

The latest technology of the UE engine with environmentally friendliness, enhanced reliability and high performance

Hironori SAKABE*

ABSTRACT

The UE engine is the only Japanese slow speed diesel engine developed since 1955. We would like to explain the latest technological development of the UE engine in this paper. The first topic we discuss is the engine program, especially LSE, a recently developed engine in the expanding series. We then discuss the UEC Eco-Engine, the first electronically controlled UE engine, which was successfully completed in November 2004. It can reduce NOx by approximately 15% or fuel oil consumption by approximately 1 to 2%. Next, we focus on the cylinder lubrication system. The SIP system has been accumulating the good service results. We will fully state our compliance policies in relation to environmental issues. To meet future regulations, we have already prepared countermeasures such as the UEC Eco-Engine and a water injection system.

Key Words: Slow speed diesel engine, Electronically controlled, Cylinder lubrication system, Environment

1. INTRODUCTION

Recently, there has been active economic development in the shipping industry, especially in China. Since shipowners constantly require larger and faster vessels, shipyards develop new types of ships, one after the other, in order to respond to shipowners requests. For example, 60,000 DWT class vessels for the Handymax bulk carrier have entered the market. Also, 82-83,000 DWT class vessels are being designed for Panamax bulk carrier. This trend toward larger and faster ships requires main engines to have more power. The UEC-LSE engine series is able to comply with such requests, and has expanded the program.

In terms of the environmental issues, Annex VI of MARPOL73/78 regulations went into effect in May 2005 and will be subject to strict revision every five years. The UEC Eco-Engine and a water injection system will comply effectively with future regulations.

Economically, the reduction of cylinder oil consumption is very important for ship operations. A brand new cylinder lubrication system, the SIP system, achieve a drastic reduction in the consumption of cylinder lubricating oil, while reducing the rate of piston ring and cylinder liner wear at the same time.

2. ENGINE PROGRAM

As Fig. 1 shows, the UE engine was developed since 1955 in step with our original technology. The current main series is the LSII, which has a good service record across more than 400 engines. In 1998, we began the development of a new series, the "LSE", feeding back the good service results of

the LSII. The UEC52LSE, the UEC68LSE and the UEC60LSE engines is already complete, and we have just finished developing the UEC50LSE in collaboration with Wartsila Switzerland. We will then start developing the UEC45LSE, targeted for 30k to 40k DWT class bulk carriers.

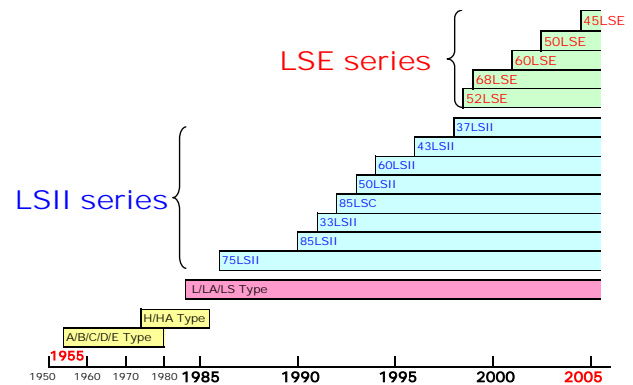


Fig.1 Development history of UE engine

Table1 compares the latest line-up of the LSII and LSE series. The LSII has a bore size of 33 to 85 cm with a stroke bore ratio of less than 4.0. The BMEP is 1.7 to 1.8 MPa and the mean piston speed is around 8 m/s. As for the LSE, the stroke bore ratio is 4.0 to 4.1, the BMEP is 1.9 to 2.0 MPa, and the mean piston speed is 8.0 to 8.5 m/s. The LSE series can be applied as the main engine for the recent larger and faster ships.

