Service experience

MAN Energy Solutions
Future in the making

MAN B&W two-stroke engines

Contents

Introduction

MAN Energy Solutions has introduced MAN B&W dual-fuel engines (ME-GI/E and ME-LGIM/P) for liquefied natural gas (LNG), methanol (MeOH), ethane (LEG), and liquefied petroleum gas (LPG).

The range of application of these engines has expanded from main engines on LNG, methanol, and LPG carriers to cover the full range of vessel types.

Dual-fuel service experience

ME-GI service experience

ME-GI Mk. 1 vs. ME-GI Mk. 2 design
When comparing Mk. 1 and Mk. 2 designs of the ME-GI engine, several improvements have been implemented in the Mk. 2 design:
- ME-GI Mk. 2 has only one chain pipe.
- Resume valve, purge/blow-off and non-return valves have been omitted.
- New gas injection valves, where the supply of control and sealing oil has been led through bores in the cylinder cover, making high-pressure pipes obsolete.

The hydraulic interlock has been changed by adding an extra valve, the electronic gas injection block (ELGIB) valve. The window valve (WV) has been designed with one-step hydraulic actuation, and the sealing on the connection pieces has been changed to axial seals. A window valve forced close (WVFC) has been introduced, and a gas channel relief valve (GCRV) has been added to the ME-GI Mk. 2 design. All ME-GI Mk. 2 changes have been introduced to simplify the design. Hereby both reliability and cost have been addressed.

Pilot injection valves (PIV), with control valve, sludge valve, sensor, and high-pressure (HP) pipes, are standard on ME-GI Mk. 2 engines.

We have added a sealing oil block valve (SOB) and a sealing oil sensor to the ME-GI Mk. 2 to accommodate single-cylinder gas cut-out. Fig. 1 illustrates the ME-GI Mk. 2 gas block design.

Pilot injection valve
The introduction of the PIV has been successful, see Fig. 2. Not only has the specific pilot oil consumption (SPOC) been reduced considerably, but the safety margin against gas shutdown due to missing gas ignition has also improved significantly.

The reduced lift of the cut-off shaft only allows injection of oil through the two small atomising nozzle holes (Fig. 3).

When injecting through the two small holes only, the amount injected will be kept at a low level and the duration will be longer. The longer injection duration gives a more reliable gas ignition.

ME-GI Mk. 2 gas cylinder cut-out
Based on feedback from engine operators, we have introduced a new feature with the ME-GI Mk. 2. The new gas cylinder cut-out (GCCO) feature enables the engine to continue running on gas even if one cylinder is unable to run on gas.

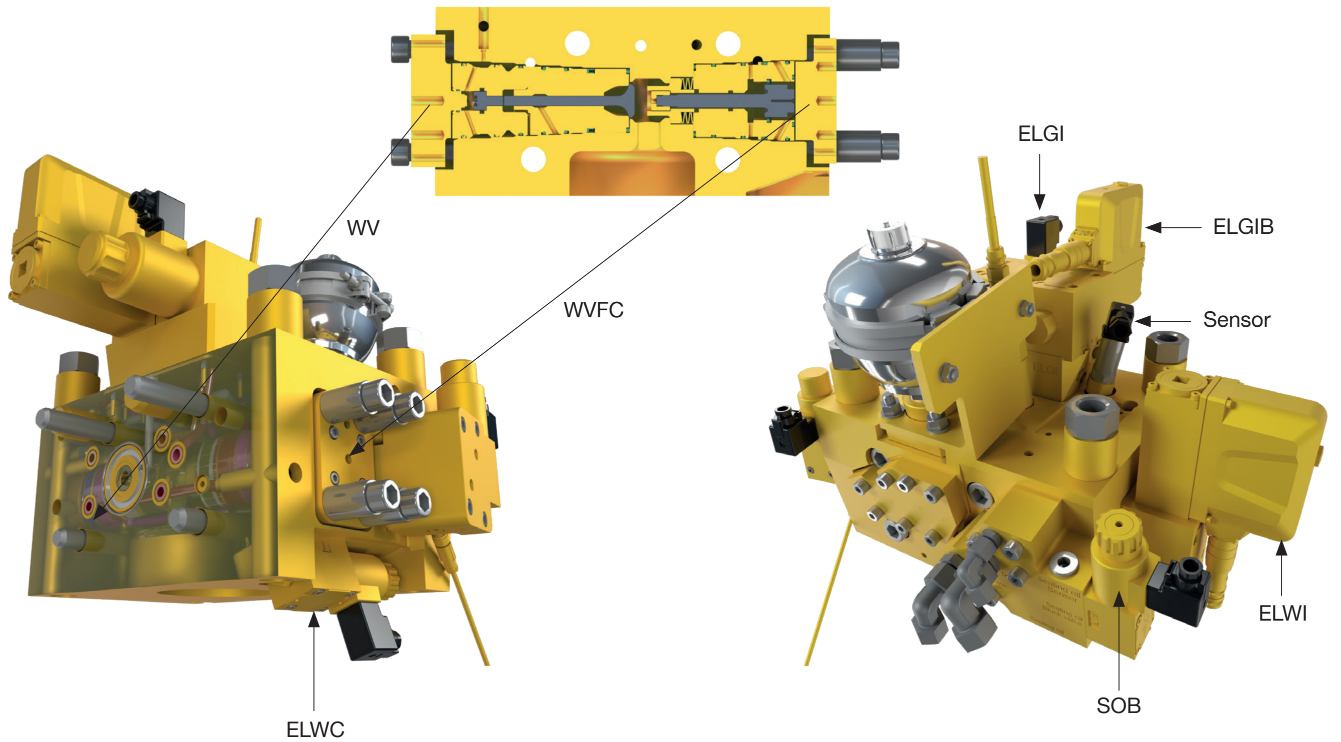


Fig. 1: ME-GI Mk. 2 gas block design

A hazard and operability study (HAZOP) was made to determine which failure scenarios would allow GCCO. The HAZOP identified that GCCO would be allowed with one of the following components failing:

1. Electronic window (ELWI) valve
2. Electronic gas injection (ELGI) valve
3. Electronic window control (ELWC) valve
4. ELGIB.

If both ELGI and ELGIB valves fail on a cylinder, gas operation on the remaining cylinders with GCCO is not allowed.

Only one cylinder can be cut out of gas operation and run on fuel oil instead. Fig. 4 shows gas cut-out of cylinder No. 8 via the MOP and the second fuel cylinder sensor unit (SCSU) gas channel sensor measurements on an 11G90ME-C10.5-GI Mk. 2 engine.

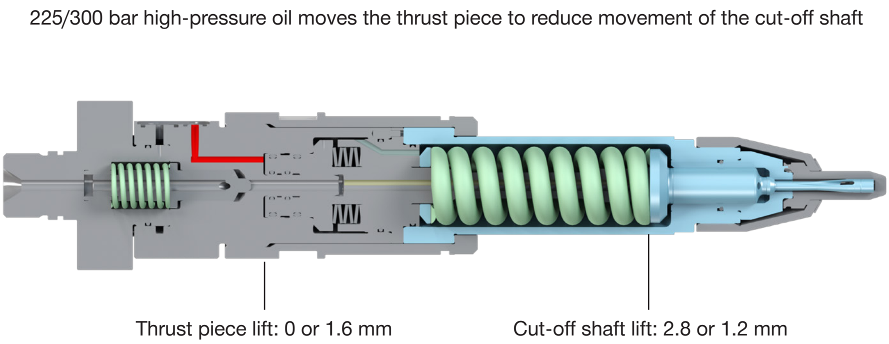
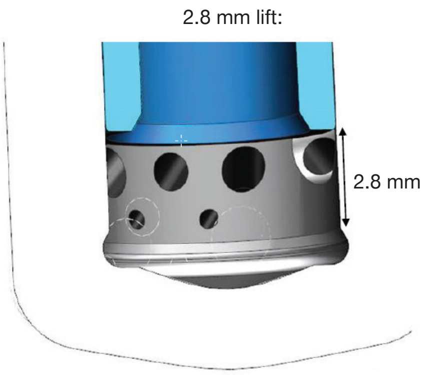


Fig. 2: Pilot injection valve



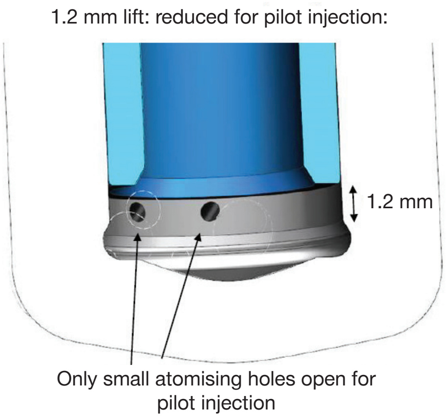


Fig. 3: Cut-off shaft with full lift as well as reduced lift

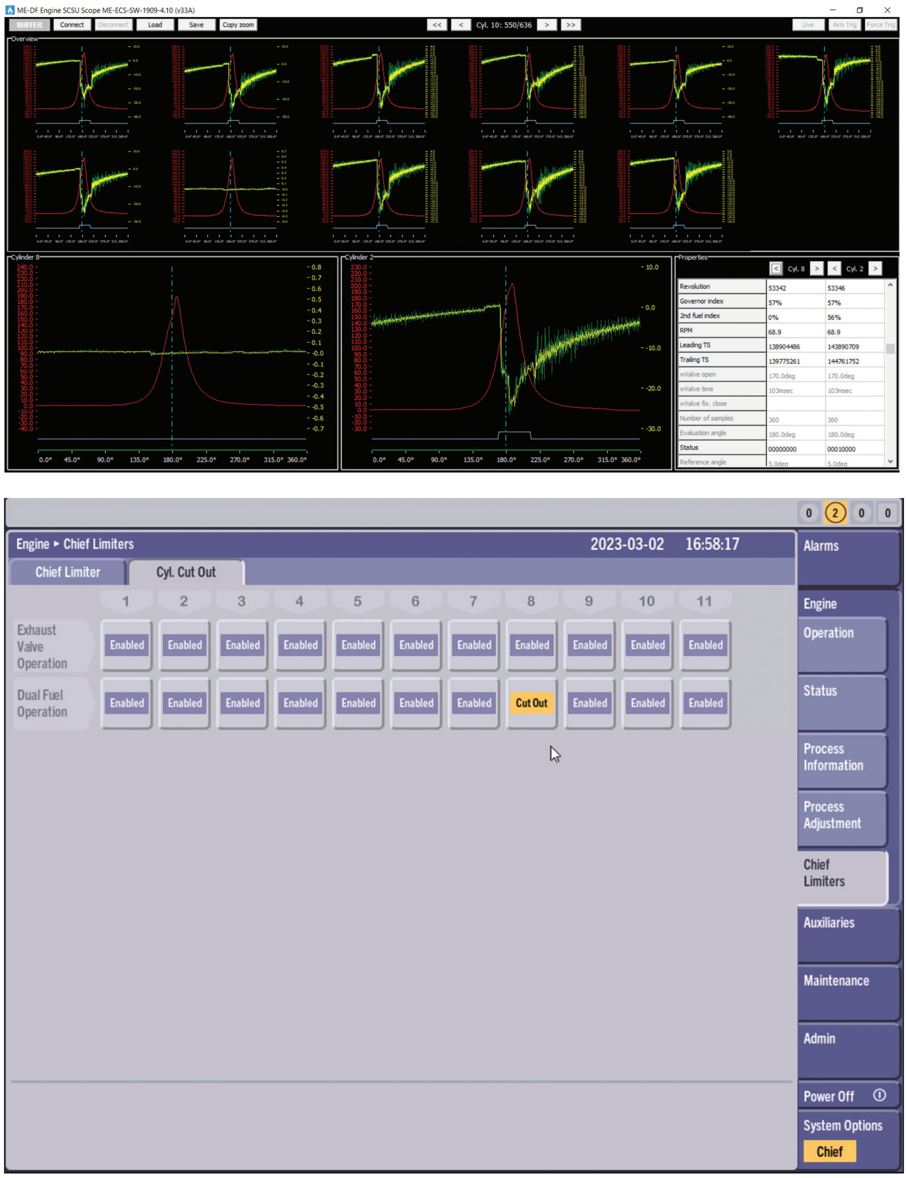


Fig. 4: Gas cut-out of cylinder No. 8 via the MOP and the SCSU gas channel sensor

ME-LGIM service experience

This section outlines the service experience from three generations of 50-bore LGIM engines.

