposes around 2026. By collaborating with shipping and shipbuilding companies, in addition, they will run engine prototypes on a trial basis on board real vessels, hoping they will actually be implemented in the real world.

KHI will be responsible for the development of marine hydrogen fuel tanks and an MHFS as well. Together with the other members, it will strive to complete a hydrogen fuel propulsion system.

KHI, YPT and J-ENG will also join hands—through HyEng Corp., a joint venture they have set up—in conducting a basic combustion analysis; developing raw material and seal technologies as well as common technology components, such as compliance with classification society rules; and using shared test facilities.

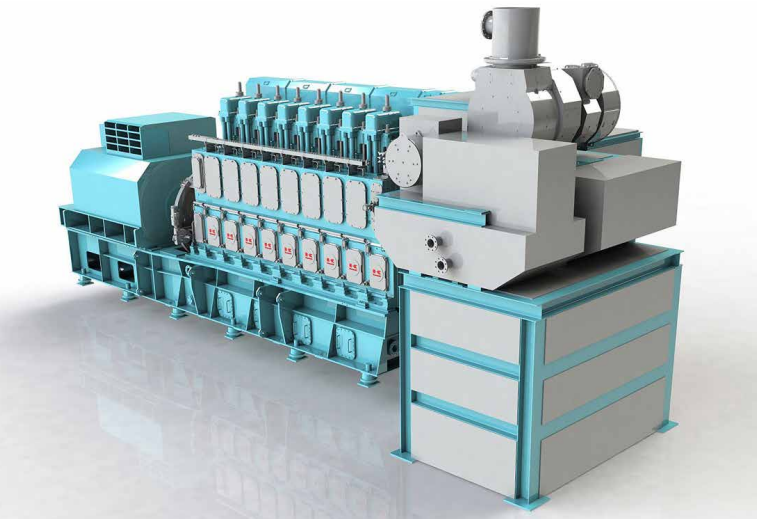
KHI, YPT and J-ENG will endeavor to develop marine hydrogen engines and an MHFS by combining the technologies and knowledge that they have accumulated. They will also work on a project to verify the commercialization of a liquefied hydrogen supply chain, proposed by KHI to further reduce costs for supplying hydrogen. By advancing the project, which has been adopted separately, they will contribute to realizing carbon neutrality by 2050.



Sources: Kawasaki Heavy Industries, Yanmar Power Technology and Japan Engine

*1 The Green Innovation Fund is a program in which the government of Japan financially supports the enterprises and others that make efforts to address business challenges to realize carbon neutrality by 2050. Financial support is provided for a period of 10 years to allow enterprises and other organizations to research, develop, demonstrate and implement outcomes. A total of 14 sectors are eligible, including hydrogen, fuel ammonia and other energy-; transport- and manufacturing-; and home- and office-related industries.

World's First AiP Granted to Kawasaki's 2.4 MW Class Dual Fuel Engine Using Hydrogen Gas as Fuel 83



Artist's rendition of a DF engine using hydrogen gas as fuel

Artist's rendition of the 160,000 m³ liquefied hydrogen carrier

November 30, 2022 — Kawasaki Heavy Industries, Ltd. announced today that an Approval in Principle (AiP)*1 was granted by Nippon Kaiji Kyokai (ClassNK) for Kawasaki's dual fuel (DF) engine using hydrogen gas as fuel, which will be installed on a 160,000 m³ liquefied hydrogen carrier developed by Kawasaki.

This DF engine allows operators to flexibly alternate between the use of hydrogen fuel and conventional low-sulfur fuel oil. When hydrogen fuel is selected, the boil-off gas that evaporates naturally from the vessel's liquefied hydrogen cargo tanks is used as the main fuel at a calorie-based ratio of 95% or higher*2, which results in a significant reduction of greenhouse gas emissions.

Kawasaki has a track record of selling more than 200 units of engines fueled solely by natural gas. To expand its product portfolio, Kawasaki developed combustion technologies tailored to hydrogen's properties — a fast combustion speed, which often results in backfire, and a high combustion temperature — and in a demonstration test using a single-cylinder test engine, the Company achieved stable combustion of hydrogen without causing abnormal combustion or the overheating of parts in the combustion chamber. Kawasaki is developing hydrogen powered engine for propulsion as a Green Innovation Fund Project of the New Energy and Industrial Technology Development Organization (NEDO). Kawasaki intends to conduct a demonstration test of this engine after installing it as a generator engine on a large-scale liquefied hydrogen carrier which is planned to be commercialized in the mid-2020s.