*Mitsubishi Heavy Industries, LTD.,
 1-1, Wadasaki-cho 1-chome, Hyogo-ku, Kobe 652-8585,
 JAPAN
 FAX: +81-78-672-3705, E-mail: hironori_sakabe@mhi.co.jp

Table 1 Line-up of UEC-LSII/LSE

Series		LSII						LSE						
Bore		33	37	43	50	60	75	85	85 C	45	50	52	60	68
Stroke/ Bore		3.2 ~ 3.5			3.7 ~ 3.9			2.8	4.1	4.0				
BMEP		MPa		1.7 ~ 1.8				1.96	2.00	1.9				
Piston Speed		m/s		8.0				8.0	8.5					

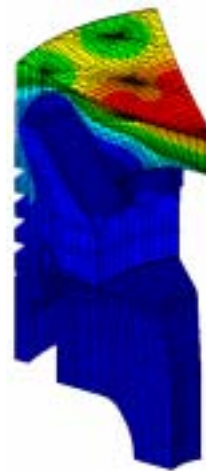


Fig.4 3-dimensional FEM analysis of piston

3. DEVELOPMENT TECHNOLOGY OF UEC-LSE

3.1 UEC50LSE

The UEC50LSE is the main engine targeted for Handymax bulk carriers, Panamax bulk carriers, Feeder container ships, etc., and its features include high performance, low fuel oil consumption, and high reliability. The main construction features are shown in Fig. 2.

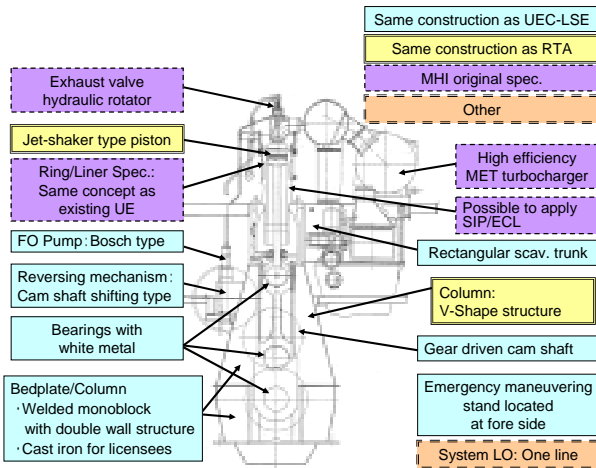


Fig.2 Construction features of UEC50LSE

The main frame has double wall with a V-shape for a welded monoblock, and has high rigidity to side thrust loading as shown in Fig. 3, which is the FEM analysis result. Domestic licensees adopt the cast iron main frame.

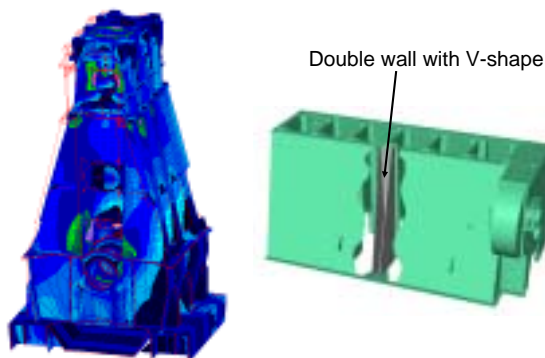


Fig.3 FEM analysis of mainframe

The piston is a bore cooling type. According to the adoption of a bore cooling type piston, the lubricating oil system consists of one line from two conventional lines. The FEM temperature analysis result of a piston is shown in Fig. 4.

As shown in Fig. 5 and Fig. 6, stress in the main frame and the temperature of the combustion chamber were measured at the shop, and all measured data were confirmed to satisfy the design targets.