A few vessels have reported a high hydrocarbon (HC) level in the outer pipe after approximately 200 hours of methanol running. Inspections showed that the connection piece seals were damaged, and O-ring seals will therefore replace the U-cup seals, see Fig. 5.

A new and stronger thrust piece design combined with a new suction valve forms a new one-piece solution of the thrust piece-suction valve design, see Fig. 6.

The new thrust piece-suction valve design has been rolled out on all 50-bore LGIM engines.

The most challenging component on the 50-bore LGIM engines has been the gas nozzles. Stainless steel nozzles, as shown in Fig. 7, have been provided for the main part of the operation time for all three generations of 50-bore LGIM engines.

However, in Tier III mode, the third generation of 50-bore LGIM (LGIM-W) engines uses either water emulsified in fuel or water in methanol to achieve Tier III compliance. The much longer injection periods used in this operating mode give rise to increased thermal fatigue stress on the nozzles, and examples of cracks are seen. Fig. 8 shows a case where five nozzles broke more or less at the same time after a period of Tier III operation in a NO_X emission control area (NECA).

At the time of writing, tungsten material is being tested as an alternative to stainless steel nozzles.

Further development of the LGIM gas nozzle specifically designed for the G95-LGIM engine is in progress. This design includes a heat shield, as illustrated in Fig. 9.

ME-LGIP service experience

Especially the 60-bore ME-C-LGIP engines have caused issues in service. 60-bore LGIP engines are available in three different versions:

a. G60ME-C9.5
b. S60ME-C10.5
c. G60ME-C10.5

For a and b, a major redesign has been made of all hydraulic pipes (ELWI actuation pipes, control oil pipes, and sealing oil pipes) and the new pipes have entered into operation on engines in service.

Furthermore, a safer pipe connection design for both sealing oil and control oil pipes has been introduced on all 60-bore engines, see Fig. 10.

A new material has been introduced for the sealing O-ring on the thrust piece. The old HNBR type O-ring suffered “explosive decompression” when the

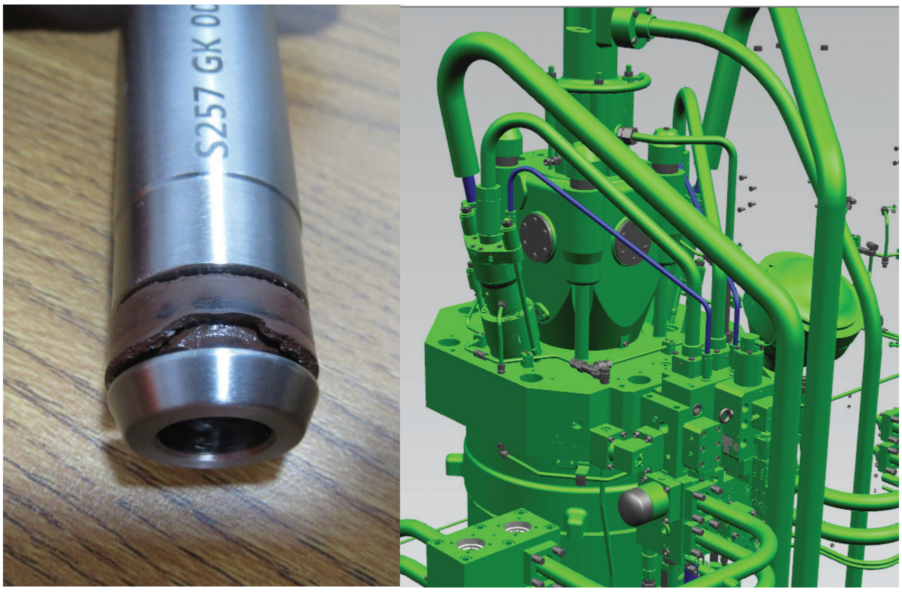


Fig. 5: New O-ring seals for the connection piece

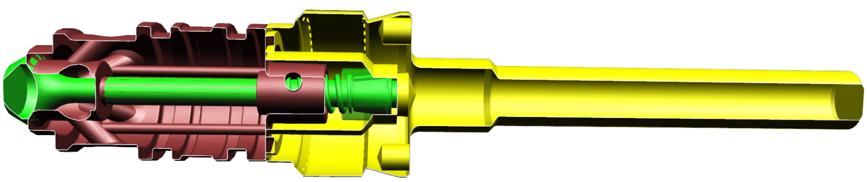


Fig. 6: New one-piece thrust piece-suction valve design

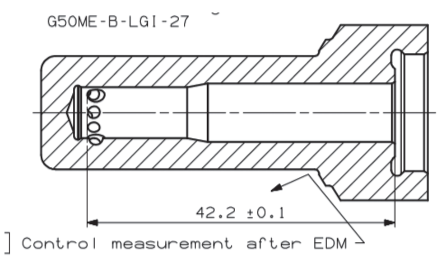


Fig. 7: Stainless steel gas nozzles

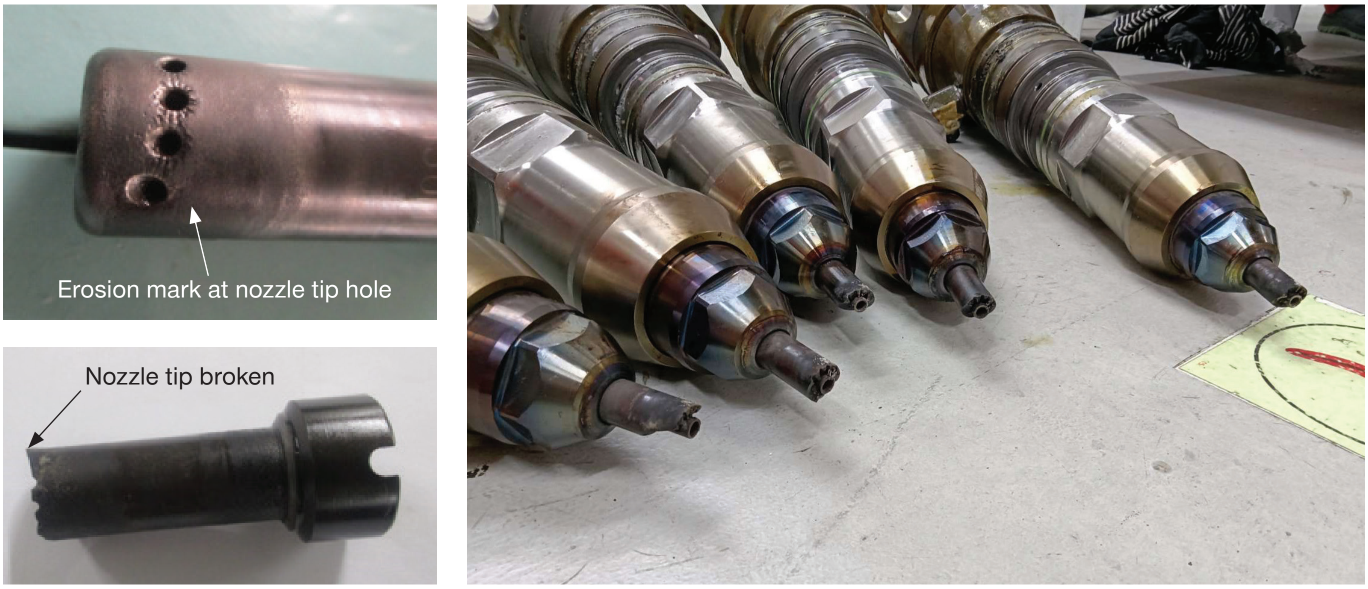


Fig. 8: Nozzle failure after a period of Tier III operation with water addition

Fig. 9: LGIM gas nozzle with heat shield for G95-LGIM engines

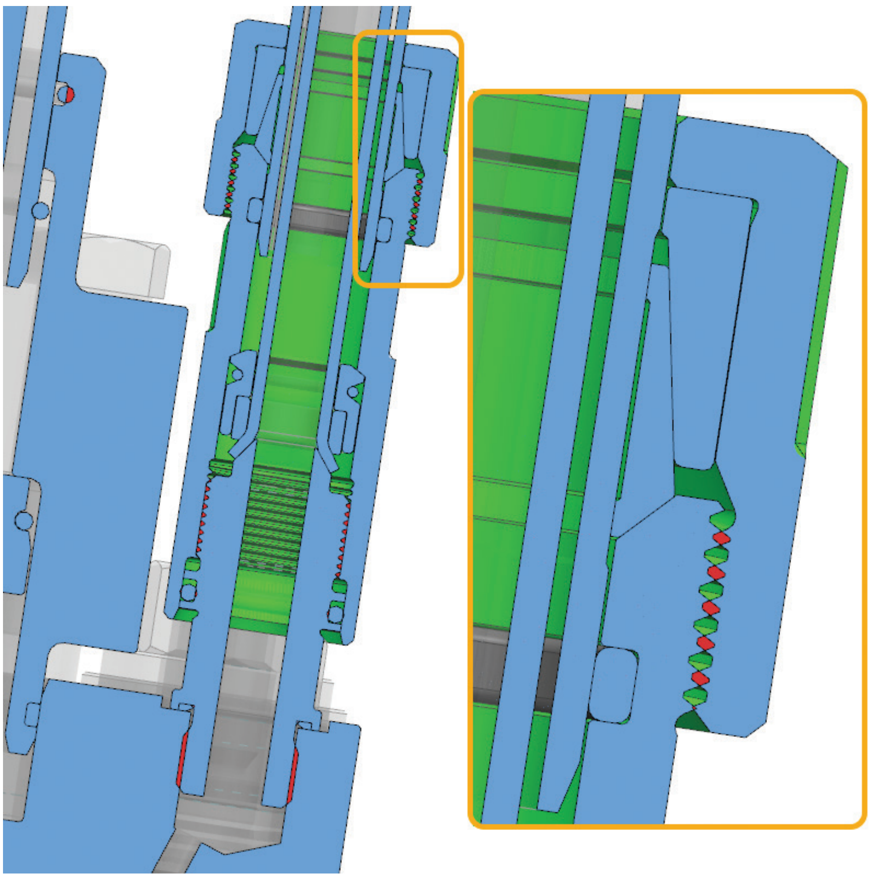


Fig. 10: New pipe connection design for sealing oil and control oil pipes

pressure was rapidly released, see Fig. 11. A new O-ring design made of PU material (Fig. 11) has demonstrated good service results and is now being introduced as the standard on all engines.

The integrity of this thrust piece O-ring will also reduce the sealing oil consumption and, thereby, also reduce the risk of nozzle clogging.

Nozzle clogging has been one of the main obstacles for reliable LPG operation on the LGIP engines. Fig. 12 shows the redesigned nozzle.

The updated nozzle is slightly longer (5 mm), and the central main bore is also longer. The new nozzle design has reduced the need for removing clogged material in the nozzle holes.

In order to make the fuel booster injection valve with control oil needle control (FBIVP) more reliable with respect to de-aeration, a new concept comprising the following parts will be introduced:

1. New FBIV top cover
2. New piping to low-pressure supply (LPS) and drain
3. ELGI adapter block.

The new parts can be seen in Fig. 13.