As Kawasaki foresees a significant increase in the use of hydrogen energy in the future, which will play a vital role in achieving a decarbonized society, the Company is developing a range of technologies for a hydrogen supply chain (production, transportation, storage, and utilization). The technology used for this engine serves the "transportation" and "utilization" stages, covering both the demand and supply aspects of the supply chain. Moving forward, Kawasaki will continue to develop more products that capitalize on hydrogen energy, contributing to the realization of carbon neutrality.

Specifications of DF generator engine using hydrogen gas as fuel

Rated output: 2,400 kWe (when hydrogen fuel is used)
Cylinder diameter: 300 mm

***1 At the initial stage of designing or before a decision is made regarding which ship on which the product will be used, the product's design is examined based on existing regulations, such as international treaties and ship classification rules, and an Approval in Principle (AiP) is issued as proof of conformity with such requirements. This time, an AiP was granted by ClassNK based on the result of a risk assessment using the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (the IGC Code, to which all liquefied gas carriers built during and after 1986 must conform, and which is included in ClassNK's rules for steel ships) and the Hazard Identification Study (HAZID, a method of assessing risks which are determined by experts based on the frequency with which potential hazards in a system arise, and aimed at identifying ways to minimize that frequency).**

***2 A calorie-based ratio of hydrogen boil-off gas to low-sulfur fuel oil.**

Delivery of G95ME-C10.6 engine for Large Container Ships 84

Largest two-stroke marine propulsion engine G95ME-C10

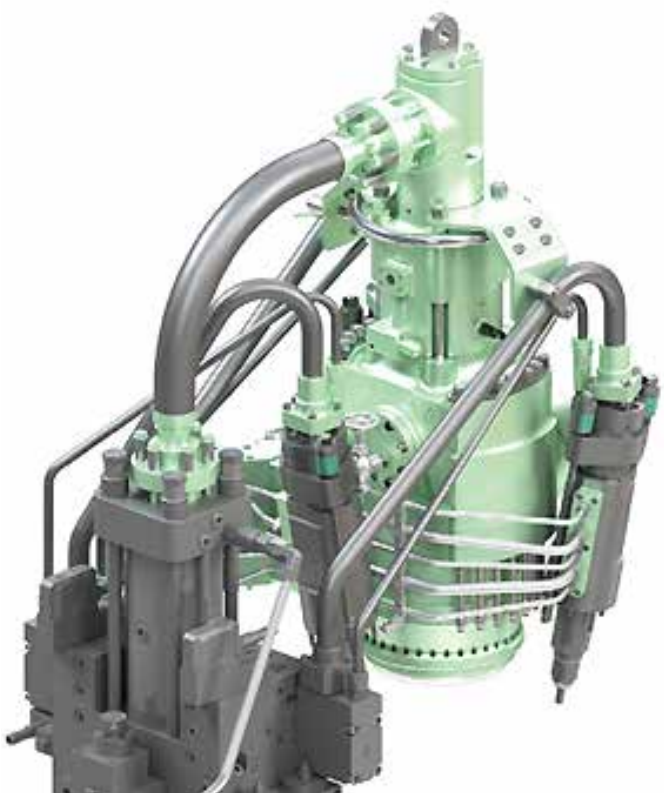
We, MITSUI E&S Co., Ltd. manufacture a two-stroke marine propulsion engine under license from MAN energy solutions. G95ME-C engine is the largest engine applied to container vessels with output range from 27MW to 82MW.

G95ME-C10.6

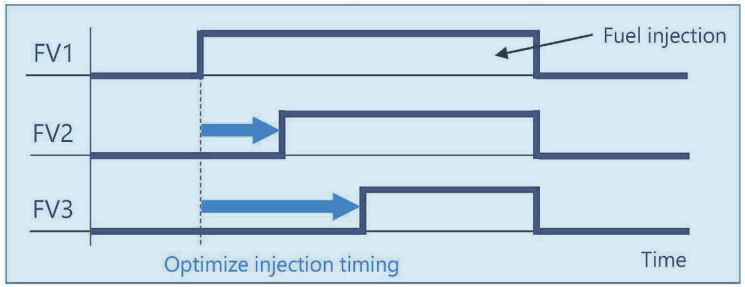
The engine with improved SFOC (Specific Fuel Oil Consumption) in the low load range based on the existing G95ME-C10.5. The layout area and engine footprint are same as conventional engine. G95ME-C10.6 has the following feature.

Sequential fuel injection

The sequential fuel injection can be applied in the high load range and NOx emission rate is reduced. The technology controls fuel injection timing individually for each injection valve. Reduced NOx emission rate in the high load range is used as SFOC improvement in the low load range.