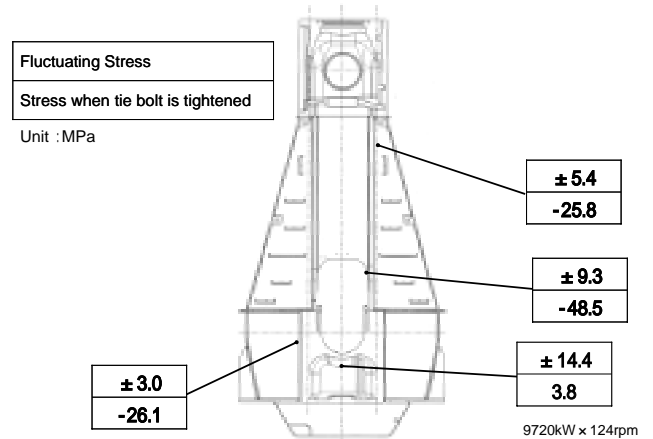


Fig.5 Main frame stress measurement result of 6UEC50LSE

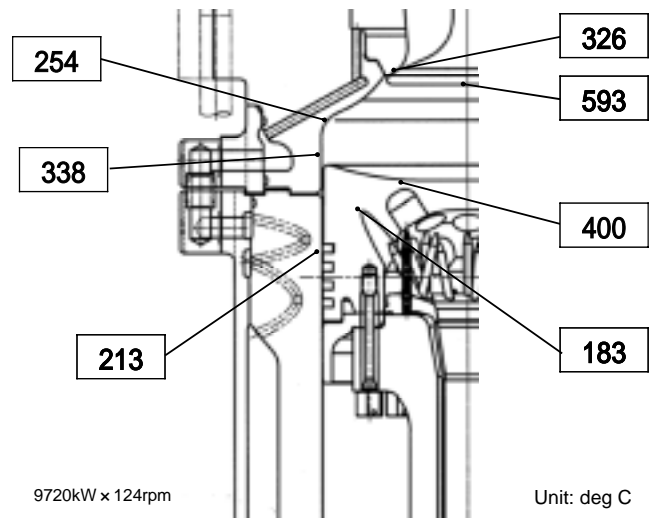


Fig.6 Combustion chamber temperature measurement result of 6UEC50LSE

Engine performance is shown in Fig. 7. Each value was checked to ensure it acquired the planned value, and NOx also cleared the IMO-NOx regulation sufficiently.

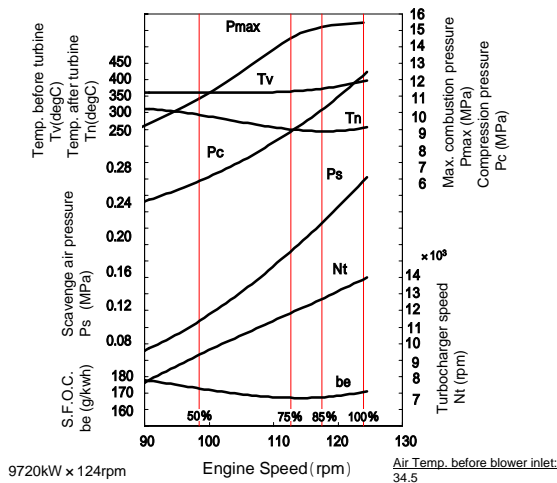


Fig.7 Engine performance of 6UEC50LSE

The additional design of this engine is one that can equip the SIP system that are described later. Therefore, the UEC50LSE is highly economical engine because its consumption of cylinder lubricating oil is extremely low by the SIP system.

Specification of ring and liner follows the concept of existing UE engine. Wide honing machining and optimized liner temperatures are applied. Fig. 8 shows photographs of the ring and liner after running-in at the shop, and they are clearly in good condition.