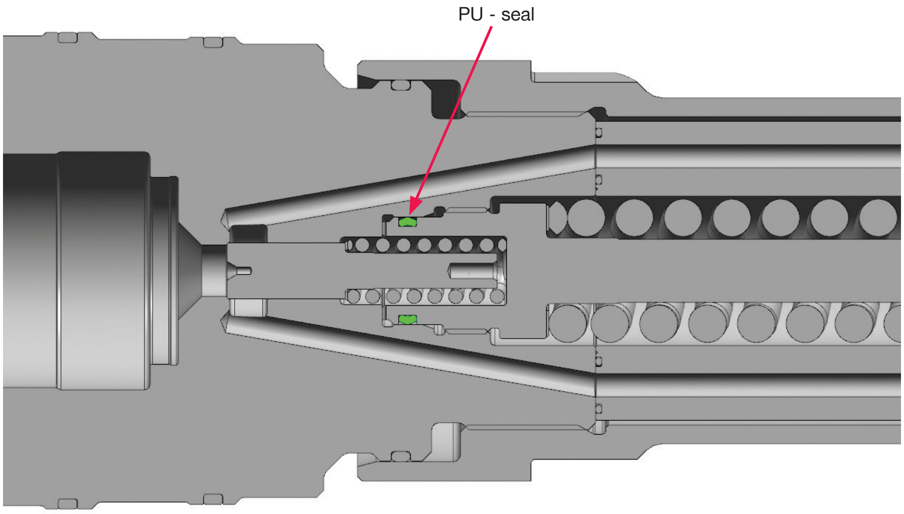


Fig. 11: Updated O-ring material for the thrust piece

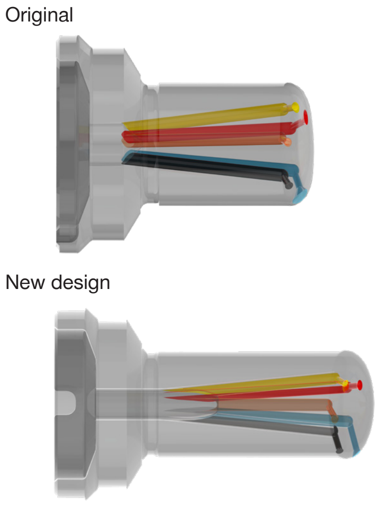


Fig. 12: Redesigned nozzle for LPG operation

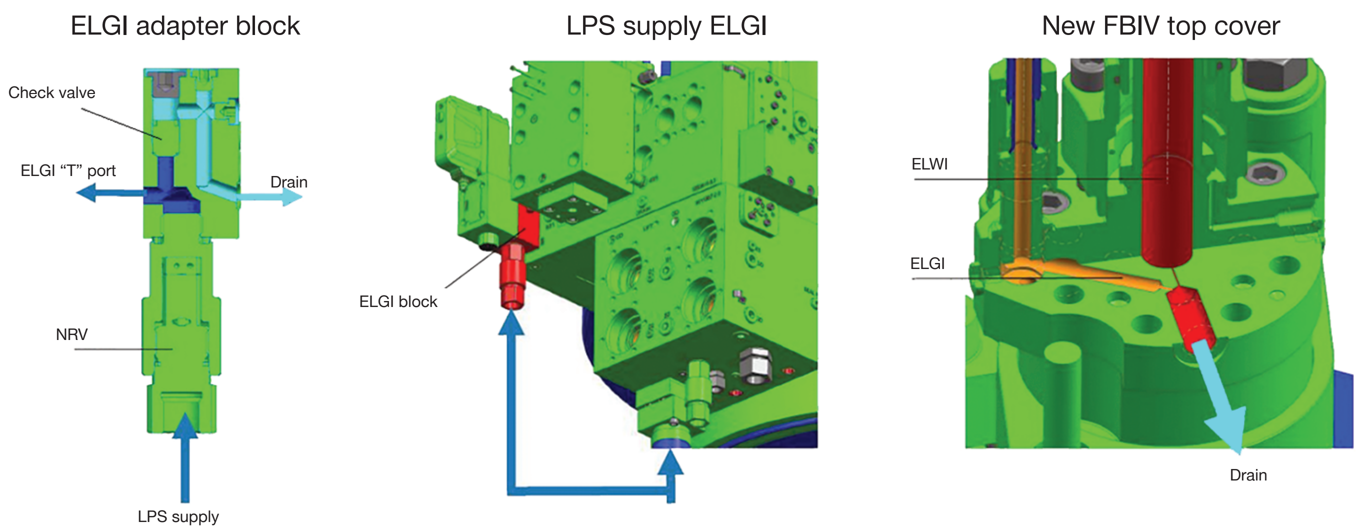


Fig. 13: New ELGI adapter block, piping (LPS and drain), and FBIV top cover

Cylinder condition with focus on dual-fuel engines

The number of engine running hours spent in a low-sulphur regime has increased significantly compared to pre-2015 values. This is mainly the result of the global IMO 0.50% S fuel limit (2020) and the 0.10% SECA (2015), but it is also the result of the availability of dual-fuel engines operating on the new low-sulphur fuels. This change affects cylinder condition and wear patterns.

The outlook is positive. Low wear rates, longer times between overhaul (TBO), and longer component life times are possible when using a cylinder oil with sufficient cleaning ability.

Wear types

There are a number of different wear types, the most commonly occurring inside the combustion chamber are:

Abrasion
Abrasion is created by hard particles that are mixed into the cylinder oil film, causing wear on piston rings, piston crown, and cylinder liner. Cat fines (catalytic fines) are small, very hard particles originating from the refining process. They can wear down the engine very fast, and must be removed by a fuel cleaning system on board the ship.

Corrosion
Corrosion occurs when acid is present in the combustion chamber. Sulphuric acid is formed when operating on sulphur-containing fuels. The acid must be neutralised to prevent harm to the components. High base number (BN) cylinder oils are excellent for this purpose.

Adhesion
Micro-seizures or scuffing may be initiated if the lube oil film is disturbed and contact between the metal surfaces occurs.

The case studies presented in this paper show that the corrosion and abrasion wear types are almost absent in dual-fuel engines operating on <0.10% S fuels, <0.50% S fuels, and LNG. The reason is the low concentration of sulphur in the fuels and the possibility to remove cat fines efficiently from <0.50% S fuels, which generally have a lower viscosity than high-sulphur fuel oils (HSFO). And <0.10% S fuels and LNG do not contain cat fines.

Also, service experience has not shown any increase in the adhesive wear.

ME-GI service experience pre-0.50% S limit

Many of the first ME-GI engines started using high-sulphur fuel as pilot fuel and for single-fuel mode operation. The challenges with wear on cylinder liner, piston, and piston rings were similar to those seen for single-fuel engines operating on high-sulphur fuel. During this type of operation, most wear comes from corrosion, abrasion (from cat fines), and adhesion.

The high neutralisation ability of high-BN cylinder oils keeps the corrosive wear in control. Proper fuel cleaning that removes cat fines is key to keeping abrasive wear low. When combining an optimised cylinder oil feed rate and condition-based maintenance, the expected TBO can be met and even prolonged. But cold corrosion and abrasive particles in the fuel, nonetheless, lead to continuous wear that has to be monitored continuously.

Changed fuel – changed wear pattern

When operators started to prepare for the IMO 0.50% S fuel limit and bunkered <0.50% S fuel and <0.10% S fuel for use as single or pilot fuel, wear patterns started to change. One example is that the running-in coating (alu-coat) on the piston rings remained on the surface much longer compared to high-sulphur operation. The wear-down rate of the cermet coating was also reduced.

The corrosive wear was reduced considerably when using LNG or methanol and <0.50% S fuel or <0.10% S fuel as pilot fuel. The abrasive wear also decreased because of the very low content of abrasive material in LNG and methanol.

With less sulphur, the need for neutralisation in the cylinder oil is reduced, whereas the importance of other properties increases, such as the

Fig. 14: Condition after test bed when A. using a low-BN cylinder oil, B. using a 70-BN cylinder oil. Notice the difference in the piston ring land cleanliness.

cleaning ability of the lubricant, as the free movement of the rings in the grooves is crucial.

This paper describes how low-sulphur fuels and proper lubrication can facilitate the introduction of a new maintenance strategy (preventive maintenance) and realise dock-to-dock lifetimes of the piston rings.

Keeping the balance – cylinder condition

The basis for a good cylinder condition requires that the engine process, the design of the parts, e.g. piston rings, the lubrication, and the fuel all fit together. When one or several of these parameters change, the balance between acceptable or less acceptable cylinder conditions changes, and the time between overhaul (TBO) may change and actions have to be taken.

One example was the cold corrosion challenge in 2012 and later, following the introduction of new and more efficient engines with a higher part-load cylinder pressure (Mark 8 and newer) combined with changes in operating conditions. These changes led to an increased corrosive tendency of the engines. Design changes were made and the balance was partially restored. The real game changer was the introduction of 100-BN cylinder oil. It could keep the corrosion in control during high-sulphur fuel operation, and thereby reestablish the balance.

Hence, cylinder lubricating oil has always been an important tool in obtaining a good cylinder condition and an acceptable TBO.

Deposits in ring pack area
The balance shifted again some years ago. After utilising the low-BN cylinder oils available at the time, a severe deposit build-up was experienced on ring lands, in ring grooves, and on the back of the rings leading to stuck piston rings. The engines affected by this issue were the optimised and fuel-efficient ME-C and ME-GI 9.5 engines operating on low-sulphur fuel. The issues were detected on test bed, during sea trial, and later in service. The deposit build-up and damage was partly attributable to the cylinder oil, partly to the operating conditions, and partly to the engine design.

Service experience from other engine types also showed that many of the previous cylinder oils aimed for low-sulphur applications had difficulties keeping the ring pack area in good condition. This issue meant extra challenges and expenses to both engine owners and licensees.

Measures introduced
To solve this issue, MAN Energy Solutions reintroduced the use of 70–100 BN cylinder oils on shop test and sea trial, regardless of fuel type. In addition, 70–100 BN cylinder oils were recommended for certain engine types during the initial 2,000 running hours to prevent deposit-formation and ensure the free movement of the rings.

Another measure was to start using 100 BN as a cleaning lubricant and then switch back to the low-BN product, a so-called alternation regime.

However, deposit formation is a quick process. It occurs within a few days of operation, whereas the cleaning process is usually slow and steady, if an appropriate cylinder oil and appropriate feed rates are employed. A spotless condition is not required; however, the piston ring design and the lubricant should cooperate to minimise the deposit build-up. If deposits have been formed, the lubricant should preferably support deposit removal.

The actions taken have improved the deposit situation, see Fig. 14.

Initiative – the controlled pressure relief three-ring pack
To improve the cylinder condition and cleanliness, and also improve the margin against scuffing, MAN Energy Solutions introduced the controlled pressure relief (CPR) three-ring pack. The rings are all coated with a cermet coating that provides a more seizure-resistant surface against the liner.

The rings are designed with gastight finger locks on all three rings. The gas leakage is managed by the controlled leakage (CL) grooves on the two upper rings, whereas the third ring is gastight. Thereby, the gas leakage is reduced to a minimum. Another major benefit of this design is that the leakage through the piston rings is not affected by cylinder liner or piston ring wear. The pressure distribution is thus kept constant throughout the entire service life of the components.

This ring design reduces the risk of extensive deposit build-up on ring lands, the back of the rings, in the ring grooves, and to some extent on the top land, see Fig. 15.

Initiative – raise the performance of cylinder oils
Another initiative was presented to the lube oil industry under the slogan ”let's

Fig. 15: Comparison between A. a four-ring pack and B. a three-ring pack on an ME-GI engine. The cleanliness is improved by changing the ring pack.