G95ME-C10.6 engine



Overview of Sequential fuel injection

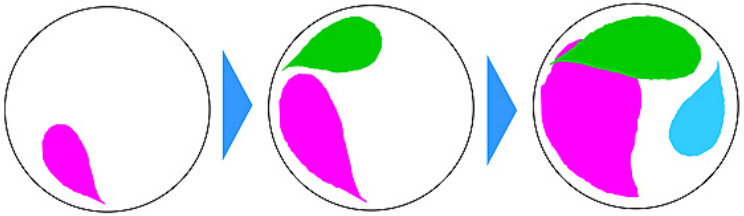


Image of fuel injection

Delivery of LNG-fuelled main engine S60MEC10.5-GI for car carriers 85

In 2015, MITSUI E&S Co., Ltd. manufactured LNG-fueled engine; ME-GI (Gas Injection) which offers environmental benefit of decreasing large amount of CO_2, SOx and PM emission. It has been adopted and delivered the container ship, LNG carrier and car carrier and so on.

Now, we have delivered 6S60ME-C10.5-GI engine applied with the latest ME-GI Mk.2 for car carrier, which has the following features.

Features of ME-GI Mk.2 system

- **Reduction of pilot oil consumption**
  The ME-GI engine needs the injection of a small amount of pilot oil as ignition sources. The conventional type (ME-GI Mk.1) required 3% pilot oil consumption at L1 point. On the other hand, it is possible to reduce from 3% to 1.5% of pilot oil for ME-GI Mk.2. By adding a lift function to the fuel valve, it is possible to inject small amount of pilot oil using only small atomizer holes during gas operation.
- **1cyl. Gas cut operation function**
  When a problem occurs in a specific cylinder during gas operation, the gas operation is stopped in all cylinders and changeover to fuel oil operation. By identifying the cylinder in which the problem occurred, the other cylinders can restart gas operation.
- **Simplification around the cylinder cover and piping**
  Removing the double wall return pipe has simplified around the cylinder cover and piping.

