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Lubtronic SIP Promise Remarkably Low Wear Rates With Low CLO Consumption

Topic 05 Components & Tribology

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The Congress programme centres around the presentation of Technical papers on engine research and development, application engineering on the original equipment side and engine operation and maintenance on the end-user side. The topics of the 2016 event covered Product Development of gas and diesel engines, Fuel Injection, Turbochargers, Components & Tribology, Controls & Automation, Exhaust Gas Aftertreatment, Basic Research & Advanced Engineering, System Integration & Optimization, Fuels & Lubricants, as well as Users' Aspects for marine and land-based applications.

ABSTRACT

The recent years’ change in the operation of two stroke marine diesel engines driven by fuel optimization and legislation of exhaust gas emissions, has been the main reason for changes in the design of the two stroke marine diesel engine. The changes are seen in the development of the electronically controlled engine, which enables higher combustion pressure, as well as engines with much longer stroke lengths for more efficient propulsion. The design changes and operation at low loads (slowsteaming) has led to increased corrosion including cold corrosion as a high priority problem. Focus is also on optimization of cylinder oil consumption, as this is a very high cost when looking at the total cost of operating a vessel (OPEX), where the recent years’ solution to challenges with cold corrosion has been to increase the consumption.

The design changes, and challenges with cold corrosion have initiated a joined test between MAN Diesel & turbo, Hans Jensen Lubricators A/S and Costamare on a Costamare owned vessel. The Lubtronic SIP system was tested in different configurations against the standard MDT lubrication. The purpose was to test the Lubtronic SIP equipment on a new, long stroke, electronically controlled engine. The test was started in January 2014 and has until now, accumulated more than 6000 running hours, on a 9S90ME-C TII Mk 9.2 engine with JBB and T/C cut out. This engine has long stroke length and high risk of cold corrosion, because of tier II compliance and fuel oil optimization by EGR, combined with long periods with low load operation (slowsteaming).

The result of the tests on the cylinders equipped with SIP and Lubtronic are remarkable in terms of cylinder lube oil consumption, liner wear and cylinder condition. There was no sign of cold corrosion on the liner surface, despite the combination of high sulphur fuel and low load operation. The conclusion is that the consumption can be lowered, while remaining good wear rates on the new and more corrosive engine designs. Based on the findings, test managed by MDT on another new build vessel has been initiated.

The test was specified by MDT. MDT carried out all the measurements.

The paper will be authored by MAN Diesel and Turbo, Hans Jensen Lubricators A/S and Costamare. The paper will discuss and describe the test setup, go into detail about the test results and conclusion.

INTRODUCTION

The recent years changes in the way a low speed two stroke engine is being run has led to challenges when it comes to lubrication. The below list describes the main factors when it comes to determining correct cylinder lubrication:

- Legislation of exhaust gas emission
- Design changes to the engines
- Low load operation(slow steaming)
- Cold corrosion
- Fuel Types

The challenges will be individually described in the following sub sections:

LEGISLATION OF EXHAUST GAS EMISSION – In the recent years the IMO has introduced legislations towards NOx and SOx emission of engines through MARPOL Annex VI [1]. The legislations introduced NOx Emission Control Areas (NECA) and Sulphur Emission Control Areas (SECA) around North America and northern Europe. In addition to SECA areas, a global max for SOx emission will be introduced.

When it comes to cylinder lubrication the varying sulphur content in the fuel requires changes in the lubrication of the cylinder liners, as one of the main objectives for cylinder oil is to neutralize the sulphuric acid from the combustion of the fuel.

DESIGN CHANGES OF THE ENGINE – The drive towards more effective engines has let to design changes of the slow speed two stroke marine diesel engines. These changes are mainly seen in the development of the electronic engine, which allow more flexible usage and higher combustion pressure [2].

Longer stroke length – The longer stroke length introduced on the MDT S(Super long) and G(Ultra long) type engines in order to improve efficiency of the engines are all designed with standard MDT lubrication. The lubrication level is normally placed approximately 1/3 of the total stroke length from TDC, none return valves injects the lubrication oil in to the ring pack and the lubrication oil is distributed to the liner surface by the piston rings. Distributing the right amount of oil to the top of the liner can be a challenge since the distance from the lubrication point to the TDC has increased.

Increased pressure – The electric engines introduces the ability to increase the combustion pressure [2] this will increase the risk of cold corrosion described below.

