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The latest technologies of the J-ENG UE engine

Dual Fuel / Gas / Diesel

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ABSTRACT

As efforts to reduce GHG emissions become more active worldwide, Japan Engine Corporation (J-ENG) is working to achieve zero emissions as a marine two-stroke engine licensor. For over half a century, UE engines have been characterized by high economy, high reliability, and environmental friendliness. Currently, J-ENG is focusing on the development of GHG emission reduction technologies, including the development of new fuel compatible engines. This article describes these latest technologies.

The latest UEC-LSH series engines achieve high power and low fuel consumption, contributing to the reduction of CO2 emissions. The UEC60LSH has been added to the series, expanding the lineup to include bore diameters of 33 to 60 cm. Version 4, which achieves even lower fuel consumption, has also been added to the series. The UEC-LSH series engines can also be equipped with NOx reduction technology to comply with IMO-NOx Tier 3 regulations. Low-pressure EGR (LP-EGR) systems, low-pressure SCR (LP-SCR) systems, and high-pressure SCR (HP-SCR) systems have been developed and can be installed on these engines.

In response to SOx regulations and requests to reduce GHG, the number of ships equipped with LNG-fueled engines is increasing. On the other hand, using LNG as fuel requires design changes and increased manufacturing costs for both the ship and the engine. For this reason, it is difficult to adopt it on small ships. To address this situation, a new concept UEC-LSJ series engine has been developed. The UEC-LSJ uses MGO (marine gas oil) as a dedicated fuel and is very fuel-efficient, so it has the potential to comply with not only SOx regulations but also the further strengthened EEDI regulations at the same time. In the current market situation, the cost of MGO is relatively more expensive than other marine fuels, but the impact is small due to its very high efficiency (low fuel oil consumption) and low initial cost. The UEC50LSJ was developed first. After that, the UEC35LSJ was also developed and manufactured and has already begun service.

As a next-generation fuel engine, we are developing an engine that uses ammonia and hydrogen, which are carbon-free fuels. This article provides an overview of the projects.

Development of the ammonia-fueled engine began in 2021. After basic research, verification with a test engine began in May 2023. Ammonia is a flame-retardant fuel and also potentially produces nitrous oxide (N2O) when burned, so technology to burn it efficiently is important. The first developed commercial engine is the UEC50LSJA, and the UEC60LSJA is currently under development. The first commercial engine, the 7UEC50LSJA, is scheduled to be completed in 2025. This engine will be installed on an ammonia-fueled medium gas carrier (AFMGC).

Development of the hydrogen-fueled engine began in 2021. Hydrogen is a fuel with a very high burning speed and a wide flammable range, so technology to control combustion is important. Currently, the UEC35LSGH is under development. The first commercial engine, the 6UEC35LSGH, is scheduled to be completed in 2026. This engine is scheduled to be installed on a hydrogen-fueled multi-purpose vessel.

1 INTRODUCTION

As efforts to reduce GHG emissions become more active worldwide, Japan Engine Corporation (J-ENG) is working to achieve zero emissions as the world's only marine two-stroke engine licensor that develops, designs, manufactures, and sells. For over half a century, UE engines have been characterized by high economy, high reliability, and environmental friendliness. Currently, J-ENG is focusing on the development of GHG emission reduction technologies, including the development of new fuel compatible engines. This article describes these latest technologies.

Figure 1 shows the development history and Figure 2 shows the naming convention of UE engine. LSJ series which is equipped with stratified water injection system and LSH series are the latest generation, and now ammonia-fueled LSJA series and hydrogen-fueled LSGH series are under development. Figure 3 shows the UE engine output x speed range (rating map). The lineup of UE engines meets a wide range of needs from 33 cm to 80 cm cylinder bores and is installed on various merchant ships in the world as the main engine.