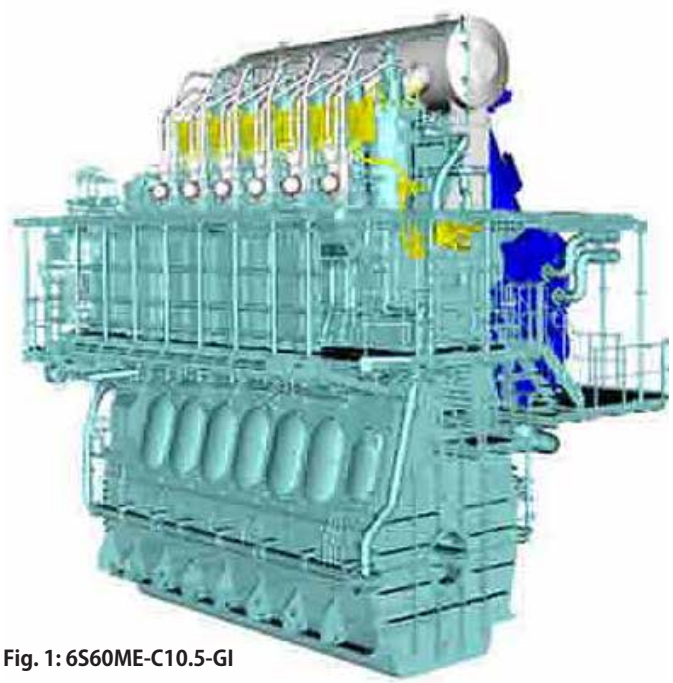


Fig. 1: 6S60ME-C10.5-GI

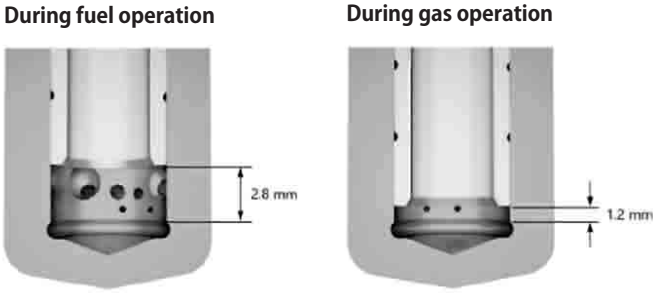


Fig. 2: Fuel valve

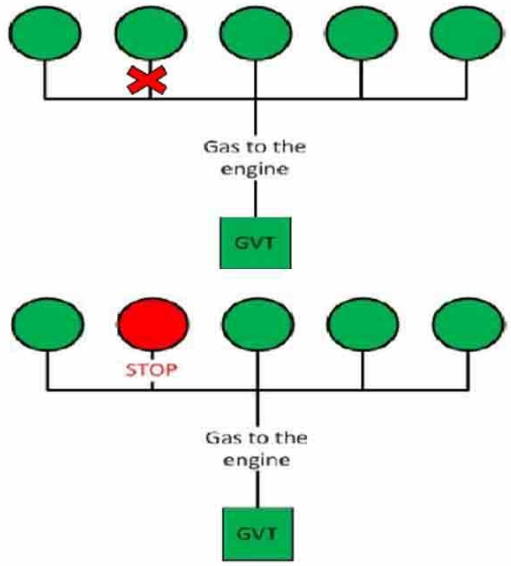
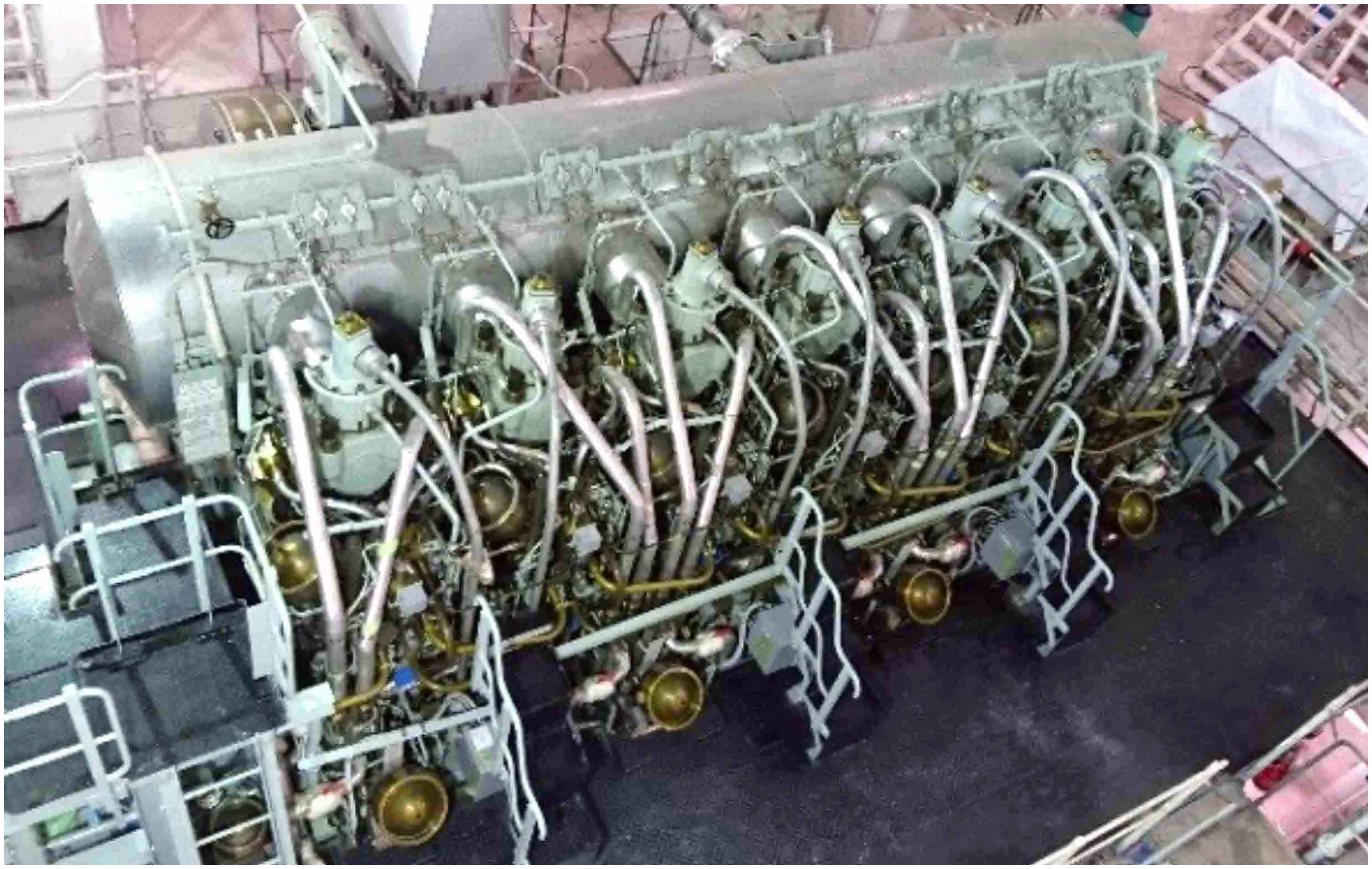