LOW LOAD OPERATION – The increased price of the fuel oil combined with increased complexity on the shipping market has to owners running their engines at low loads in order to save fuel. This has an impact on the cylinder liner condition by increasing the risk of cold corrosion as well as the risk of over lubrication. The risk of cold corrosion will be described in the sub section below.

Risk of over lubrication – When the load is decreased it is essential that the cylinder oil consumption is decreased accordingly. Omitting to do so will lead to over lubrication and there is a risk deposits will form on the piston crown causing liner polish/seizure and thereby scuffing.

COLD CORROSION – With the introduction of the new engine designs and the increased use of low load operation, cold corrosion is the biggest issue when it comes to lubricating cylinders of large two stroke marine diesel engines.

There are several factors that influence cold corrosion occurring in an engine. Basically the sulfuric acids formed during combustion condensates on the liner surface. When the pressure, as a result of engine design, is increased and the liner wall temperature is low due to slow steaming, the dew point of the sulfuric acid will increase, and more acid will condensate on the liner surface. Higher concentration of acids requires a higher concentration of alkalinity to ensure proper neutralization of the acids formed.

Cold corrosion is a very complex topic and will not be discussed in detail in this article.

FUEL TYPES – The introduction of the MARPOL Annex VI and different tier requirement means that vessels operating routes going in and out of SECA areas will switch between fuels with normal sulphur content and fuels with very low sulphur content. Changing fuels and thereby sulphur content, changes the need for neutralization of sulfuric acid. In order to deal with this many vessels are carrying two different types of cylinder oil – one for low sulphur fuel and one for high sulphur fuel.

ADJUSTMENT FACTORS – The typical approach to handle the above described factors are to control the feed rate of the cylinder oil and/or also control the BN level of the cylinder oil used.

This paper will show results from a test concluding that using a different technology to inject the cylinder oil will give remarkably low wear rates and also low consumption of cylinder oil.

FIELD TEST DESCRIPTION

A test of the HJ Lubtronic SIP system has been initiated and conducted by MAN Diesel and Turbo (MDT) in cooperation with Hans Jensen Lubricators (HJL), in order to compare the performance of the HJ Lubtronic SIP lubrication system with the MDT lubrication system focusing on cold corrosion and liner wear rates, and also to get MDT approval for the use of HJ Lubtronic SIP on MDT new build engines.

THE LUBRICATION SYSTEMS – The test engine is equipped with two different lubrication systems as described below:

Alpha lubrication pump – The alpha lubrication pump is the lubrication system for MDT engines, when combined with the Alpha injection valve. It is a positive displacement pump, and works by injecting a fixed volume of lube oil to the cylinder. The system regulates the injected amount by skipping up to ten engine revolutions where no oil is injected. The Pump can be seen on Figure 1.

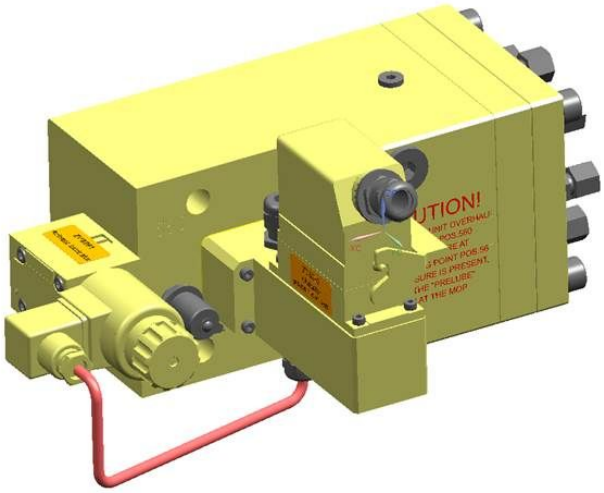

Figure 1: Alpha Lubricator

Alpha injection valves – The alpha injection valve injects the cylinder oil on to the piston, when the piston moves in upwards direction. The injection valves are equipped with two holes horizontally, one at each side, which delivers the CLO tangentially with the cylinder surface on the upper part of the piston. The piston distributes the cylinder oil to the top and bottom of the cylinder liner. See Figure 2.