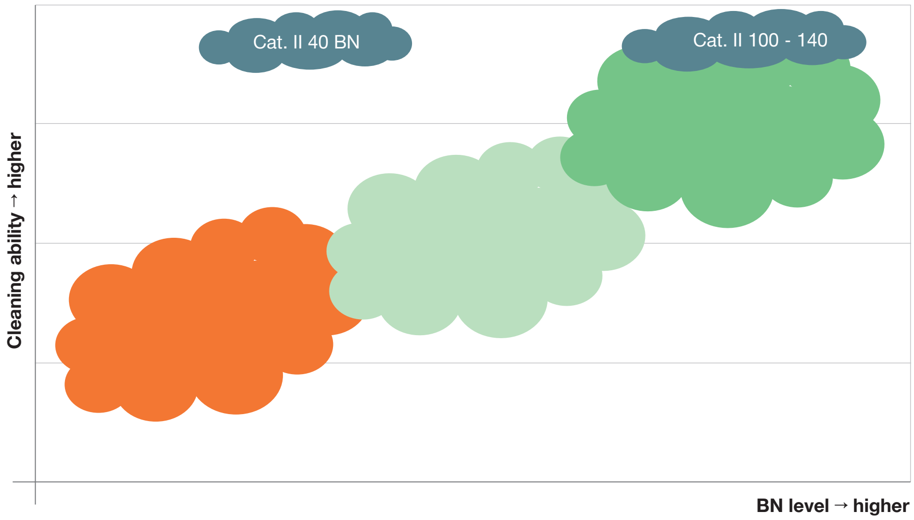


Fig. 16: Schematic representation of the perceived relationship between BN level and cleanliness and the new category II 40-BN, 100-BN, and 140-BN lubricants

raise the performance level of cylinder oils". Fuels are changing, and engines are operating at constantly increasing pressures, hence, it is only natural that lubricants must also change.

Scope: An excellent overall performing 40-BN cylinder oil with a special focus on cleaning ability. A cleaning ability equal to or better than a 100-BN cylinder oil led to the development of a category II 40-BN cylinder oil.

Lubricate, protect, and clean

The cylinder oil should be designed to:

1. lubricate the piston and liner
2. reduce friction
3. introduce wear protection
4. minimise risk of seizures
5. neutralise acids and oxidation products in accordance with the fuel used and engine requirements
6. flush to keep the piston, piston rings, piston crown, ring lands, ring grooves, and liner clean.

The above list can be summarised in three words: lubricate, protect, and clean. The main mission of a cylinder oil is to "protect". Without a lubricant, the engine will be subject to acute wear, and major overhaul will be necessary. The oil film separates the moving surfaces and protects the rings and the liner from each other. Inadequate protection may result in increased wear if the situation is not managed.

Aggressive corrosive wear will occur if a low-BN lubricant is used together with a high-sulphur fuel. The solution is to change to a high-BN cylinder oil and optimise the feed rate.

"Lubricate" covers the lubrication of piston and liner, and the reduction of friction, which are both crucial.

"Cleaning" is important for the free movement of the rings, which is crucial for an efficient engine operation. If the free movement of the rings is restricted by deposits, or for other reasons, there is a risk of seizures, loss of ring tension and scuffing, in the worst case, and ultimately a scavenge box fire.

Cleaning ability and base number

Over the years, it has been found that the ability to keep the engine clean seemed to be coupled to the BN level in the lubricant, see Fig. 16.

BN is a measure of the neutralisation ability of the calcium-based detergents with varying over-basing levels (amount of calcium carbonate, $CaCO_3$). Apart from constituting the base, the Ca-based detergents control deposit formation together with other additives.

In general, the cleaning ability of the 100-BN oils on the market is excellent and these have been valuable in a mitigation of issues related to deposit formation. However, for the current and future engines, it is important to motivate the lube oil industry to go further: that is to decouple neutralisation ability, detergency and dispersancy.

Reduce ash to lower the risk of deposits

MAN Energy Solutions considers it unnecessary to feed excessive amounts of $CaCO_3$ into the engine, and thereby increase the risk of ash deposits in and after the engine.

Engines operating on fuels with less than 0.50% S do not require the neutralisation ability of a 100-BN oil. Deposit build-up in the NO_X Tier III-equipment can drastically hamper the performance of these systems, and less ash in the lube oil may lower this risk.

This has already been the experience with exhaust gas recirculation (EGR) systems. In 2020, MAN Energy Solutions released a Service Letter (SL2020-699/JRR) on how to manage deposit build-up in the EGR system. The Service Letter recommends including EGR operation in the vessel's planned maintenance system. Regular operation of the EGR system minimises the risk of systems failing due to sticking valves, stuck blowers, or blocked filters.

MAN Energy Solutions has also introduced the following design changes to manage the particles/granulates coming mainly from the lubricant:

- EGR cooler design changed to tube-type coolers
- filter introduced in the EGR water system
- EGR shut-off valve (SOV) repositioned to avoid particle build-up on the top of the closed valve during Tier II operation (with no EGR operation).

Emission reductions are kept high on the world agenda. Reducing the amount of ash in lubricants aimed for low-sulphur applications which have a limited neutralisation need, is an obvious step towards reducing potential issues in the aftertreatment systems, but also a step towards reducing emissions.

Performance categories for cylinder oil

MAN Energy Solutions' target for cylinder oil development is to improve the performance of the cylinder oils and simplify operations. Today's and future engine designs, together with many different types of fuel, require suitably high-performing lubricants. Such high-performing lubricants are a necessary part of a well-functioning two-stroke engine.

The general lubrication strategy is to use a low-BN oil when operating on 0-0.50% S fuels and high-BN cylinder oils for high-sulphur fuels. Utilising a high-BN cylinder oil when operating on 0-0.50% S fuels or using the alternating regime (changing between low-BN oil and high-BN oil for keeping the cylinder components clean) should be viewed as interim solutions.

Performance categories (Cat. II and Cat. I) for cylinder oils were formally communicated in 2020. Cat. II is the higher performing level, and to receive this status, the oil must have an excellent overall performance with a special focus on cleaning ability.

Service Letter SL2020-694 introduces the Cat. II 100-BN and 140-BN cylinder oils. To receive this status, lube oil suppliers had to apply for a reevaluation of their already approved 100-BN and 140-BN formulations. The application included information about service experience and a team of experts from MAN Energy Solutions evaluated the application. A Cat. II no objection letter (NOL) was issued if the results were satisfactory.

Simultaneously, lube oil suppliers worked on formulating a Cat. II 40-BN cylinder oil, which is a 40-BN cylinder oil with a cleaning ability better than or equal to a 100-BN oil.

In 2022, MAN Energy Solutions was proud to present the first Cat. II 40-BN cylinder oils in SL2022-728. The lube oil industry showed that it is indeed possible to decouple the neutralisation ability from detergency and dispersancy. A huge leap in cylinder lubrication oil development!

G70ME-C9.5-GI case study

The G70ME-C9.5-GI engine has been the preferred choice for LNG carriers, typically with twin engines, using LNG from the cargo tanks.

Many engines of this type entered service before the 2020 sulphur legislation came into effect, and used HSFO as pilot fuel. However, over time the pilot fuel type changed, and late-2019 engines typically started to use MGO (marine gas oil with <0.10% S) as the pilot fuel.

The wear of combustion chamber components is typically checked during scavenge port inspections, where piston rings and piston crowns are measured to obtain the wear of the ring grooves in the crown and the coating on the piston ring.

Engines specified for running on VLSFO and ULSFO (including dual-fuel engines) are equipped with piston rings with a cermet coating for the duration of the operational lifetime. These rings need to be replaced once the coating is in risk of wearing off.

Cylinder liner and piston ring wear are typically the most critical, and cermet coating wear is relatively easy to measure during scavenge port inspections, and is therefore a good indicator of the general wear.

Fig. 17 shows a plot of cermet coating wear on the first ring of multiple G70ME-C9.5-GI engines. It shows a positive overall trend, where wear progresses slowly. For all engines, the

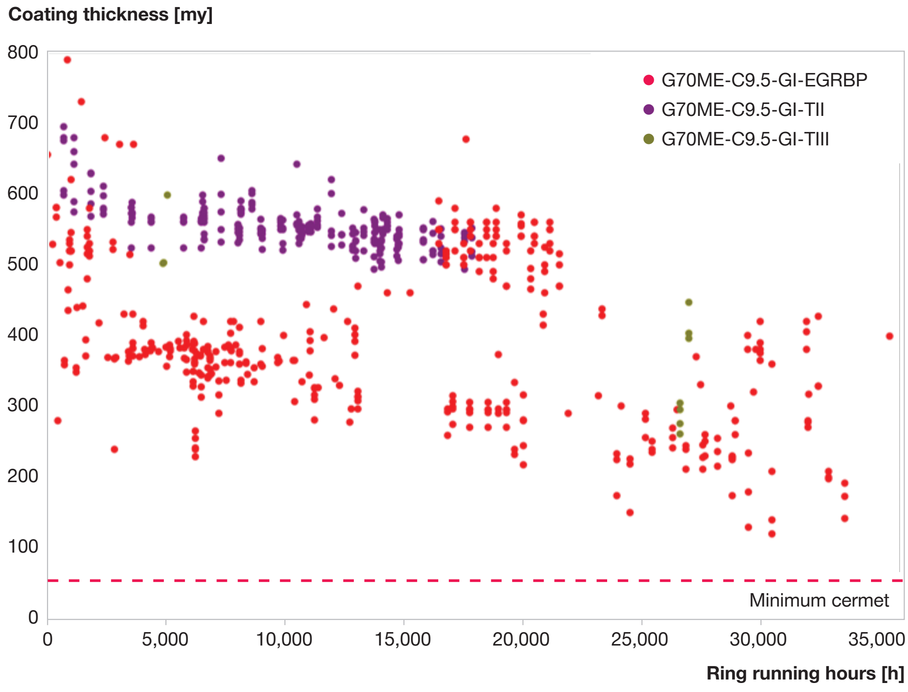


Fig. 17: Cermet coating thickness on the first piston ring. Data points from measurements on nine vessels (data from 90 cylinder units) during five years in service (G70ME-C9.5-GI).

wear trend indicates that wear-out will occur after 33,000 running hours, which is usually after five years.

A field study of three vessels has been conducted (the red series in Fig. 17). Each vessel has two main engines with five cylinders each, which means a total of 30 cylinders. The study covers operating hours for a period of approximately five years for two of the vessels, and just over four years for the third vessel, resulting in a total of 900,000 cylinder running hours.