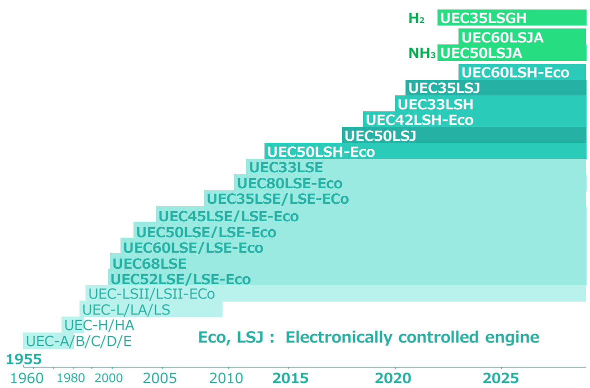

Figure 1. Development history of UE engine

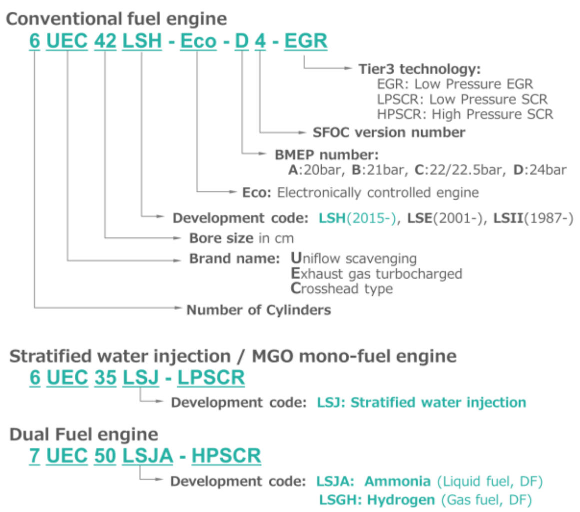

Figure 2. Naming convention of UE engine

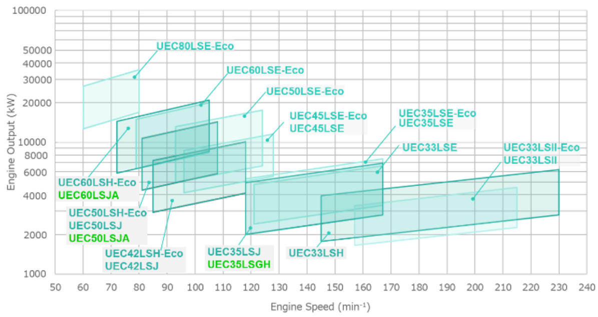

Figure 3. UE engine output x speed range

2 TECHNICAL STRATEGY

In UE engine development, based on the technology strategy shown in Figure 4, The UEC-LSH engine lineup is expanding, which are the latest fuel-efficient engines for heavy fueled engines, and UEC-LSJ engines, which pursue low fuel consumption by applying stratified water injection technology. Digital transformation is also being promoted with the aim of automatic and autonomous operation. As part of efforts to achieve carbon neutrality by 2050, ammonia-fueled engines and hydrogen-fueled engines are being developed with support from the Green Innovation Fund of the New Energy and Industrial Technology Development Organization (NEDO).

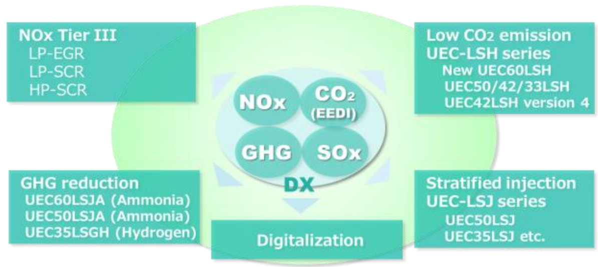

Figure 4. Technical strategy of UE engine

Table 1 shows six types of fuels, including heavy oil, which is a conventional fuel, and low-carbon and decarbonized fuels used in internal combustion engines. Although not shown in the table, biofuels, and carbon-recycled fuels such as methanol and methane can be used in existing engines, but competition with the automobile and aviation sectors is expected.

When comparing the GHG reduction rates of individual fuels (Tank to Wake evaluation), the GHG reduction rates of low-carbon fuels such as methanol, LPG, and LNG are only about 20% or less. For this reason, decarbonized fuels such as ammonia and hydrogen, which can significantly reduce GHG emissions, are necessary to achieve carbon neutrality.

Table 1. Comparison of fuels (J-ENG research)

Fuel	Heavy Fuel	Methanol	LPG (Propane)	LNG (Methane)	Ammonia	Hydrogen
Molecular Formula	(over $C_{17}H_{36}$)	CH_3OH	C_3H_8	CH_4	NH_3	H_2
CO_2 reduction rate	0 (Base)	8 %	14 %	24 %	100 %	100 %
Pilot fuel [%]		Several	Several	Several	Several	Several
Reduction factor of GHG reduction rate				Methane slip	Nitrous Oxide (N_2O)	
Required fuel volume (Approx.)	1 (Base)	2.4	1.5	1.7	2.9 (-33°C) 3.4* (45°C) *) pressurized	4.5
Liquefaction temperature (1atm)		65°C	-42°C	-162°C	-33°C	-253°C
Note		Colorless, alcohol odor	Colorless, odorless	Colorless, odorless	Colorless, irritant odor toxic	Colorless, odorless

3 AMMONIA-FUELED ENGINE

As a Green Innovation Fund project of the New Energy and Industrial Technology Development Organization (NEDO), J-ENG is developing the engine that uses ammonia as fuel, which are expected to be next-generation fuels, with the aim of achieving carbon neutrality in 2050.