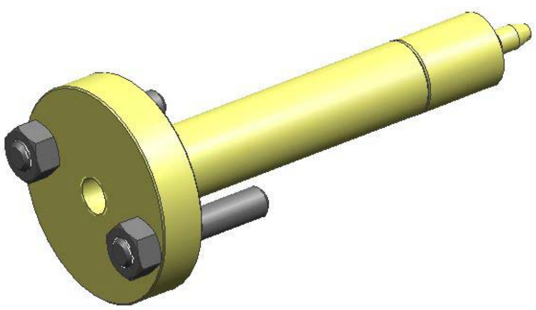

Figure 2: Alpha injection valve

HJ Lubtronic – the HJ Lubtronic lubricator is a positive displacement pump which regulates the stroke length automatically and thereby injects a certain amount of lubrication oil in every revolution. The injection amount is automatically adjusted according to the chosen lubrication algorithm. The HJ Lubtronic lubricator can be seen on Figure 3.

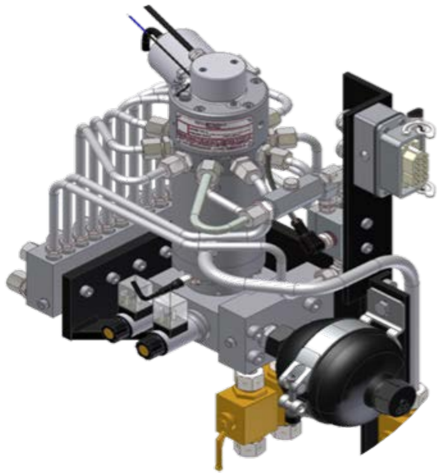

Figure 3: HJ Lubtronic Lubricator

HJ SIP injection valve – The HJ SIP injection valve was firstly presented on the CIMAC congress in 2001 [3] where it proved very low cylinder oil consumption with same or better cylinder wear rates than standard lubrication.

The principle of the HJ SIP valve is related to the distribution of the cylinder oil, by giving a uniform circumferential distribution of the oil with optimal oil consumption. A HJ SIP valve can be seen on Figure 4.

The HJ SIP valve works by injecting the oil at higher pressure which will transform the oil to a spray of droplets being injected tangentially in the direction of the swirl from the scavenge air along the liner wall. The swirl from the scavenge air will help to lift the cylinder oil and distribute the oil evenly around the circumference of the cylinder liner before the piston passes to give even better distribution. The injection angles of the HJ SIP valves are defined in a way that the spray from one HJ SIP valve will cover the area to the next, and make sure there is an overlap of the oil. The injection timing of the HJ SIP valves is defined so that the injection are above the piston, utilizing the oil efficiently by getting the oil where it is needed, and also less oil is blown out in the scavenge air ports.

Figure 4: SIP injection valve

THE TEST ENGINE - The engine chosen for the test was a “corrosive” engine type with the designation: 9S90ME-C9.2TII having 9 cylinders, super long stroke length, cylinder diameter of 900mm, electronically controlled mark 9.2 with Tier II compliance. The engine is part load optimized by exhaust gas bypass (EGB). This specific engine type has increased risk of cold corrosion when running low load operation. Overall parameter for the test engine can be seen on Table 1.

Table 1: Overall parameters for the test engine

Overall engine data:	
Cylinder bore, mm	900
Stroke, mm	3188
Revolutions at MCR, rpm	84
Max. combustion pressure, MPa	17.5
Max. continues rating, kW	52290
Engine configuration	
Monocast liner	
0,3mm PM80 + 0,3 alu-coat piston rings	
Jacket water bypass basic (JBB) liner cooling	
Part-load optimization by EGB	
Variable exhaust valve timing	

TEST TIMELINE – the test started in January 2014 where the vessel was delivered to Costamare, and the HJ Lubtronic SIP system was retrofitted on the engine and was commissioned in May. The cylinder liners for cylinders 1+2 were replaced to new special liners which had mounting holes for the high injection level, at the time of HJ Lubtronic SIP installation. Throughout the test period from January 2014 until today several measurements of the cylinder wear has been made, and based on these measurements and observations, HJ Lubtronic SIP has been approved for use on MDT new build engines on 26th of June 2015. Attendance on the vessel is still being made to check the wear and condition of the liner and piston. The latest was made in January 2016, from which the results in this paper are based on. The time line for the test can be seen on Figure 5.