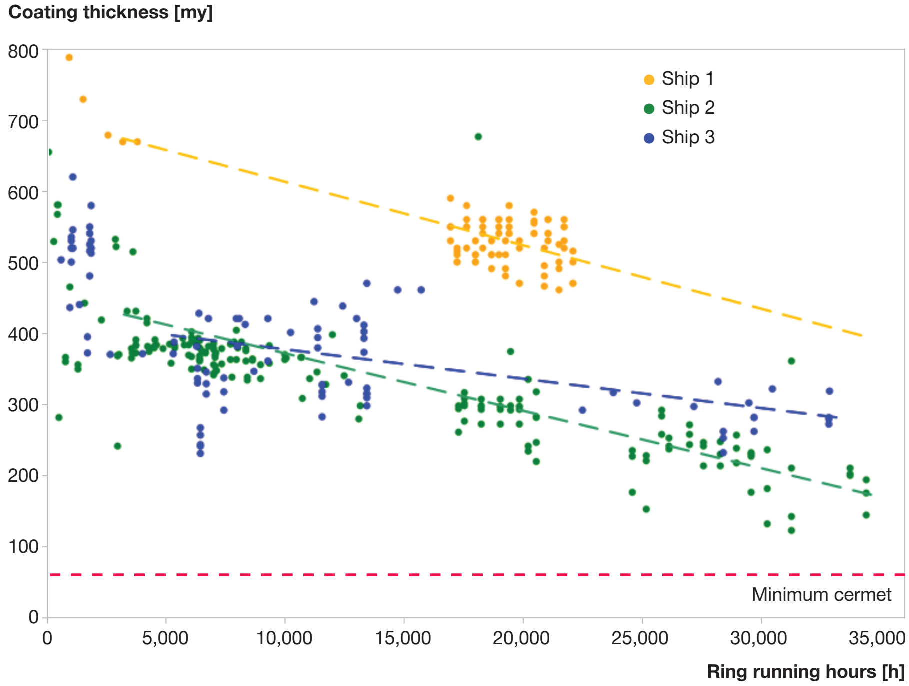


Fig. 18: Cermet coating thickness on the first ring for Ships 1–3 and a total of 30 cylinder units (G70ME-C9.5-GI)

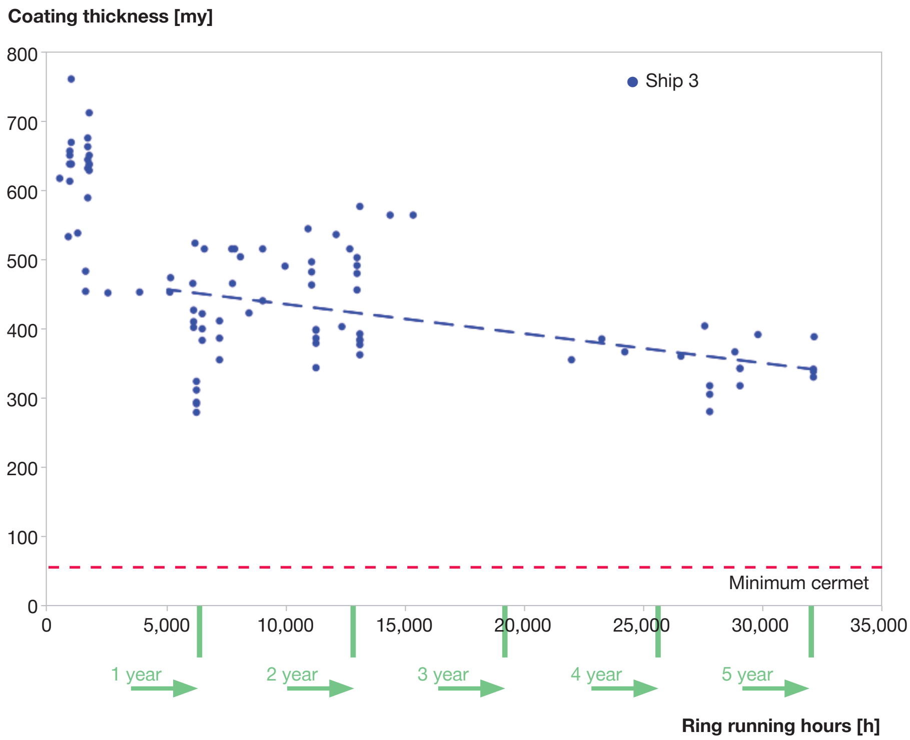


Fig. 19: Cermet coating thickness on the first ring of ten cylinder units for Ship 3 (G70ME-C9.5-GI)

Fig. 18 shows cermet coating thickness on the first piston ring as measured during scavenge port inspections. The three series of measurements from each vessel (two engines each) represent ten cylinders of similar design. The x-axis shows the time range: 0–35,000 running hours, and the figure illustrates these data.

Ships 2 and 3, with most running hours, started using HSFO as pilot fuel and as main fuel when not operating on LNG in dual-fuel mode. As a consequence, wear was observed. However, after the 0.5% S cap came into force, the pilot fuel was changed to 0.5% S or lower. The wear rate change can be observed, and the rings installed later in service also showed improved wear potential.

As explained, many cylinder lube oils have lacked a proper cleaning ability. This was also showing on these engines. On Ship 3, six of the ten units had the piston rings replaced since the ring locks were burnt, and rings got stuck, or lost tension.

The wear prediction shows that wear-down will not necessarily be the decisive matter for piston ring exchange, and it will improve in the future as higher performing cylinder oils will increase ring cleanness and keep them running. Fig. 19 shows measurements for the oldest vessel (Ship 3) where all rings were replaced during the 5-year dry docking regardless of the running hours.

Liner wear was measured at the 5-year dry docking and showed little or no wear. Fig. 20 shows liner wear measurements after 12,747 and 33,000 running hours.

Fig. 20 shows that the wear does not increase from 12,747 to 33,000+ hours. The liner wear measurement was in fact slightly higher after 12,474 running hours. The reason was an in-situ measurement and a tight cylinder cover, which resulted in deformation wear being added to the wear measurement. The measurement at 33,000+ running hours was made with the cylinder cover removed.

The experience on the second vessel was similar to the first vessel (Fig. 21).

The third vessel (Ship 1) entered service in 2019 and used HSFO for only three months, after which the pilot fuel was changed to ULSFO. The short period on HSFO had little effect on wear. The progression of wear is shown in Fig. 22, and it could be expected that the piston rings would last for much longer than the 5-year docking period.

For all three vessels, the wear rate on the cylinder liner and piston ring cermet coating was reduced once the fuel was changed to ULSFO. Other factors resulted in a need for replacing the piston rings, as, at the time, the cylinder oils were not adequate, and deposit control became the main cause of the challenges as shown in Fig. 23.

Note the amount of deposits on the piston ring lands and piston top land.

G70ME-C10.5-GI case study

The updated G70ME-C10.5-GI has the same general application as the G70ME-C9.5-GI engine, and is often chosen for LNG carriers. As this engine type is newer, the service history is not as extensive as for the G70ME-C9.5-GI. However, the same positive wear trends are seen for the G70ME-C10.5-GI engine. This can be seen on Fig. 24, where a plot of the wear from this engine type compared to the G70ME-C9.5-GI engine shows similar wear.

A better understanding of the role of the cylinder oil and improvements of the combustion chamber component design have also led to better deposit control. Fig. 25 shows a typical picture of the piston rings after more than one year in service, where the yellow alu-coating is still visible.

Liner bore [mm]

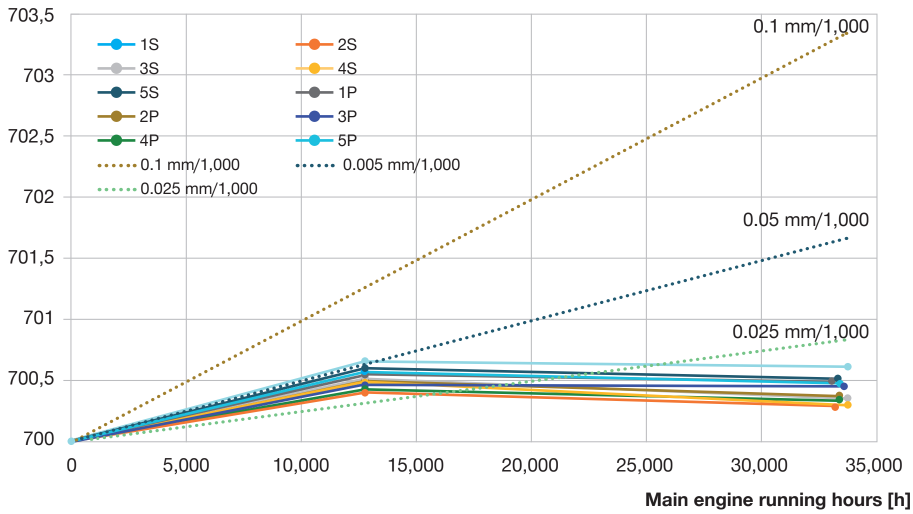


Fig. 20: Liner wear during five years in service for Ship 3 (G70ME-C9.5-GI)

Coating thickness [my]

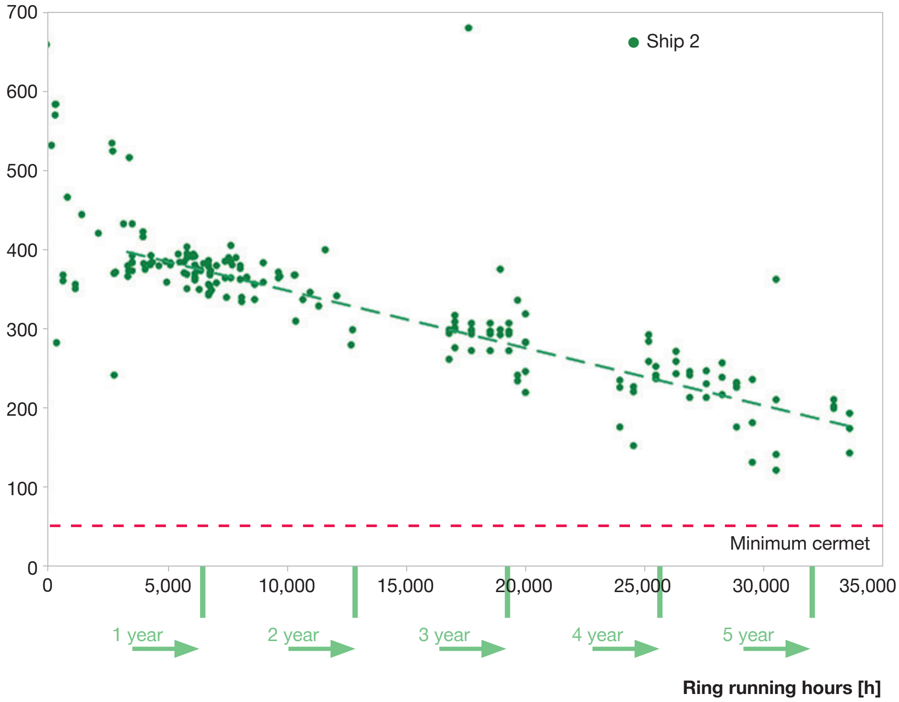


Fig. 21: First ring wear-down for Ship 2 during 35,000 running hours (G70ME-C9.5-GI)

The alu-coating is the running-in coating sprayed on top of the cermet coating, intended to be worn off after 1,000–1,200 running hours. The piston rings shown in Fig. 25 have been in service for around 8,000 running hours and the running-in coating remains, indicating a very low wear rate.

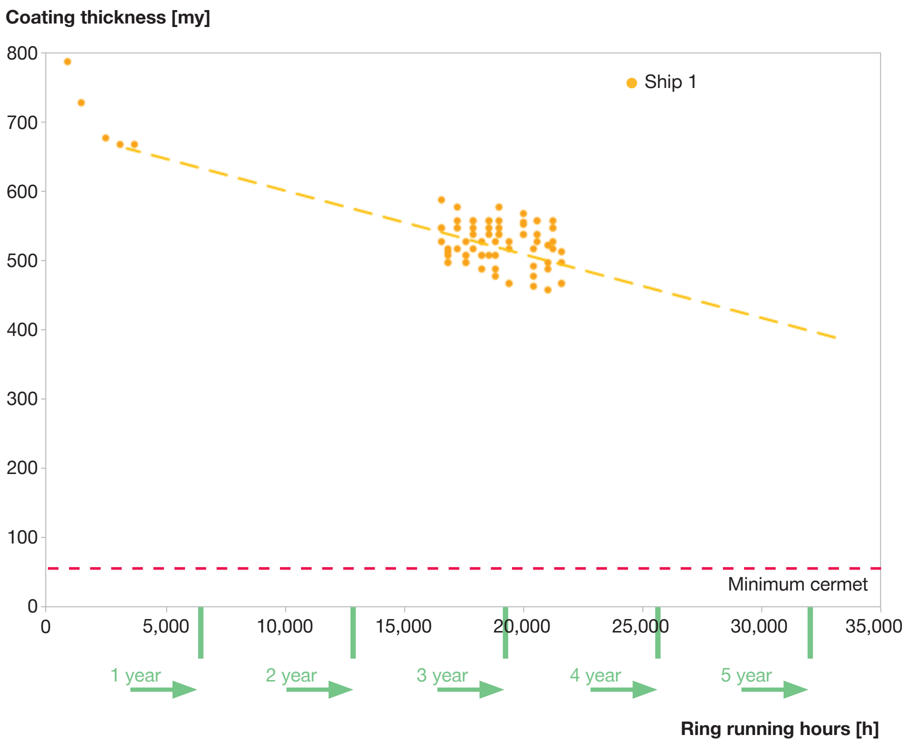


Fig. 22: First ring wear-down for Ship 1 during 20,000 running hours

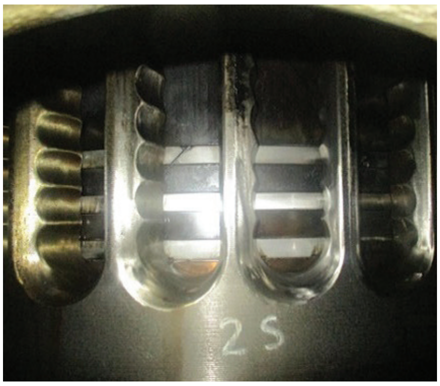


Fig. 23: View of cylinder condition after 32,000 running hours – note the deposit build-up (5G70ME-C9.5-GI)