3.1 Ammonia-fueled UEC50LSJA

The 7UEC50LSJA, the first ammonia-fueled low-speed two-stroke marine engine, is scheduled to be completed in 2025 (Figure 5). Development is proceeding as scheduled. Details of the ammonia-fueled engine development are explained in Paper No. 125, CIMAC Congress 2025 [2]. This paper describes the equipment that can be combined with UEC-LSJA and the lineup of UEC-LSJA series.

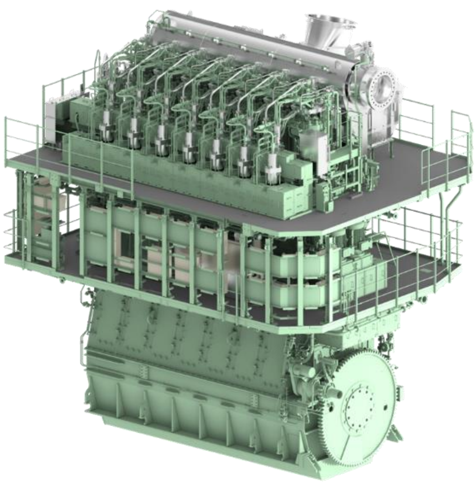

Figure 5. Ammonia-fueled 7UEC50LSJA

3.2 Combination with HPSCR

The ammonia-fueled UEC-LSJA engine is combined with an HPSCR (High Pressure Selective Catalytic Reduction) system (Figure 6) to comply with IMO NOx Tier 3 regulations and to reduce unburned ammonia at the engine outlet to below the specified concentration by reacting NOx and ammonia in the exhaust gas when operating on ammonia fuel. Therefore, the HPSCR will also be used in IMO NOx Tier 2 at NH3 mode. In this case, urea water is not injected.

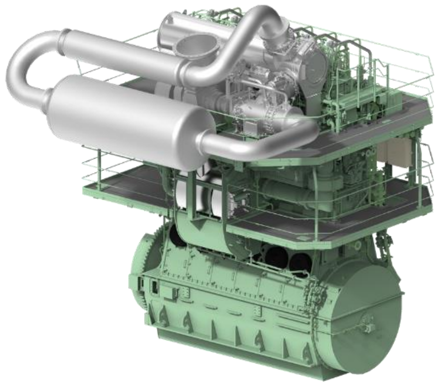

Figure 6. HPSCR system

Furthermore, in an ammonia-fueled engine, some amount of ammonia water is generated in the ammonia abatement system, etc. This ammonia water is stored in a tank and will be discharged on land or disposed of by incineration, etc. To avoid or reduce the need for these procedures, an optional specification can be applied in which ammonia water is consumed by injecting it into the HPSCR in FO mode. In that case, an ammonia injection system is also installed in addition to the urea water injection system.

The expected lifetime of the catalyst in the SCR system is usually set at 10,000 hours or 5 years for conventional fuel engines. This assumes that catalyst performance will be reduced by sulfur in the fuel, and in actual operation, the need for replacement is determined considering the result of spot check. For ammonia-fueled engines, SCR is planned to be used also in IMO NOx Tier 2 mode for reducing unburned ammonia, but since the proportion of sulfur in the total fuel (pilot fuel + ammonia) will be very low, it is expected that the lifetime will be longer than usual. The progress of catalyst performance after entering service will be continuously monitored.

3.3 Combination with shaft generator

Ships equipped with ammonia-fueled engine are in demand for shaft generator due to the increased amount of electricity required and to reduce GHG emissions. Table 2 shows major types of shaft generator layout and structure.

Intermediate shaft mounted type (Case 1 in Table2) requires a certain amount of space behind the engine, which limits the types of ships that can be applied. Connected to the front of the main engine via an elastic coupling type (Case 2 and 3 in Table 2) may involve a reduction in cargo space, making it difficult to install. For these reasons, there is a growing need for a shaft generator built into the front end of the engine (Case 4 in Table 2).

UEC-LSJA is proceeding with the design of a built-in shaft generator at the front end of the engine as an option.

Table 2. Shaft generator (S/G) layout

Case	Layout	Structure
1	S/G M/E	Intermediate shaft mounted type
2	M/E S/G	Connected to the front of the main engine via an elastic coupling and speed increasing gear
3	M/E S/G	Connected to the front of the main engine via an elastic joint
4	M/E S/G	Main engine front end built-in type

Generally, the crankshaft of marine two-stroke engine is directly connected (without an elastic coupling or gear) to the intermediate shaft, propeller shaft, and propeller, so measures against torsional vibration of the shafting system are necessary.