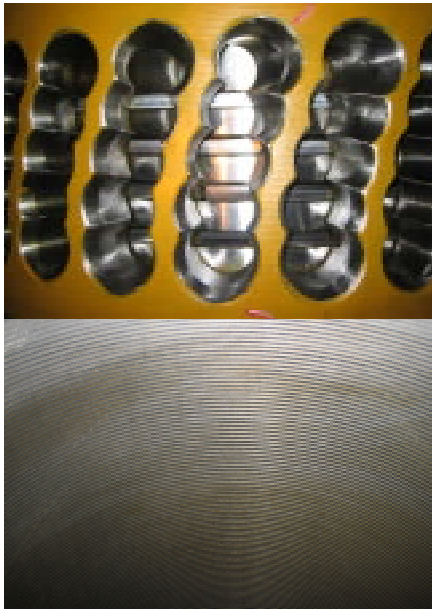


Fig.8 Ring and liner condition after running-in at shop on 6UEC50LSE

3.2 UEC45LSE

As the main engine of many 30k to 40k DWT class bulk carriers, many shipyards in Japan adopted the UEC52LA. The UEC52LA has obtained the highest evaluation from worldwide shipowners due to its high reliability and low fuel oil consumption. As 20 years have already passed since its initial development, the latest engine type is desired by market because of its longer engine length, heavier engine weight, etc.

After comprehensive market research, the development of the UEC45LSE, which is suitable for 30k to 40k DWT class bulk carriers, was started. It has attained high output, a light-weight and low fuel consumption as shown in table 2.

Table 2 Main particulars of UEC45LSE

Engine Type		6UEC45LSE	6UEC52LA
Bore	mm	450	520
Stroke	mm	1,840	1,600
Stroke/bore	-	4.10	3.08
Output	kW (PS)	7,470 (10,140)	7,080 (9,600)
Engine speed	rpm	130	133
B.M.E.P.	MPa	1.96	1.57
Piston speed	m/s	7.97	7.09
Engine length	mm	5,894	7,270
Piston overhaul height	mm	8,600	7,700
Crankshaft center	mm	1,000	930
Bedplate width	mm	3,000	3,000
Engine weight	ton	195	239

The engine outline of the UEC45LSE is shown in Fig. 9. Its basic construction is in line with the earlier model, the UEC52LSE, which is same class bore engine, however, it has the further compactness as a small bore engine, (for example, 6 sets of cover bolt and 2 sets of exhaust valve cage bolt). Since the UEC45LSE is mainly manufactured by the licensee, it is designed taking the licensee into account, for example, the cast iron main frame, etc. This engine can also apply the SIP system. We are making progress on a detailed design, and completion of the first engine is scheduled for 2007.



Fig.9 UEC45LSE

4. ELECTRONICALLY CONTROLLED ENGINE

Fig. 10 shows the design change points of an electronically controlled engine, named the UEC Eco-Engine, from conventional engine. The camshaft in the engine has been removed. The fuel oil injection unit, the exhaust valve driving unit, and the starting unit are controlled by a solenoid valve. Due to an increase in the flexibility of the fuel injection and exhaust valve open and close timings, an approximately 15% reduction is possible for NOx or an approximately 1 to 2% reduction in fuel oil consumption is possible as shown in Fig. 11. In addition, since fuel oil can be injected with high pressure from a low load, lengthy continuous operation at a low load, an improvement in the smoke levels, a reduction of the lowest revolution, and a long MTBO can be achieved. The first UEC Eco-Engine, the 8UEC60LSII-Eco, entered service in June 2005, and has been operating satisfactorily.

Design of Eco system for the UEC33LSII, the UEC50LSII and the UEC60LSII has already been completed, and engines that can apply the Eco system will continue to expand.