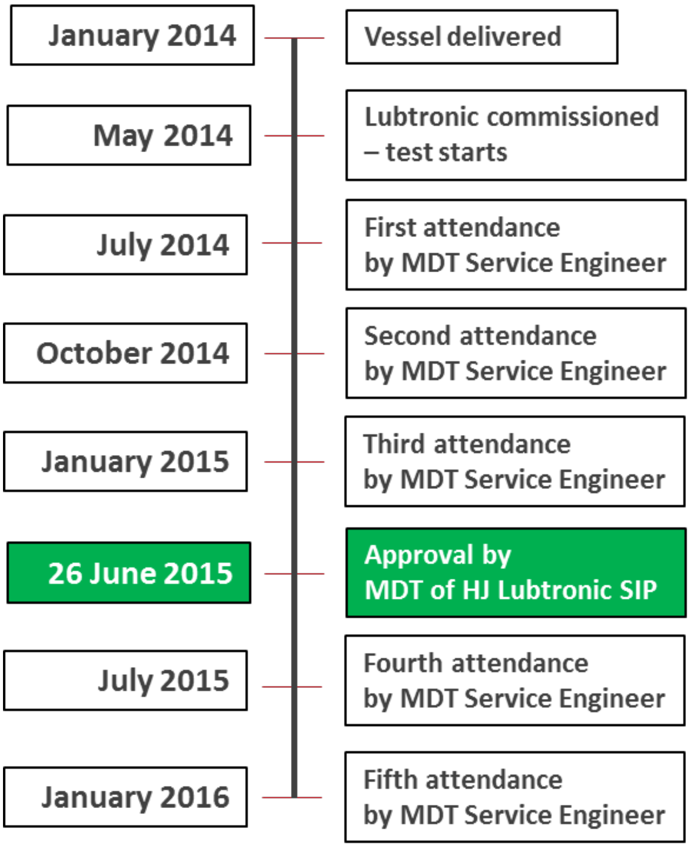

Figure 5: Test timeline

OPERATION PATTERN OF THE TEST VESSEL – The vessel has been operating a route from Asia to South America in the start of the test which meant that the sulphur content of the fuel varied between 1% to 3.4%. Now it is operating a route from Africa to Europe going. This means that the sulphur content of the fuel is varying between 0.1% and 3.4% due to the operation inside the ECA in northern Europe. The load of the engine is varying between 10-75% load with average of 35%. The graph on Figure 6 shows how much the sulphur, ACC factor (FRF) and feed rate varies.

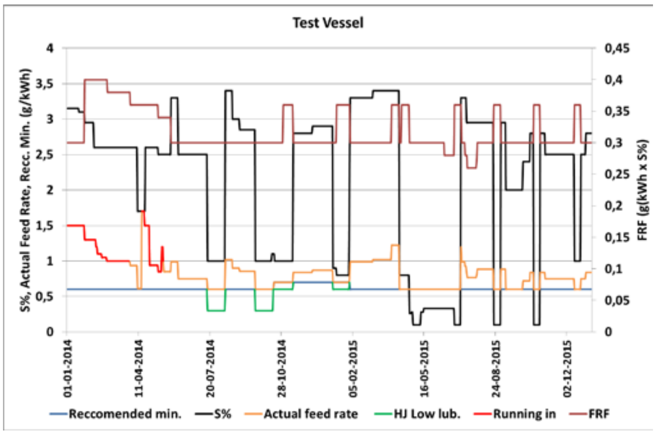

Figure 6: Operation pattern

The BN level of the cylinder oil used have been varied throughout the test period

- BN 70 from start until July 2014
- BN 100 cylinder oil onwards
- BN 40 cylinder oil when sailing inside ECA.

Feed rate – Both systems have been using the alpha ACC algorithm to control the feed rate based on the load and the sulphur content of the fuel. There have been a few exceptions, which are described below:

- The HJ Lubtronic system did not have a minimum feed rate adjustment in the beginning of the test, which meant that for two periods of about one month each, the liners with HJ Lubtronic had a feed rate of 0.3 g/kWh while the reference units had a feed rate of 0.6 g/kWh.
- MDT recommended after the inspection made October 2014 that the reference units minimum feed rate should be increased to 0.7 g/kWh, due to too dry liners.
- After the inspection made in July 2015 MDT concluded that the ACC factor of 0.26 g/kWhS% seems to have negative effect for all units except 1+2.

THE TEST SETUP

Unit 1+2 – These are equipped with HJ Lubtronic SIP. The injection level of the HJ SIP valves is for these units 1/8th of the stroke length from TDC, chosen by MDT. The use of the high level injection was a test from MDT, as it isn't standard lubrication level [4]. See Figure 7 for illustration of the setup.