Fig. 3: 1cyl. Gas cut

Received consecutive orders for methanol-fuelled main engine (ME-LGIM) 86

In 2015, MITSUI E&S Co., Ltd. released world's first methanol-fuelled ME-LGIM (Liquid Gas Injection Methanol) engine, which offers environmental benefit of decreasing amount of CO_2, SOx, PM emission. As methanol is liquid form and easy to handle, the cost of methanol supply system can be lower compared to gas system. Three ME-LGIM engines, 7S50ME-B9.3-LGIM, were delivered to shipyard and installed on methanol carriers. These three methanol-powered vessels went into service in 2016.
And in 2023, we have received the orders of many LGIM engines ; 6G80ME-C10.5-LGIM for Container vessels and 7G50ME-C9.6-LGIM for Panamax bulk carriers. Many customers are interested in methanol fuelled vessels for using "green methanol" in future to comply with GHG regulations.



7S50ME-B9.3-LGIM

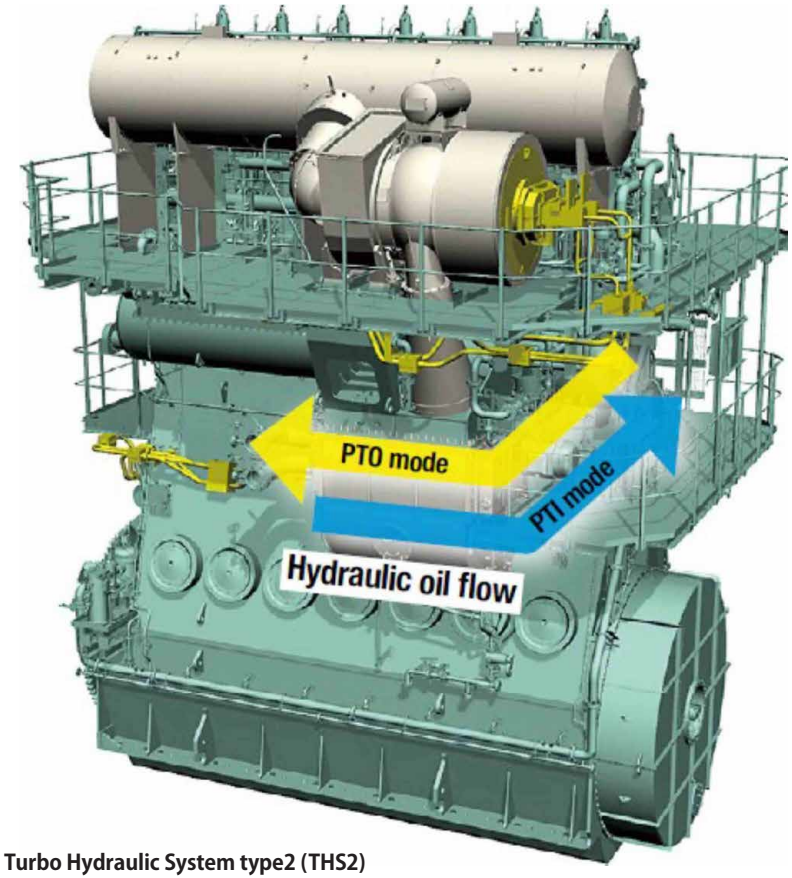
Features of ME-LGIM system

- Same as ME-GI engine, ME-LGIM is dual fuel engine which can run on both conventional fuel oil as primary fuel and methanol as secondary fuel. Engine operation mode can be selected between FO mode (fuel oil running) and SF mode (methanol running).
- Diesel type combustion is adopted to methanol running as same as fuel oil running.
- Compared with normal ME engine, only the supply line and fuel injection valve for methanol are newly added on the engine and the other parts including fuel oil line are remaining as conventional.
- Engine output and load response of methanol running is almost the same as that of fuel oil running, and totally independent of weather/sea condition or engine load.
- In case of detecting abnormal condition during methanol running, the engine automatically changes to fuel oil running immediately.
- ME-LGI type engine can also be adopted for the other secondary fuel such as ethanol, LPG, and dimethyl ether

Entered service of hydraulic waste heat recovery system, THS2 87

Turbo Hydraulic System type2 (THS2)

The excess exhaust gas energy can be utilized by the recent improvement of the efficiency of turbocharger for the marine engine. THS (Turbo Hydraulic System), developed by MITSUI E&S Co., Ltd., is a system which recovers and uses the excess gas energy as hydraulic power.