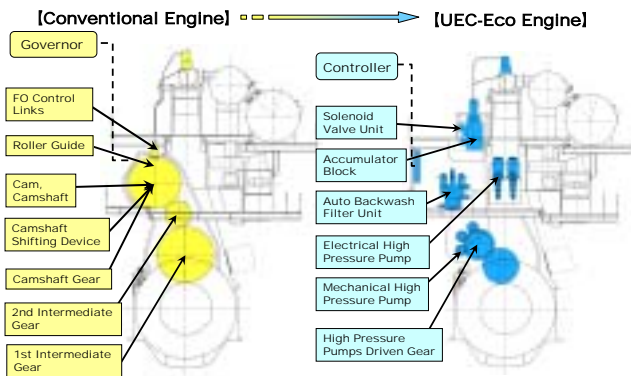


Fig.10 Design change points of UEC Eco-Engine from conventional engine

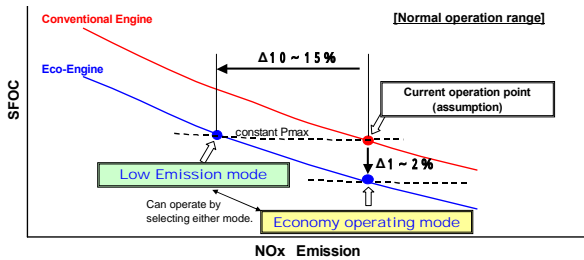


Fig.11 Reduction of NOx and S.F.O.C. by UEC Eco-Engine

5. SIP SYSTEM

The SIP system is a new cylinder lubrication system that was developed by a Danish shipowner and lubricator manufacturer, and was brushed up with our technology. We joined up with the manufacturer and its orders reached more than 1200 cylinders.

A feature of the SIP system is that it sprays cylinder oil by high-pressure injection. With a conventional system, cylinder oil, which is fed into the cylinder, is spread by a ring movement. However, in the upward process of the piston, some cylinder oil is splashed up into the cylinder. In the downward process of the piston, some cylinder oil is splashed down to the under side of the piston. Therefore, when cylinder oil is fed in, 30% to 50% of it is wasted. However, the SIP

system can save such wasted oil, since thin and uniform oil distribution is made by the spray injection of the cylinder oil. That is why the SIP system can achieve a low cylinder oil feed rate.

A basic test rig of the spray injection for SIP system is shown in Fig. 12. The SIP system lubricator is actuated by the motor, and it can be made to carry out high-speed video of the cylinder oil spray condition in a constant volume chamber. The cylinder oil temperature, the SIP valve* temperature, the pipe temperature, the pipe length, etc. are adjustable according to the actual condition of the engine.

(*) SIP valve: Cylinder oil injection valve equipped on the liner

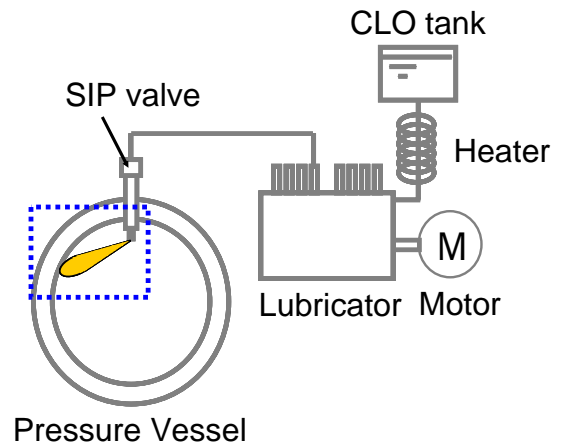


Fig.12 Test rig of SIP system

An example of oil spray in the SIP system is shown in Fig. 13. Cylinder oil is injected as a jet spray right after injection, and reaches the liner surface.

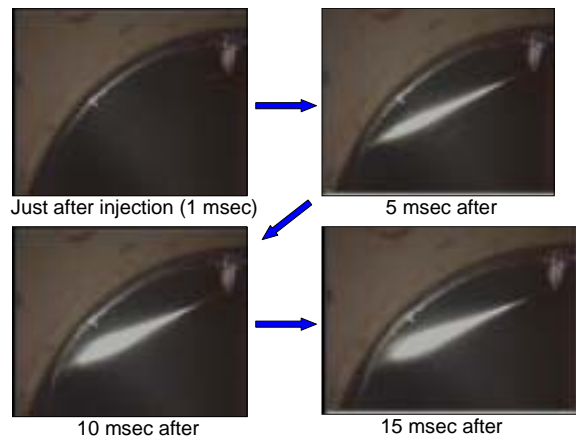


Fig.13 Spray injection by SIP system

The spray injection of the SIP system is influenced by the way of oil temperature control as shown in Fig. 14. The upper figure is a photograph taken when the cylinder oil temperature is heated appropriately. The lower figure is a photograph taken when the cylinder oil is at room temperature. The spray at room temperature is in poor condition, and has not reached the liner surface.