One of the main measures is to increase the moment of inertia of the shafting system, lowering the resonant revolution speed and reduce stress, and setting a barred speed range so that the engine can pass through it in a short time. A specific example of increasing the moment of inertia of the shafting system is to change the flywheel at the rear end of the engine to a heavier specification and install a heavy object called a tuning wheel at the front end of the engine. For this reason, marine two-stroke engines are designed so that a casing for the tuning wheel can be attached to the front end of the engine. (Figure 7)

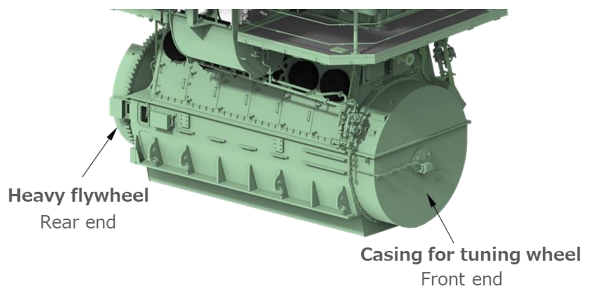

Figure 7. Casing for tuning wheel

Using this engine structure, the shaft generator stator is connected to the tuning wheel casing. The generator rotor is connected to the crankshaft. Therefore, the casing at the front end of the engine needs to be rigid enough to withstand the weight of the generator stator and keep the change in the clearance between the generator stator and rotor within an appropriate range.

The generator side needs to generate stable power even under conditions where torsional and axial vibrations of the crankshaft occur. It is expected that in the future, more generator manufacturers will have built-in type shaft generators in their lineup, so the engine side may need to have multiple variations to accommodate these.

3.4 Ammonia Fuel Supply System (AFSS)

Figure 8 shows an overview of the ammonia fuel supply system. The high-pressure pump supplies ammonia to the main engine at 5 MPa, and a pressurized circulation line is configured. The main equipment, such as the fuel valve train, heat exchanger, high-pressure pump, and catch tank, are in the Fuel Preparation Room.

Ammonia is purged in two different procedures depending on the situation. When ammonia mode operation ends, the master valve of the supply line closes, N2 gas purges the ammonia, and the ammonia is collected in the catch tank. After that, the master valve of the return line closes, and the ammonia is purged to the knockout drum. In the event of an emergency shutdown, both the supply and return master valves close, and ammonia is purged directly to the knockout drum.

The ammonia is removed by an ammonia gas abatement system until it reaches a specified emission concentration, and then released overboard.

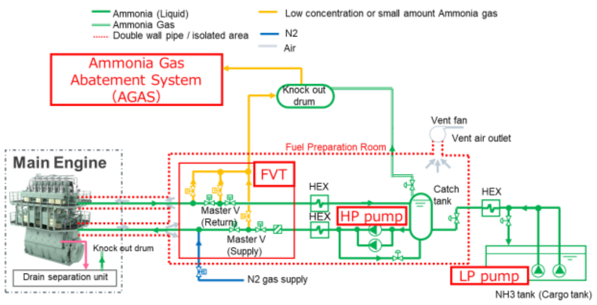

Figure 8. Ammonia Fuel Supply System

3.5 Release of cylinder bore 60 cm class

3.5.1 Ammonia-fueled UEC60LSJA

In parallel with the development of the UEC50LSJA, the development of the UEC60LSJA is also underway. The UEC60LSJA is an ammonia-fueled engine version of the UEC60LSH engine, and applies the knowledge gained from the development of the UEC50LSJA. UEC60LSJA is scheduled for completion in 2028 (Figure 9).

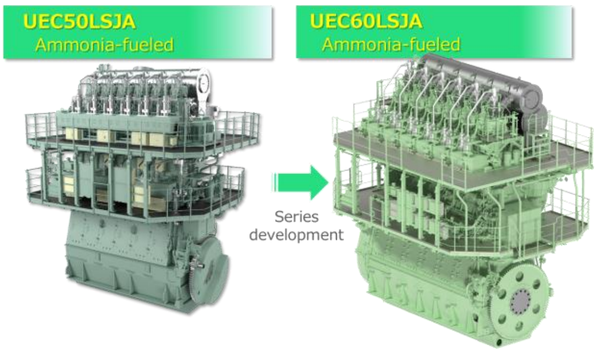

Figure 9. UEC50LSJA and UEC60LSJA

3.5.2 Expected type of vessels

By introducing cylinder bore 60 cm class ammonia-fueled engine to the market, many ship types can be covered. Ammonia carrier such as VLGC (Very Large Gas Carrier) and VLAC (Very Large Ammonia Carrier), and car carrier are the ship types expected to adopt ammonia-fueled engines early on (Figure 10).