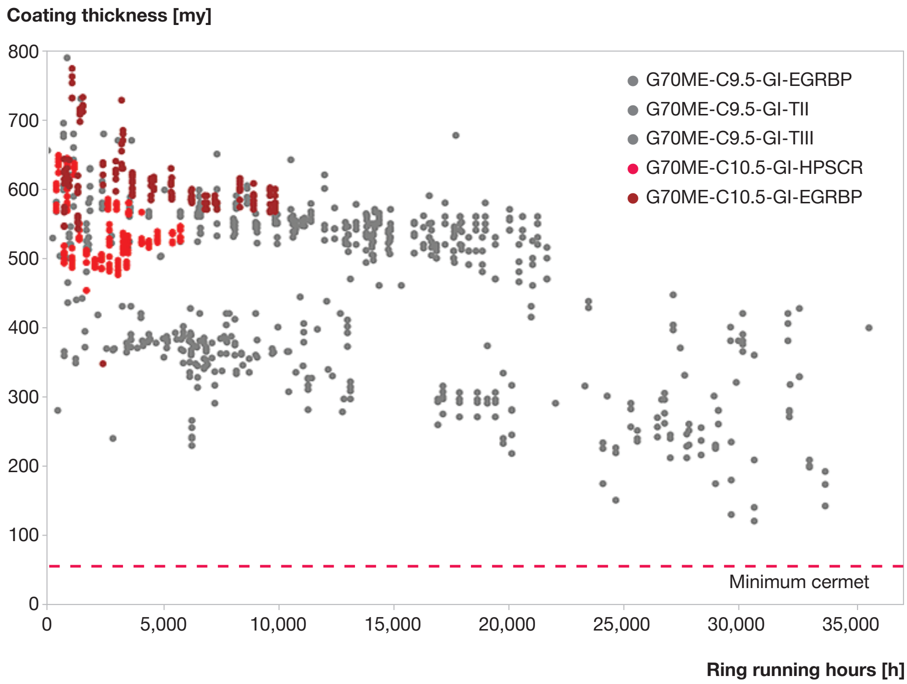


Fig. 24: Cermet-coated first piston ring wear measurements (G70ME-C10.5-GI) compared to the G70ME-C9.5-GI engine (grey)

Fig. 25: Cylinder condition after 8,000 running hours – remaining running-in coating is yellow (G70ME-C10.5-GI)

G90ME-C10.5-GI case study

ME-GI engines have also entered service as the main engines on large container vessels. Some G90ME-C10.5-GI engines have been in service for over two years and have demonstrated excellent service experience. When using high-detergent Cat. II cylinder oils, the cylinder condition looks great. Fig. 26 shows a typical view of the piston rings during a scavenge port inspection.

When looking in detail on the wear trend of the piston ring wear for the G90ME-C10.5-GI engine it shows a trend similar to the 5G70ME-C9.5-GI engine. The wear is low, as Fig. 27 shows.

Fig. 28 gives an estimate of the wear to come, indicating that the ring wear-down will not happen until after the 5-year docking, potentially, lasting far beyond five years.

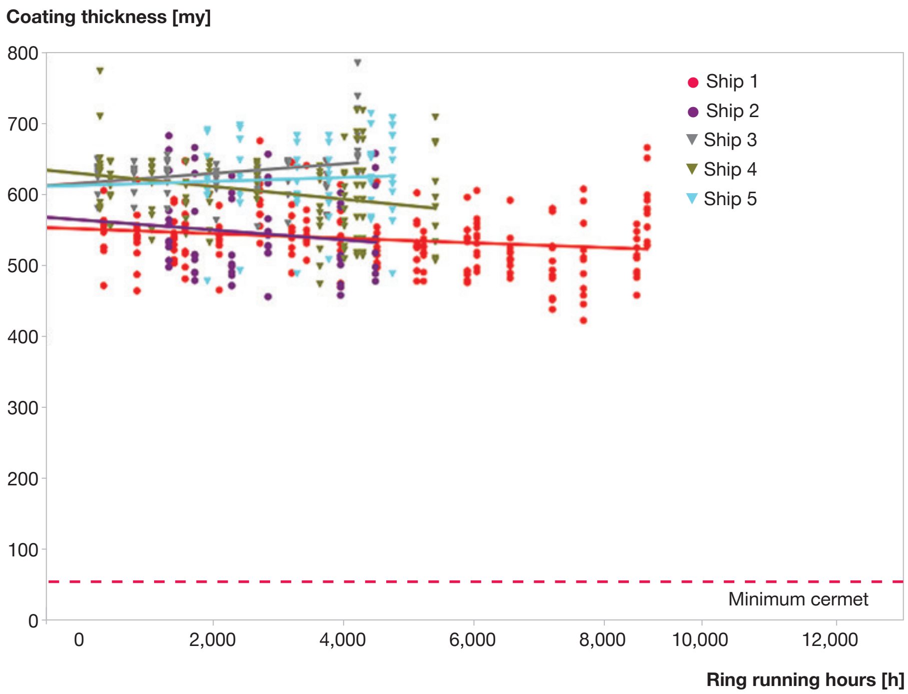


Fig. 27: First ring cermet coating thickness measured during scavenge port inspection (G90ME-C10.5-GI)

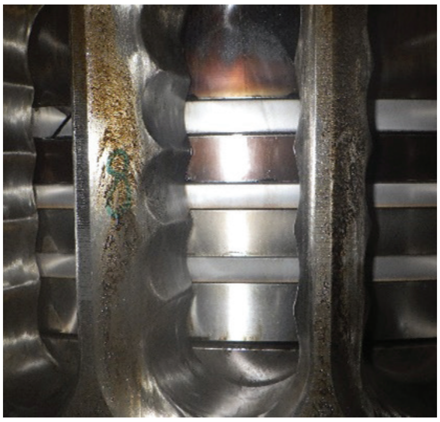


Fig. 26: Cylinder condition after 9,532 running hours (G90ME-C10.5-GI)

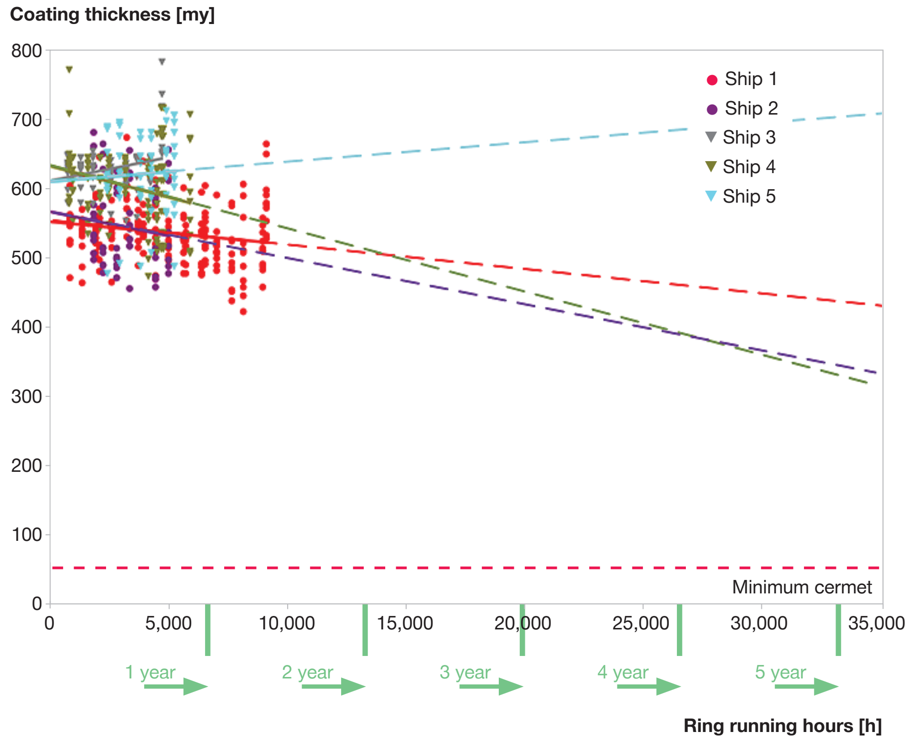


Fig. 28: Estimated progression of the wear rate up to 35,000 running hours (G90ME-C10.5-GI)

Maintenance strategy

Given the outlook of low wear rates and long TBOs, the philosophy of maintenance planning needs to be thought about. The progression of the wear should be recorded on inspections, wear trends should be followed, and the lube oil dosage should be adjusted to support a condition-based maintenance strategy. The typical indicators supporting condition-based maintenance are piston ring wear, piston crown ring groove wear, cylinder liner wear, and the physical appearance of the parts, for example, deposit-build up, and seizures.

On a dual-fuel engine, these indicators do not show much progression as the wear of piston rings and cylinder liners is between slight to none. But, the physical appearance comes into focus. The indicators of reduced piston ring performance will typically only show on the surface appearance and/or as black deposits concentrated on the top and ring lands on the piston crown.

Keeping a close eye on the amount of deposits on the ring land is important, and using the correct cylinder oil is necessary. If accumulation of deposits occurs, it is highly recommended switching to a cylinder oil with a high cleaning ability, such as a Cat. II cylinder oil.

Scavenge drain oil is a useful tool to spot unfortunate situations of abrasion, adhesion, or corrosive wear. Frequent sampling gives early indications on lubrication disturbance and makes quick action possible, thereby ensuring a long service life.

Dual-fuel engines may have the possibility to operate for long service periods, longer than the typical 5-year dry dock schedule. However, to achieve this, operators must plan ahead and assess which planned maintenance type is most suitable for their operation. The planned maintenance strategies can typically be divided into three types.

Corrective maintenance
Running the engine until piston ring failure is not a recommended maintenance strategy. Broken, collapsed, or stuck rings increase the risk of scavenge fires or other consequential damage.

Preventive maintenance
This strategy is time based. The aim is low wear rates and the possibility to operate within the planned maintenance period, for example, until dry docking. A preventive maintenance strategy is recommended when a high availability of the ship is important or when main engine maintenance is difficult to arrange on short notice.

Condition-based maintenance
The aim is to ensure the longest possible use of the wearing parts, such as piston rings. This strategy requires a trained crew that records wear down during inspections and a supervision system that can record the measurements and evaluate the condition. This strategy is mainly for vessels where maintenance can be performed on short notice without interfering with the ship schedule.

Sequential injection

A hydraulic oil pressure of 300 bar generates a fuel oil pressure at 800 bar. When the non-return valve opens, fuel oil at 800 bar fuel enters the spring chamber through bores and is ready for injection. The hydraulic oil pressure at 300 bar on top of the hydraulic piston keeps the valve closed, and when this pressure is released, the cut-off shaft is lifted and fuel oil is injected, see Fig. 29.

An electronic sequential valve (ELSQ) controls the pressure release from 300 to 0 bar on the hydraulic piston. There is one ELSQ control valve for each FBIV. This enables individual actuation of the three FBIVs and therefore opening timing and injection amount.