Turbo Hydraulic System type2 (THS2)

THS is very compact compared to traditional waste heat recovery system and consequently large modification of the engine room is not required. THS2 is a system specialized ME-C engine, following the conventional THS technology, and is also applicable to Tier III engine. Furthermore, it is used with EcoEGR at the same time. THS2 has the following two operating mode.

PTO mode - Hydraulic oil power supply to assist engine rotation

PTO (Power Take Off) mode can be applied at 50% load or more. THS is a system which recovers and uses the excess gas energy as hydraulic power, thereby, specific fuel oil consumption can be reduced by max. 2% and EEDI can be improved. In addition, it is also possible to assist the engine rotation by using excess exhaust gas energy to crankshaft side.

PTI mode – Hydraulic oil power supply to assist T/C rotation

PTI (Power Take In) mode can be applied in the low load range. Turbocharger speed is increased and the scavenging pressure is also increased. As a result, the engine operating range with the auxiliary blower stopped condition can be extended, contributing to further slow steaming. In addition, the required engine load is reduced by PTI and thereby, the acceleration time of the engine speed can be shortened.

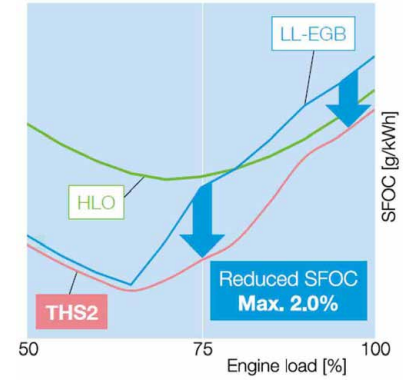
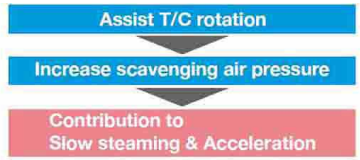


Image of Fuel consumption rate of THS2



Concept of PTI mode

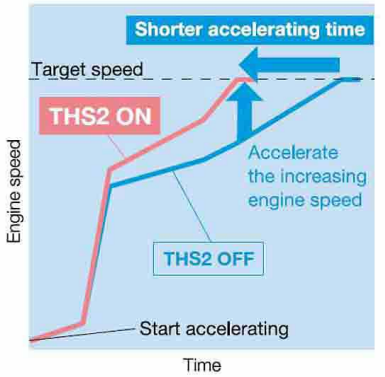
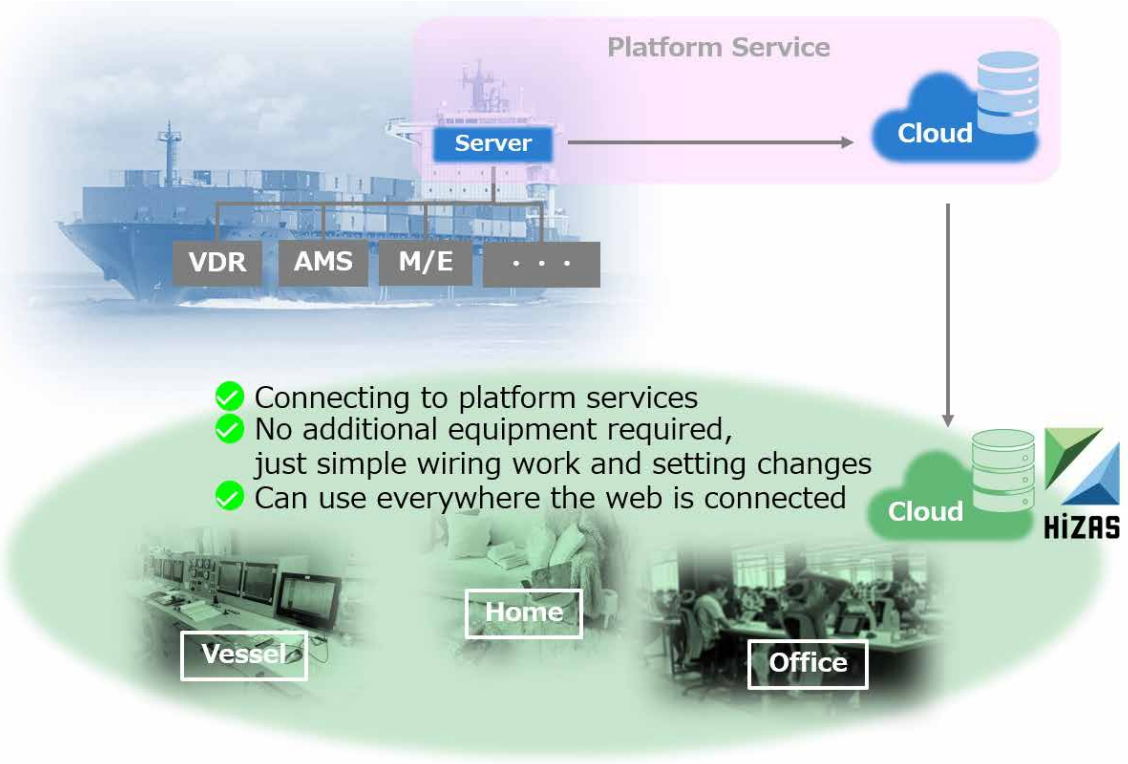
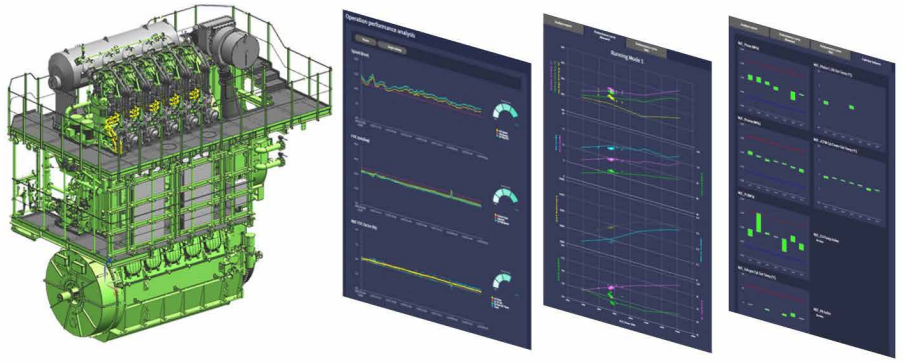