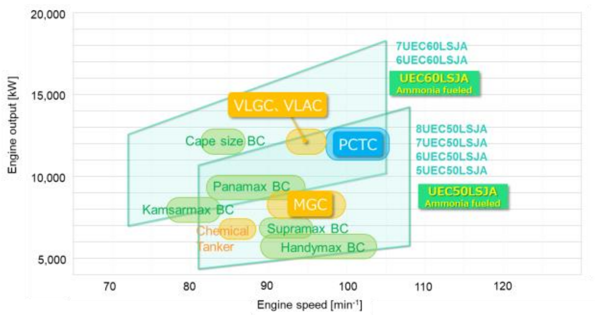

Figure 10. Expected type of vessels

4 GHG REDUCTION WITH COVENTIONAL FUELS

There is an urgent need to reduce GHG emissions from marine engines, but the introduction of engines that use next-generation fuels is very costly. In addition, small and medium-sized ships often do not have fixed routes and call at various ports, so it can be difficult to obtain next-generation fuels steadily. Therefore, there is a strong demand for reducing GHG emissions from conventional fuels and improving the EEDI, and improvements are being made to UE engines that use conventional fuels.

4.1 UEC-LSH Series

4.1.1 New UEC60LSH/LSJA

Figure 11 shows main specifications and rating map of UEC60LSH type engine. It is the successor to the UEC60LSE, which is widely used in car carriers and coal carrier and is set to an optimal output and speed range for VLAC, VLGC, car carrier, capesize bulk carrier, coal carrier, and other vessels. In particular, the minimum speed covers 72 rpm, contributing to reducing EEDI by improving propeller propulsion efficiency. It is also a lightweight and compact engine that makes installation at the shipyard easier.

As for the environmental performance, UEC60LSH is a world-class low-fuel consumption engine like the existing UEC50LSH and UEC42LSH. For carbon neutrality by 2050, the ammonia-fueled engine UEC60LSJA is also being developed at the same time. For NOx Tier 3 compliance, UEC60LSH is scheduled to have a low-pressure EGR lineup, and the UEC60LSJA is scheduled to have a high-pressure SCR lineup. In terms of reliability, the UEC60LSH/LSJA has the reliable structure and specifications that have been proven in the LSH series. Equipped with the latest 5th generation electronic control system (Eco5G), it is also compatible with future digital transformation.

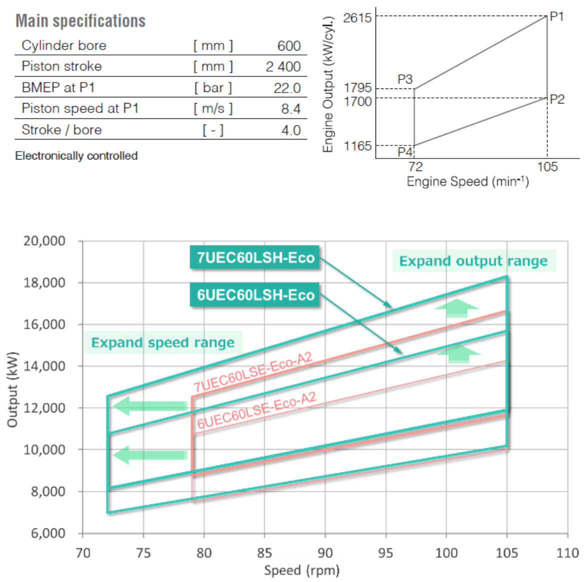

Figure 11. Main specifications and rating map of UEC60LSH-Eco type engine

4.1.2 SFOC version 4

For the UEC-LSH series, SFOC version 4 was developed to further reduce fuel consumption across the entire load range by improving and optimizing the fuel injection system, and the first UEC42LSH-Eco-D4, shown in Figure 12, was completed in December 2023. In version 4, the injection amount at the beginning of combustion is reduced by individually controlling the injection patterns of multiple fuel valves equipped on the cylinder cover, improving the trade-off between NOx and fuel consumption.

Figure 12. 6UEC42LSH-Eco-D4 type engine

The fuel injection system of UEC42LSH-Eco-D4 is shown in Figure 13. The measured fuel injection pressure and fuel pump lift of SFOC version 4 are shown in Figure 14. The fuel injection system and injection pressure of conventional engine is shown in Figure 15. The comparison of fuel injection system between conventional engine and SFOC version 4 engine is shown in Table 3.