In addition, it was observed that at low temperatures, the plunger efficiency of the lubricator decreased and the feed rate was reduced.



Good injection



Poor injection due to low temperature

Fig.14 Effect of oil temperature for SIP injection

On the other hand, if the cylinder oil is heated excessively, cylinder oil carbonization or extraction of the cylinder oil component may occur. That is why excessive heating is not desirable. Therefore, temperature control is very important for the SIP system. Recently, many ships have adopted circulation system to easily control oil temperatures as shown in Fig. 15.

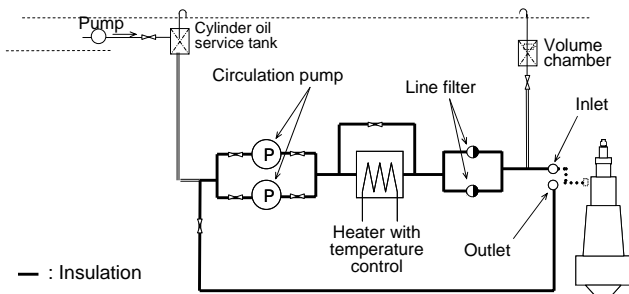


Fig.15 Cylinder oil supply line of SIP system

Fig. 16 shows the example of analysis of spray injection by the SIP system. The left figure shows the cylinder oil consistency distribution on the liner surface, and the right figure shows the spray condition of the SIP system. It turns out

that cylinder oil is uniformly distributed on the liner surface around the spray hitting point.

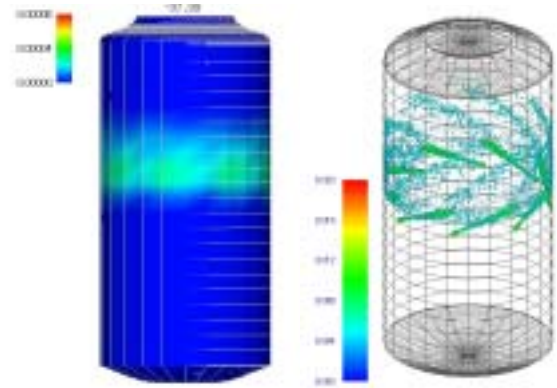


Fig.16 Analysis of spray injection by SIP system

Since the injection hole of the SIP valve is machined to a diameter of 0.3mm, clogging in the injection hole may occasionally occur in a case where the detergency of the cylinder oil is not maintained. For that reason, a fine filter is installed in the cylinder oil supply line. And it is also necessary to execute pipe flashing etc. carefully in a fitting. Furthermore, small particles exist in cylinder oil and there are cases in which they interfere with the SIP valve action. Fig. 17 shows particles in cylinder oil caught in the filter installed in the cylinder oil supply line. These particles are diatomaceous earth and silica gel, and they are a result of the X-ray diffraction analysis. They are used as filter aids or are added for ease of transportation because they increase fluidity, however, it is better to filter them out before they reach the engine inlet because of the possibility they may clog the SIP valve.