There are two sequential injection system designs:

1. Design with integrated top-controlled exhaust valve (TCEV). The design is used on the first generation of G95ME-C10.6 engines, see Fig. 30.
2. Design with hydraulic control unit – sequential (HCU-S). The design is used on G60ME-C10.6 and G80ME-C10.6 engines, and on second generation of G95ME-C10.6 engines, see Fig. 31.

At the time of writing, ten vessels with the TCEV version of the sequential injection design are in service. Service experience from these ten engines will be described.

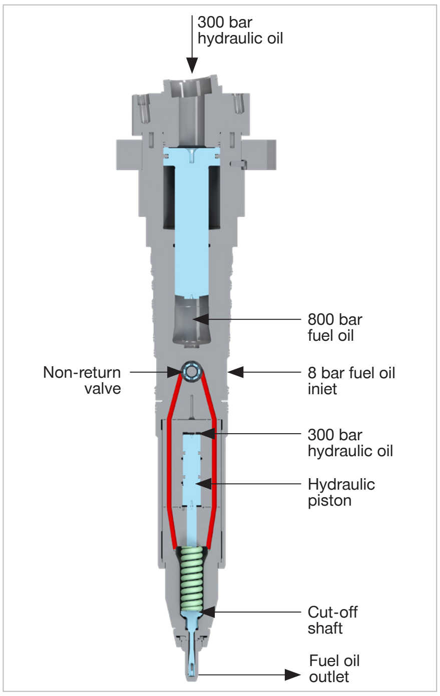


Fig. 29: Injection of fuel

Fig. 30: Sequential injection system with integrated top-controlled exhaust valve

Fig. 31: Sequential injection system with a hydraulic control unit – sequential

ELSQ pipe vibrations
Vessels have experienced pipe breakage due to elevated vibration levels where the breakage resulted in an ejection of oil mist between the pipe and the union, see Fig. 33.

The cause was found to be poor manufacturing of the piping combined with excessive vibrations induced by the TCEV. The ELSQ pipe was supported by brackets to reduce vibrations, see Fig. 30.

Furthermore, the union design was updated to prevent oil sprays in the event of an inner pipe breakage.

Spindle guide failures
Spindle guide failures for the FBIVS have been reported after 100 hours of operation, see Fig. 34.

In a few cases, this resulted in a substantial fuel oil spray into the engine room, see Fig. 35.

The line contact between the spindle and spindle guide seat creates highly concentrated stress during landing, see Fig. 32.

Combined with the brittle nature of the spindle guide material S85W6Mo (55–60 HRC), this is the cause of the failure. As a countermeasure, an alternative and more ductile tool steel has been chosen, and the seat contact is now defined as an area with parallel contact surfaces.

All spindle guides of the old design have been exchanged.

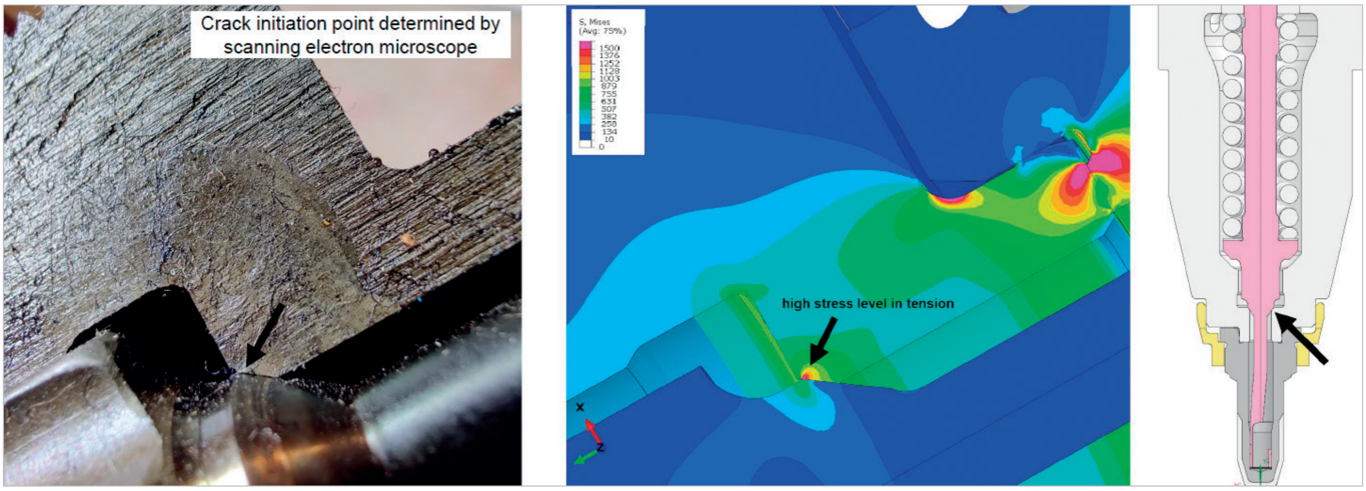


Fig. 32: High stress at contact between spindle and spindle guide seat

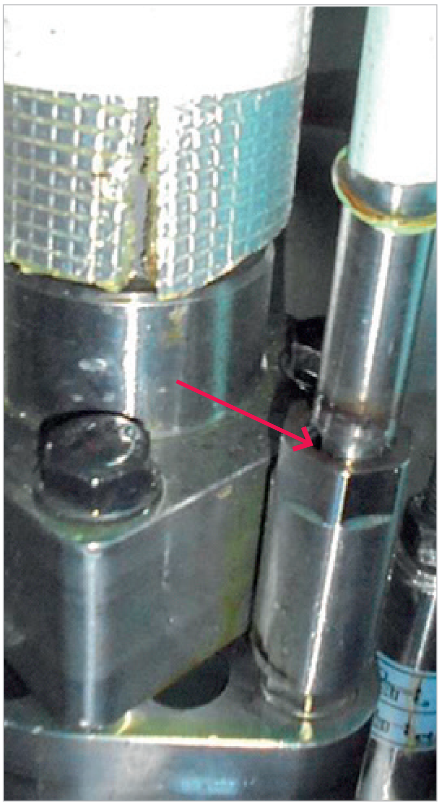


Fig. 33: Oil mist leak point

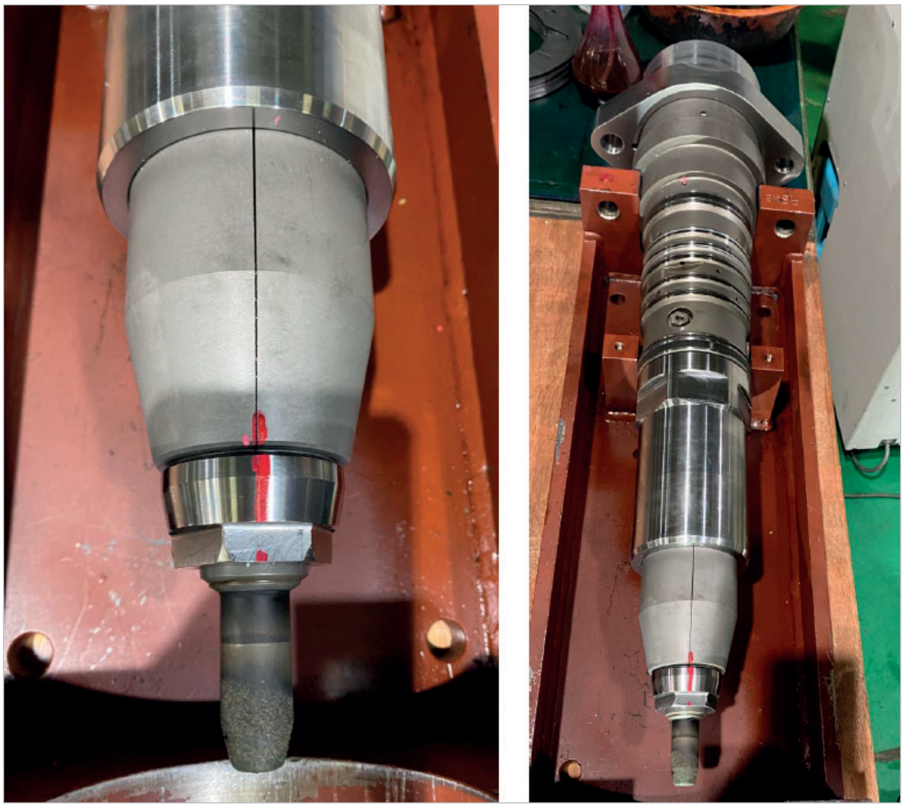


Fig. 34: FBIVS spindle guide failure

Exhaust valves

During recent years, exhaust valve issues have caused some concern. Excessive burn-away on the flame face of the exhaust valve spindle has led to a search for more heat-resistant spindle materials and a redesign of the bottom piece in the seating area. The well-proven W-seat has been changed to the wide-seat design as the standard. This design can remove more heat from the spindle, especially when combined with a bore-cooled version of the bottom piece, see Fig. 35.

For some engines (e.g. G80ME-C9.5), we have seen an increase in units with blow-by from the seating area, see Fig. 36.

For these engines, we have reintroduced the W-seat with the so-called soft closing damper system.

Soft closing, see Fig. 37, keeps the exhaust valve slightly open for a slightly longer time.

Hereby, the spindle is cooled by relatively cold scavenge air. Soft closing compensates for the temperature increase resulting from reintroducing the W-seat.

The latest design development of exhaust spindles has been the introduction of the XV3 design.

This design with an improved geometry of the bottom piece and the spindle reduces the heat input on the seat, improves cooling, and offers colder conditions in general for the valve spindle.

Fig. 39 shows the results of an inspection of an XV3 exhaust valve on an S60ME-C10.5 engine.

A satisfactory condition can be seen for all parts.