In conventional engines, fuel is pumped from one fuel pump to three fuel injectors, so the injection timing of the three valves is the same. The fuel injection rate is controlled by main and sub solenoid valves, but the range of variation is limited.

SFOC version 4 is equipped with three small fuel pumps, each with one solenoid valve, enabling sequential injection while maintaining the conventional fuel injection system structure.

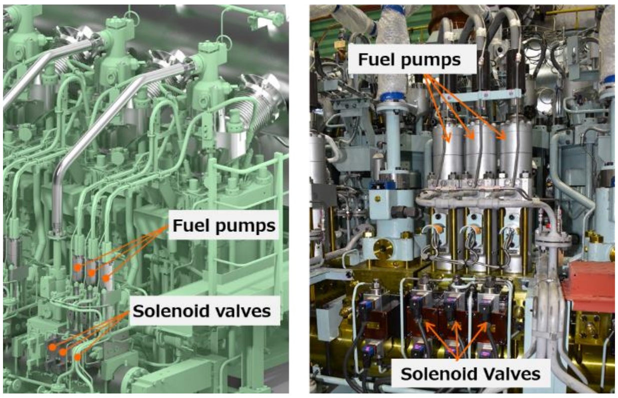

Figure 13. Fuel injection system of SFOC ver. 4

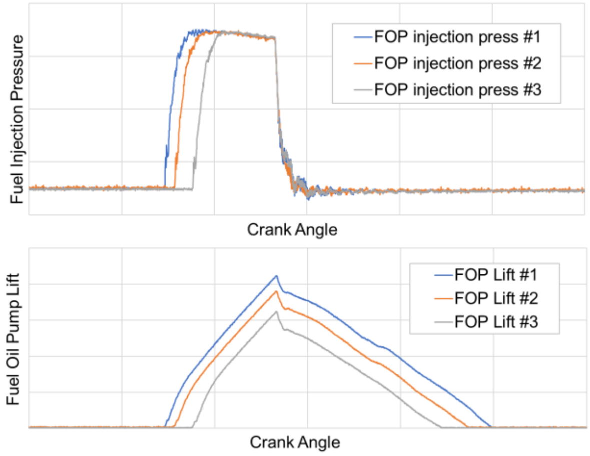

Figure 14. Fuel injection pressure and pump lift of SFOC version 4

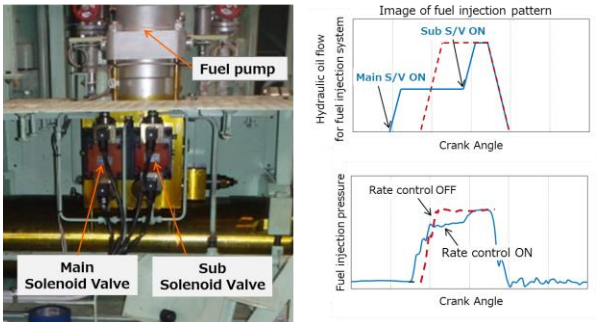

Figure 15. Fuel injection system and injection pressure of conventional engine

Table 3. Comparison of fuel injection system

Specifications	Conventional UEC42LSH-Eco-D3	SFOC Version 4 UEC42LSH-Eco-D4
Fuel injection valve	Conventional x 3 pcs/cyl	Conventional x 3 pcs/cyl
Fuel injection pump	Conventional x 1 pc/cyl	Small pump x 3pcs/cyl (controlled individually)
Solenoid valve unit (for Fuel injection)	Solenoid Valve x 2pcs/cyl (Main S/V, Sub S/V)	Solenoid Valve x 3pcs/cyl
Eco engine control unit	Conventional	Major component is about twice that of conventional (Driver, Box etc.,)

4.1.3 UEC42LSH

UEC42LSH (first UEC42LSH-Eco-D3 completed in 2021) has been steadily receiving orders for handy-sized bulk carriers, as well as small and medium-sized chemical tankers and feeder container ships and is now in mass production both at J-ENG HQ factory and UE licensees, with the addition of the more fuel-efficient UEC42LSH-Eco-D4.

The first UEC42LSH entered in service in March 2022. The number of orders has increased significantly, and the vessels are in good condition after entering service and are being continuously monitored. The inspection results of the UEC42LSH are shown in Figure 16.