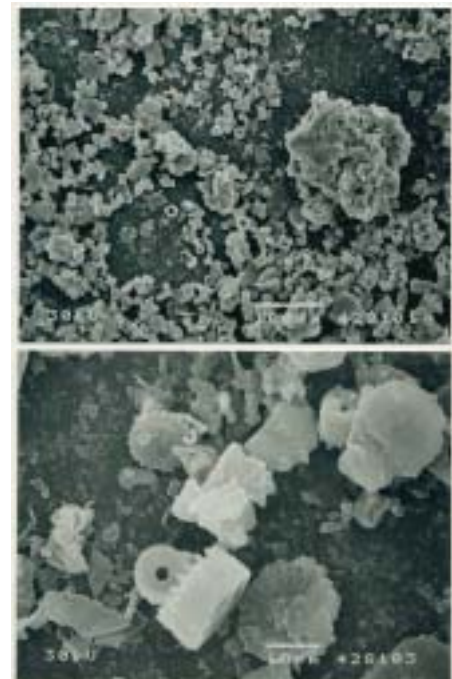


Fig.17 Particles in cylinder oil

Fig. 18 shows the trend of the cylinder oil feed rate of the 7UEC85LSC installed the SIP system. Since the ring and/or liner were renewed with retrofitting work for the installation of the SIP system, the cylinder oil feed rate was temporarily increased at the initial stage. However, it was

reduced down to 0.79 (g/kWh) at present. In addition, the reduction speed of the cylinder oil feed rate is much faster than in the conventional system.

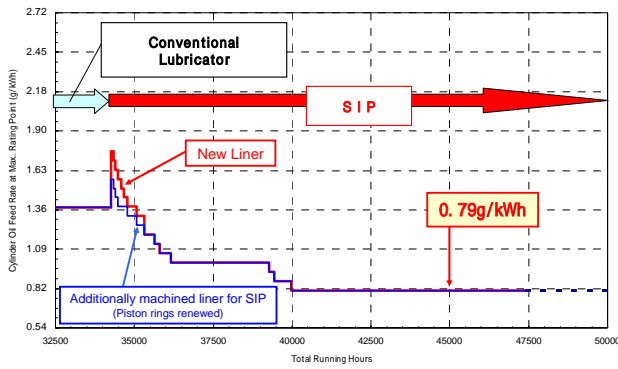


Fig.18 Trend of cylinder LO feed rate on 7UEC85LSC

Fig. 19 shows the liner wear rate trend of said vessel. The wear rate is very low after the installation of the SIP system as well as before installation. One of the SIP system's features is that the wear rate of the ring and liner is small, in spite of a very low cylinder oil feed rate.

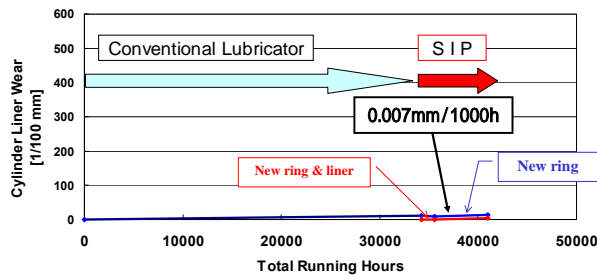


Fig.19 Cylinder liner wear trend on 7UEC85LSC

Fig. 20 shows the good condition of the ring and liner approximately 1 year after being installed in the SIP system on the vessel.

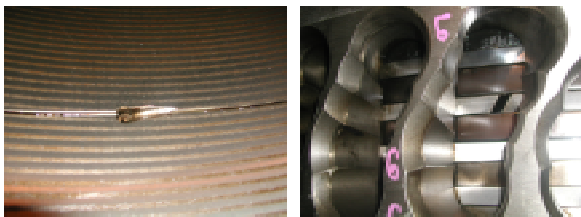


Fig.20 Ring and liner condition on 7UEC85LSC after 6720H of SIP system installation

6. ENVIRONMENT

Annex VI of MARPOL73/78 went into effect on May 19, 2005. The current NOx limit is 17 g/kWh for low speed marine engines of less than 130 rpm. However, in the future we will see progressively stricter regulation, as with other regulations such as EPA. Fig. 21 shows the estimated movement of the regulations and the compliance policy for the UE engine. A water injection system, or an electronically controlled engine can achieve up to a 30% reduction from the present 17 g/kWh. An 80% reduction can be achieved with an electronically controlled engine combined with a water injection system.