Image of improved acceleration by THS2

HiZAS VDA Service 88



- Automatic M/E performance analysis
- Supports multiple M/E running modes
- Evaluation of advanced analysis values (TC efficiency, etc.)



Various companies are providing platform services that automatically transmit measured data from ship to shore, and these services are increasingly being applied to new vessels. By connecting to each platform services of these companies, HiZAS is provided as web applications with various functions at minimal cost and without installing additional equipment on vessel.

For vessels that are not applied with platform service, HiZAS is available by manual data upload.

- **Service**
  Cloud base web application
- **Contract**
  Annual contract (subscription)
- **Main functions**
  - Main engine performance analysis
  - Alarm notification
  - Vessel operation performance visualization and evaluation
  - Parts measurement data management
  - Data export

Hitachi Zosen Marine Engine Co., Ltd. is one of the group companies of Hitachi Zosen Corporation

Received first order of High Pressure BOG Compressor for LNG fuelled vessel with ME-GI engine

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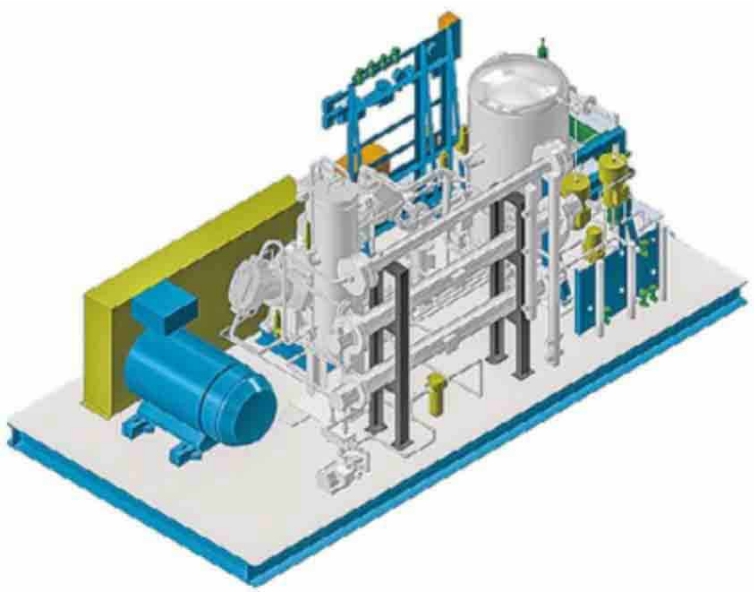
High Pressure BOG Compressor System Outline

MITSUI E&S Co., Ltd. has released a BOG (Boil Off Gas) Compressor for LNG fueled vessels. The product can compress BOG to high pressure and supply it as fuel for the main engine. This technology is attracting attention as energy saving with effective utilization of excess BOG. The capacity is suitable for excess BOG treatment of LNG fueled vessels and applicable for various ship types.