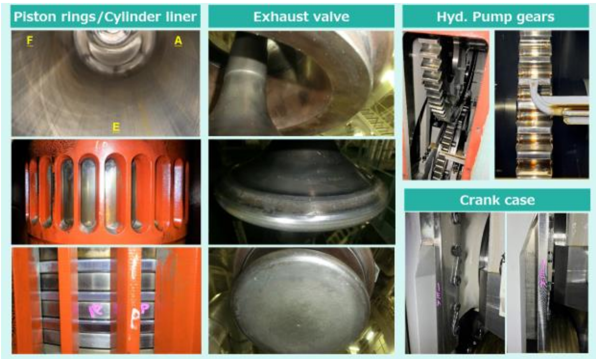

Figure 16. Inspection results on UEC42LSH

4.1.4 UEC50LSH

UEC50LSH (the first UEC50LSH-Eco-C2 was completed in 2015, and the first UEC50LSH-Eco-C3 was completed in 2021) has good service results and has been manufactured in large numbers. UEC50LSH has been steadily receiving orders and is now in mass production both at J-ENG HQ factory and UE licensees, mainly for bulk carriers, refrigerated carriers, chemical tankers, and feeder container ships.

4.2 UEC-LSJ series

4.2.1 Alternative solution for GHG reduction

In response to SOx regulations and requests to reduce GHG, the number of ships equipped with LNG-fueled engines is increasing. On the other hand, using LNG as fuel requires design changes and increased manufacturing costs for both the ship and the engine. For this reason, it is difficult to adopt it on small ships. To address this situation, a new concept UEC-LSJ series engine has been developed.

UEC-LSJ series is a model that integrates the LSH series with the UE engine's independently developed technologies of complete combustion and stratified water injection (Figure 17) to achieves a significantly lower fuel consumption (improving fuel efficiency by approx. 5% compared to the previous models) while complying with NOx regulations. By sandwiching water in layers in the fuel spray, the leading fuel ignites quickly, and the heat of vaporization of the water lowers the flame temperature and reduces NOx. In addition, the kinetic energy of the water helps to draw air into the fuel spray, resulting in a quick end of combustion. This improves the trade-off between fuel efficiency and NOx emission.

UEC-LSJ uses MGO/MDO (Marine Gas Oil / Marine Diesel Oil) as a dedicated fuel and is very fuel-efficient, so it has the potential to comply with not only SOx regulations but also the further strengthened EEDI regulations at the same time. In the current market situation, the cost of MGO is relatively more expensive than other marine fuels, but the impact is small due to its very high efficiency (low fuel oil consumption) and low initial cost. The UEC50LSJ was developed first. After that, the UEC35LSJ was also developed and manufactured and had already begun service.

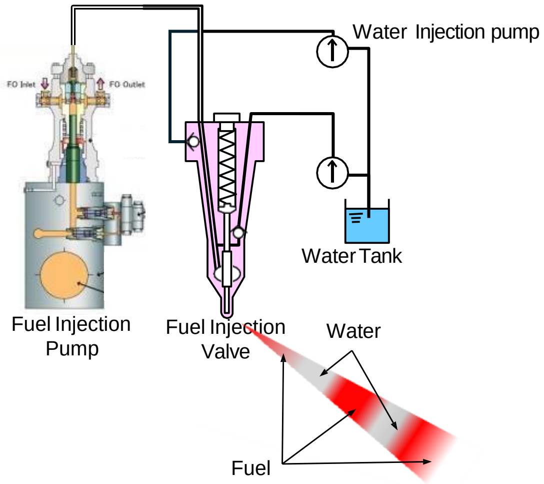

Figure 17. Stratified water injection system

4.2.2 Additional benefit of UEC-LSJ

In addition to the above, UEC-LSJ series can provide many other benefits to each shipping stakeholders. Figure 18 shows the benefits of UEC-LSJ series.

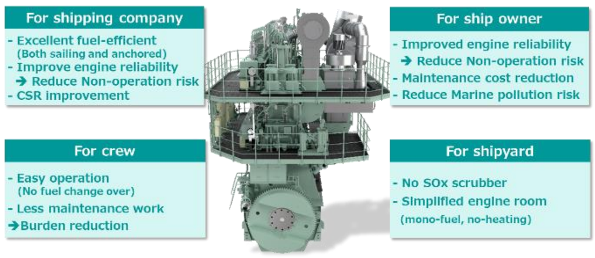

Figure 18. Benefits of UEC-LSJ series

For shipping company, it is possible to reduce operating costs through low fuel consumption. By using MGO/MDO as fuel oil, fuel heating and steam heating lines (heat tracing) to fuel piping can be omitted, making it possible to reduce warming costs not only during operation but also while at anchor. In addition, the use of MGO/MDO, a high-quality oil, reduces contamination and wear of combustion chamber components, improving engine reliability and reducing the risk of the ship being unable to operate.

For ship owner, improved engine reliability reduces maintenance costs.

For crew members, it is possible to reduce the burden on crew members by eliminating the need to switch fuel oil, making operation easier, and reducing wear and tear on combustion chamber components and reducing maintenance work.