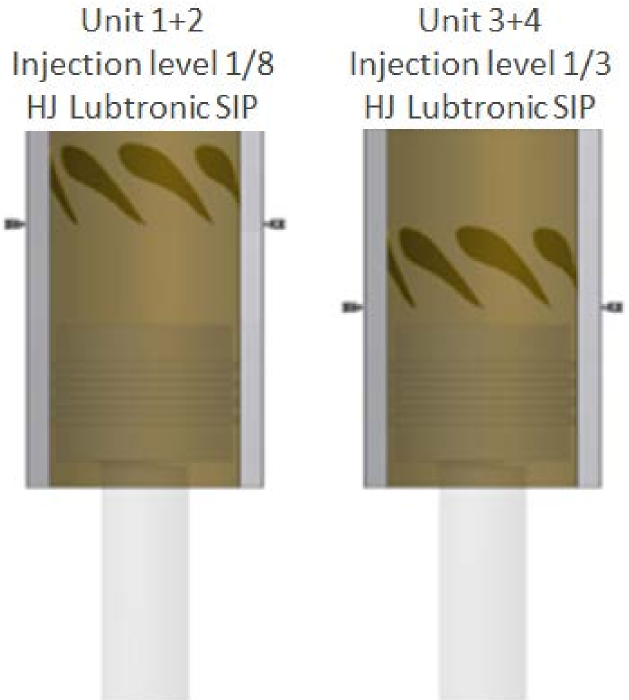

Figure 7: Setup of unit 1+2 & unit 3+4

Unit 3+4 – These units are equipped with HJ Lubtronic SIP, with the SIP valves positioned 1/3rd of the stroke length from TDC which is the standard position [4]. Please see Figure 7 for illustration of the setup.

Unit 5+6 – These units are equipped with HJ Lubtronic lubricator and alpha injection valves. The timing of the valves is same as that of the reference units. The main difference between these units and the reference units are that the oil is injected with higher frequency and in most cases every revolution of the engine. The alpha injection valves are positioned 1/3rd of the stroke length from TDC which is the standard position [4]. See Figure 8 for illustration of the setup.

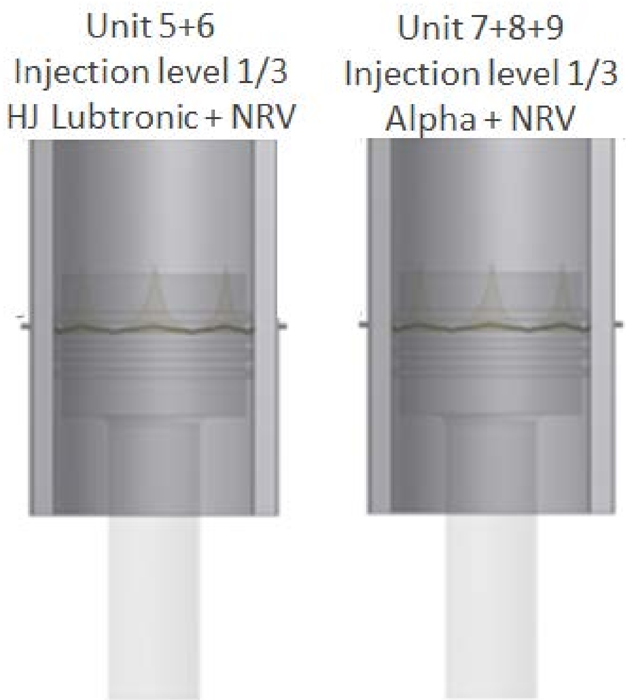

Figure 8: Setup of unit 5+6 & unit 7+8+9

Unit 7+8+9 – These units are equipped with Alpha injection pump in combination with alpha injection valves for injection of the oil. The alpha injection valves are positioned 1/3rd of the stroke length from TDC. See Figure 8 for illustration of the setup.

RESULTS

MEASURING METHODS – The wear of the liner was measured manually, by lifting the top cover and using a micrometre gauge to measure the diameter at 11 predefined points down the liner. The measuring points were both on the Fore-Aft direction and Exhaust – Manoeuvre direction. Figure 9 shows the measuring points. The wear results of the liners are based on the maximum wear measured.

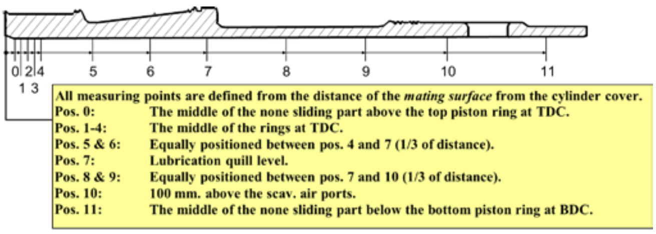

Figure 9: Measuring points

MAXIMUM WEAR – Table 2 shows the maximum wear for all the units from the latest measurements made 6th of January 2016.