Water injection is one of the most effective methods in the NOx reduction approach. There are two kinds of water

injection systems. One is the stratified fuel water injection system, which injects fuel oil and water in layers from the same injection valve shown in Fig. 22. Another is the independent water injection system, which injects the water directly to the cylinder from the independent water valve as shown in Fig. 23. Comprehensive verification tests of the stratified fuel water injection system on an actual ship have been successfully completed, and it is ready to be applied to a commercial engine. This system is mainly applied to a conventional cam shaft engine. In the case of an electronically controlled engine, the application of an independent water injection system is under development.



Fig.21 Compliance policy for NOx regulation

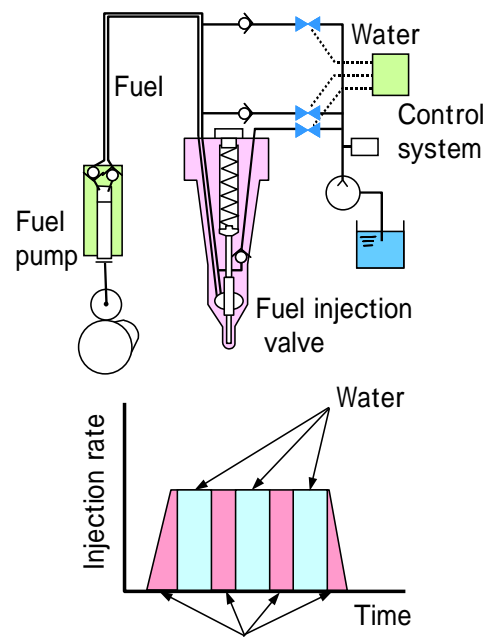


Fig.22 Stratified fuel water injection system

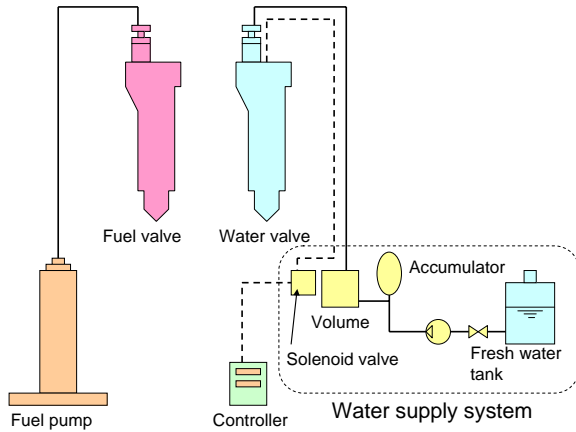


Fig.23 Independent water injection system

7. CONCLUSION

The UEC-LSE is continuously developing to expand the series as the main engine which is able to apply to recent larger and faster ships. In particular, medium and small bore class engines have been developed ahead according to market demands, and we completed the first UEC50LSE in July 2005 and started the development of the UEC45LSE.

A lower cylinder oil feed rate is better for both the economy and the environment, however, maintaining reliability in the ring and liner will be a key point. The SIP system established both a low cylinder oil feed rate and a low ring and liner wear rate by the spray injection of cylinder oil, and a lot of service results have already been piled up.

In terms of the environmental issue, the electronically controlled engine and the water injection system were developed as technologies that will comply with the increasingly severe restrictions. We intend to develop technologies that contribute to the maintenance of the global environment now and in the future.

8. REFERENCES

- [1]K.Sakaguchi, H.Sakabe, Journal of the JIME, Vol.40, No.2 (2005), p53.
- [2]K.Sakaguchi, T.Yamamoto, Journal of the JIME, Vol.40, No.2 (2005), p72.
- [3]H.Sakabe, K.Sakaguchi, CIMAC 2004, Paper No.224