For shipyard, it is possible to design a simple engine room by eliminating the need for SOx scrubbers and reducing fuel heating and oil purifiers. In this way, the stratified water injection system, a feature of LSJ engines, offers benefits to all shipping stakeholders and is easier to operate than conventional heavy fuel oil engines, making it an ideal concept for coastal ships and small ships.

4.2.3 Service results of UEC35LSJ

Figure 19 shows the inspection results of the first UEC35LSJ engine. The combustion chamber and scavenging air trunk are compared with the conventional engine using heavy fuel oil.

The photo on the left is a conventional engine using very low sulphur heavy fuel oil (VLSFO), and the photo on the right is the UEC35LSJ engine using MGO/MDO. UEC-LSJ has less soot and sludge in all areas, including the scavenging air trunk, piston underside space, piston rings, cylinder liner running surface, piston crown surface, and piston crown top land, which is expected to improve reliability and extend maintenance intervals. In addition, there were concerns that injected water into the cylinder may cause corrosion and wear to the piston rings and cylinder liners, but it was confirmed that all of these were operating in good condition without any issues.

Figure 19. Inspection results on UEC35LSJ (right)

5 HYDROGEN-FUELED ENGINE

In parallel with the development of the ammonia-fueled engine, J-ENG is working on the development of an engine that uses hydrogen, which is expected to be one of the next-generation fuels, as a Green Innovation Fund project of the New Energy and Industrial Technology Development Organization (NEDO), a national research and development agency, with the aim of achieving carbon neutrality by 2050.

5.1 Hydrogen-fueled UEC35LSGH

The hydrogen-fueled engine currently under development is 6UEC35LSGH with 35 cm bore size (Figure 20). It will be completed in 2026 and installed on a general cargo ship for demonstration operation. Development is proceeding as scheduled. Details of the hydrogen-fueled engine development are explained in Paper No. 125, CIMAC Congress 2025 [2].

Development of the hydrogen-fueled engine started in 2021. In the early stages, basic research such as combustion analysis was conducted, and bench tests of the hydrogen injection system were started in parallel. The bench tests were successfully completed at the end of 2024.

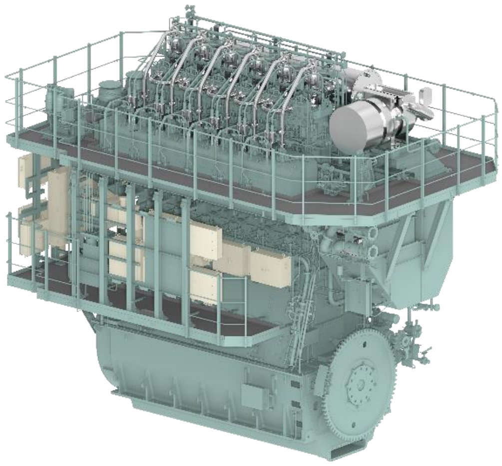

Figure 20. Hydrogen-fueled 6UEC35LSGH

6 CONCLUSIONS

As efforts to reduce greenhouse gas emissions become more active worldwide, J-ENG is working to achieve zero emissions as a licensor of two-stroke marine engines.

The ammonia-fueled engine UEC50LJSA is scheduled to be completed in 2025. The 60cm bore UEC60LSJA is also under development and is scheduled to be completed in 2028.

The hydrogen-fueled engine UEC35LSGH is scheduled to be completed in 2026.

J-ENG is also working to reduce CO_2 emissions from conventional fuel engines.

The UEC-LSH series is characterized by low fuel consumption and has been operating in good condition after entering service. A new engine with a bore size of 60cm, the UEC60LSH, is also under development. SFOC version 4, which improves the trade-off between fuel economy and NOx with sequential injection, has also been added to the LSH series.

The UEC-LSJ series applies stratified water injection technology and is characterized by lower fuel consumption than the LSH. In addition, as it is a mono-fuel engine with MGO/MDO, it benefits all stakeholders, including shipping company, ship owner, crew, and shipyard.

Through the development of carbon-free fuel engines and performance improvement of conventional fuel engines, J-ENG will contribute to reducing greenhouse gas emissions in the shipping industry and achieving carbon neutrality by 2050.

7 DEFINITIONS, ACRONYMS, ABBREVIATIONS

GHG Greenhouse Gas

EGR Exhaust Gas Recirculation

SCR Selective Catalytic Reduction

SFOC Specific Fuel Oil Consumption

BMEP Brake Mean Effective Pressure

LNG Liquefied Natural Gas

LPG Liquefied Petroleum Gas

8 ACKNOWLEDGMENTS

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