Table 2: Maximum Wear

Unit	Liner Running Hours	Maximum wear [mm]
1	10,319	0.19
2	10,139	0.16
3	11,978	0.74
4	11,978	0.46
5	11,978	0.85
6	11,978	0.71
7	11,978	0.85
8	11,978	0.59
9	11,978	0.36

WEAR RATES –Table 3 shows the average wear rates for the system.

Table 3: Average wear rates

Unit	Liner Running Hours	Wear rate mm/1000hr
1 / 2	10,229	0.02
3 / 4	11,978	0.03
5 / 6	11,978	0.07
7 / 8 / 9	11,978	0.05

LINER PHOTOS – The liners was photographed during the measurements:

Figure 10: Photo of liner number 1 after 10319 running hours – machining marks visible in the top

Figure 11: Photo of liner number 4 after 9260 running hours – machining marks visible 300mm from the top

Figure 12: Photo of liner number 8 after 4600 running hours – machining marks not visible

LINER WEAR

Units 1+2 - has lower maximum wear than the remaining units. These units have the lowest average wear rate in the engine. The wear rate is below half that of the reference units. The low maximum wear and the low wear rates on units 1+2 are confirmed by the photos taken inside the liner during the measurement where the liner machining marks still are visible. Unit number 2 is similar to the photo shown on Figure 10. The low maximum wear indicates that it is possible to lower the feed rate for these units, while maintaining low wear and cylinder condition. This was concluded at the attendance in July 2015 and also in January 2016 where the wear was so low that there was a risk of smirring. Therefore MDT recommended the vessel to lower the consumption for these units.

Units 3+4 - has the same level of maximum wear as that of the reference units. The units has low wear rate compared to the reference unit. It should be noted that these units had already seen the initial wear from alpha injection system when the HJ SIP injection valves was installed, therefore the initial wear has been deducted from the result of the wear rates on these units. Figure 11 shows unit number 4 after 9260 running hours. The low wear rates are confirmed by machining marks being visible from about 300mm and down. Liner number 3 is similar.

Units 5+6 – are above the level of the reference units. It is the author's opinion the reason for the high wear could be caused by two things:

- The two periods where the feed rate was down to 0.3 g/kWh.
- The higher frequency of injection from the HJ Lubtronic lubricator means that less oil are injected in each injection and that could lead to less effective distribution of the oil with the Alpha injection valve.

Units 7+8+9 – Has a large deviation in the maximum wear, but all are below the recommended maximum wear from MDT. The units have half the wear rate that MDT recommends as the maximum wear rate, which is 0.1mm/1000h. The picture on Figure 12 shows unit 8 after 4600 running hours, this is similar to the remaining unit and the machining marks were worn down after 4600 running hours.

PISTON RING WEAR – The piston ring wear and condition on all units were good. The condition of the piston rings on unit number 1 can be seen on Figure 13.

Figure 13: Piston ring condition on unit number 1 after 10319 running hours.

CONCLUSION

The result of the tests on the cylinders equipped with HJ SIP and HJ Lubtronic in combination is remarkable in terms of cylinder lube oil consumption, liner wear and cylinder condition. The remarkable result is achieved despite operation with varying sulphur content in the fuel and low load on a newly designed engine.

MDT observed that SIP lubricated units was properly lubricated with less oil than the remaining units.

The combination of the HJ SIP injection valve and the HJ Lubtronic lubricator is proven to be an effective lubrication system, controlling the amount of cylinder oil injected per stroke and ensuring an optimal distribution of the oil on the cylinder liner wall.

Based on the findings, test of HJ SIP valves in combination with Alpha MKII lubricator, managed by MDT on another new building vessel has been initiated.

DEFINITIONS

HJ	Hans Jensen
SIP	Swirl Injection Principle
MARPOL	International Convention for the Prevention of Pollution from Ships
SECA	Sulphur Emission Control Area
NECA	NOx Emission Control Area
SOx	Sulphur oxides
NOx	Nitrogen oxides
MDT	Man Diesel and Turbo
EGB	Exhaust Gas Bypass
TDC	Top Dead Center
BN	Base Number
MCR	Maximum Continues rating
JBB	Jacket water bypass basic
ACC	Alpha Adaptive cylinder oil control
CLO	Cylinder Lube Oil
NRV	Non-return valve

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