System Outline

The compressor itself is proven type of many delivery records for land automotive CNG stations. We provide the compressor as a integrated unit including associated equipment, e.g. snubbers and coolers.



Compressor unit type	WT3-110GH
Compressor type	W-type 3-stage
Flow rate [kg/h]	250
Discharge pressure [MPaG]	31.5

Received consecutive orders of high-pressure LNG pump for LNG-fuelled main engine (ME-GI) 90

MITSUI High Pressure LNG Pump

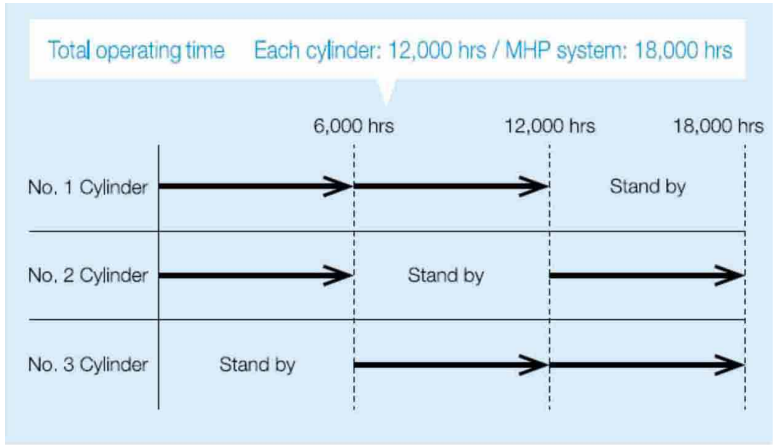
MHP System Outline

MITSUI E&S Co., Ltd. has originally developed and released Mitsui High Pressure LNG Pump (MHP) as a fuel supply system for the dual fuel engines using high pressure LNG fuel (ME-GI engines). The MHP system uses Hydraulic Drive Unit to control the operation of each cylinder of the High Pressure LNG Pump individually. Thereby standby cylinders can be installed on the same skid. In addition, the cylinder speed is designed to be low, and the life span of the cylinder is extended. Furthermore, MHP system can prevent the sudden rise of LNG discharge pressure by controlling the startup from a low-speed cycle and the rapid stop operation in case of the emergency.

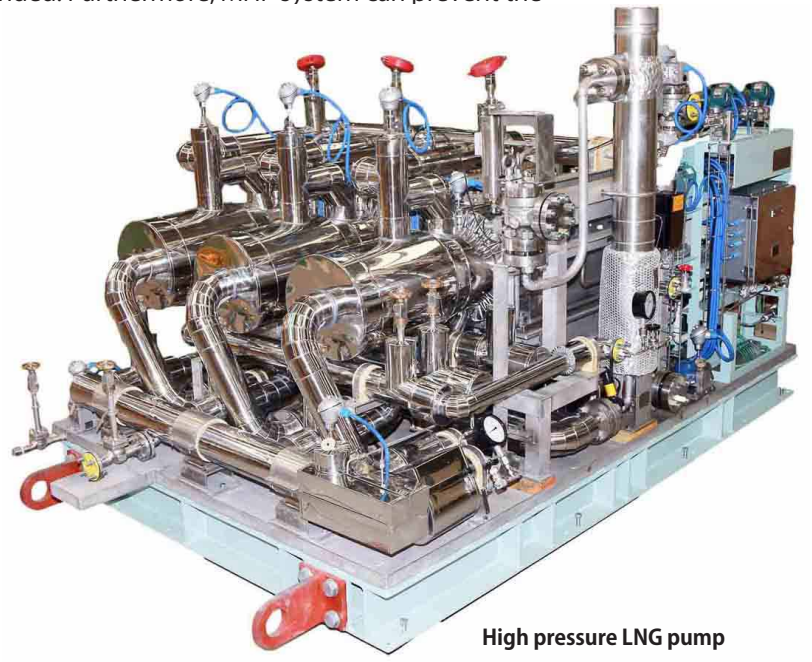
MHP Series Specifications

According to the required flow rate of the main engine, the number of cylinders can be selected as shown in the table below.

The design of the cylinder is same for all MHP models, so the cylinder can be supplied quickly even if something wrong with the cylinder.



Life span image of cylinder operation



High pressure LNG pump

Cylinder No.

TYPE	MHP-3	MHP-4	MHP-5
Engine output [MW]	~ 18.6	~ 27.9	~ 37.2
Cylinder No.	3	4	5
Operation Cylinder No.	2	3	4
Flow rate [L/min]	~ 70	~ 105	~ 140
Flow rate [kg/h] (@460kg/m^3)	~ 1,930	~ 2,895	~ 3,860