Fig. 36: Blow-by from the seating area

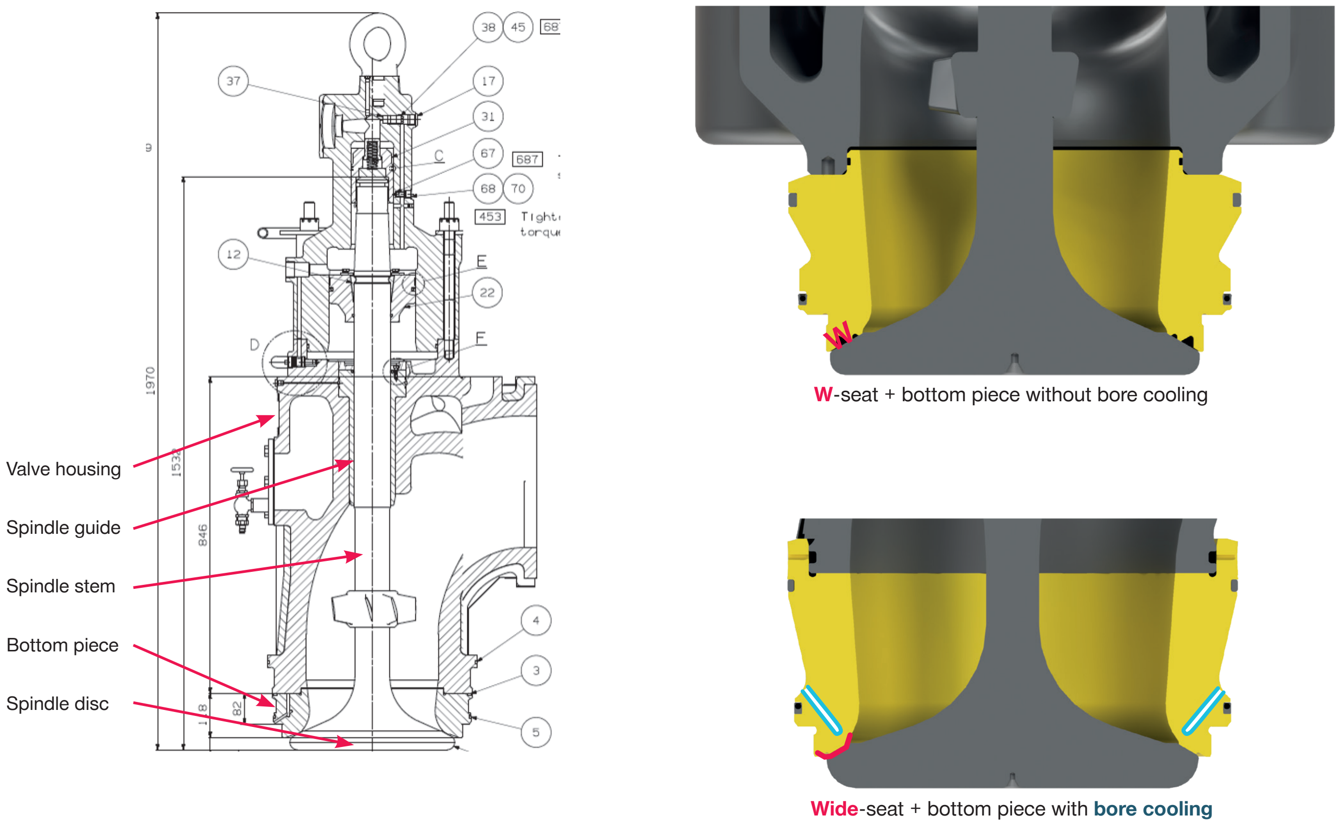


Fig. 35: W-seat design and wide-seat design

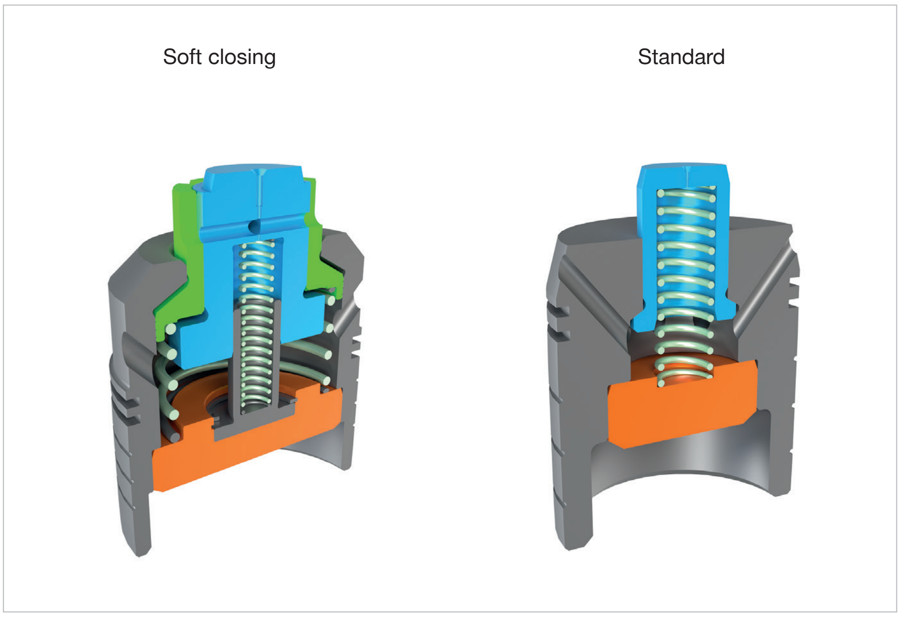


Fig. 37: Soft closing piston and standard piston

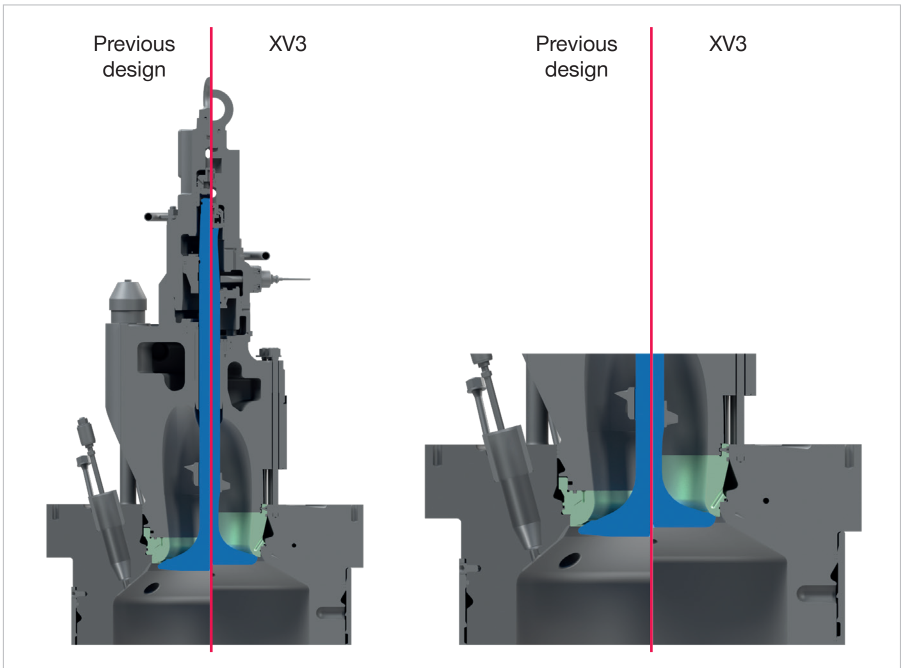
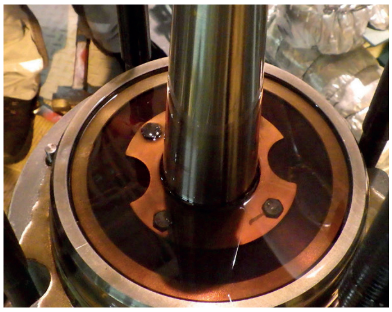
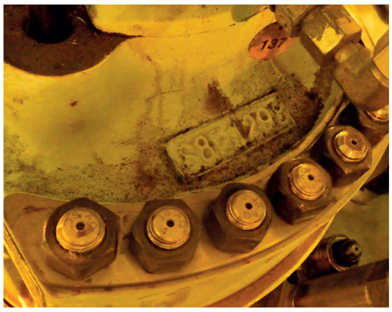


Fig. 38: Exhaust spindles of XV3 design

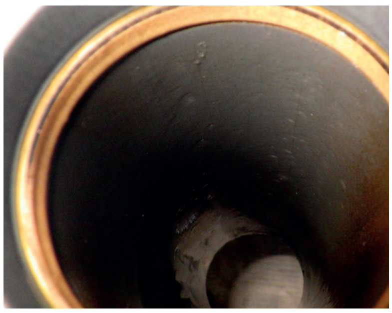


Oil on top of air piston, secure controlled oil level (COL) inside air spring



Multi-studs manually tightened from S60 and down

New spindle design



Clean and perfect spindle guide condition

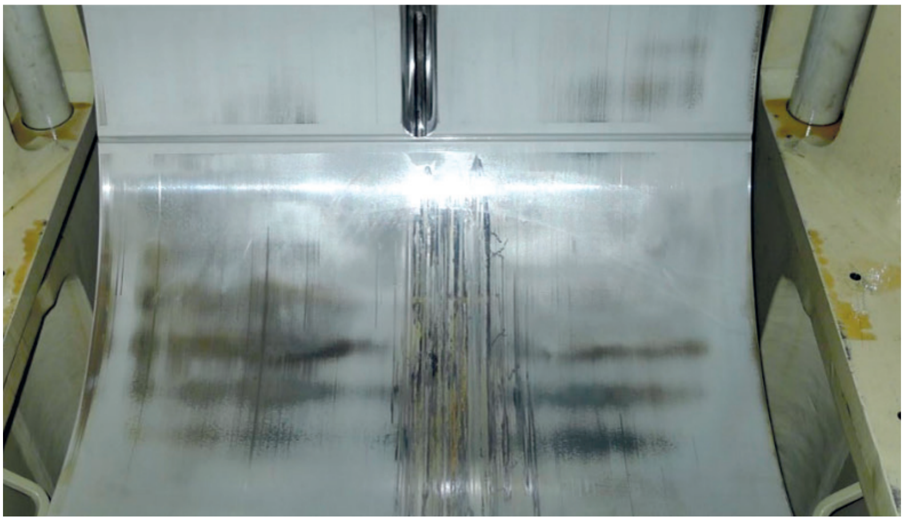
Fig. 39: Inspection of XV3 exhaust valve on S60ME-C10.5 engine at 5,500 running hours

Bearings

Crosshead bearings on some large-bore engines of Mk. 10.5 design have suffered peel-off in the lead overlay and, consequently, scuffing in the white metal bearing lining. In some cases, this has led to fatigue in the bearing lining. Service tests with various updated designs show good performance when the oil grooves are moved from +/-35 degrees to +/-25 degrees. Fig. 40 shows the result of the design change.

Based on this, an update of the bearing design has been introduced on all newer large-bore (80-95) designs. This update ensures a higher margin against various minor, production-related deviations and deficiencies.

The shell thickness of the G50ME-C crosshead bearing has been reduced from 12.5 mm to 9 mm. However, the diameter of the lubricating oil hole in the connecting rod for lubrication of the crankpin bearing was not changed. As a result, the bearing centre suffered fatigue damage (Fig. 41) that could potentially develop and spread to the entire bearing shell and spread debris to the crankpin bearing.



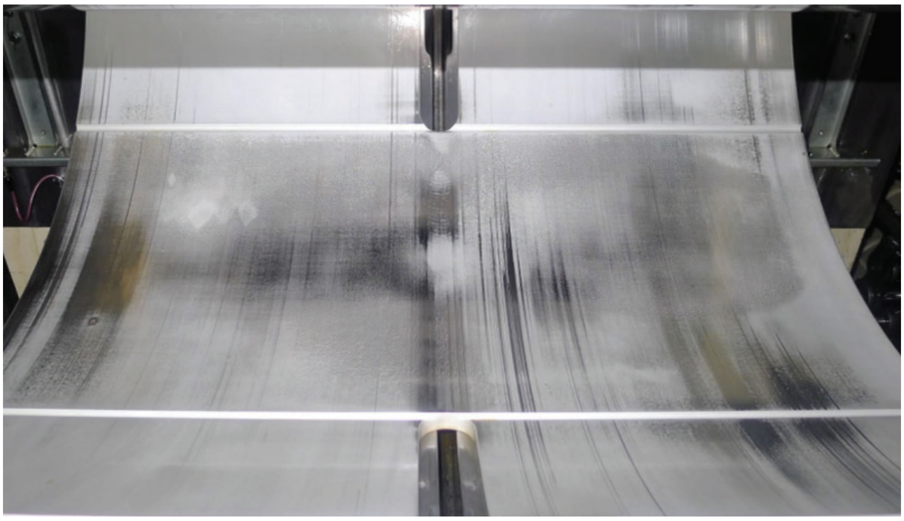


Fig. 40: Oil-groove design change (upper: old design – lower: new design)

Fig. 41: Crosshead bearing centre suffered fatigue damage on G50ME-C engine

The design was updated with a smaller lubricating hole in the connecting rod for engines not yet produced, see, Fig. 42.

For engines already produced, including those in service, we specified an AlSn40 type bearing shell, which has a higher fatigue limit.

A Circular Letter was issued to the shipowners and ship managers operating this engine type.

Slightly more than 1,400 bearing shells must be replaced in service, and this has created some logistical challenges.

The bearing wear monitoring system (BWMS) was introduced as the standard on MAN B&W two-stroke engines 12 years ago. Since the introduction, five cases of severe bearing damage on engines equipped with BWMS have been recorded by the Operation department in Copenhagen.

Three of those cases involved alarms which for different reasons had been ignored, and in two cases the BWMS was not operational.

Recently, we have experienced some cases where the BWMS was not operational due to reasons such as failing sensors, increased number of false alarms, or other abnormalities.

Based on the above excellent records for BWMS, MAN Energy Solutions emphasises the importance of maintaining the BWMS to keep the system operational. If any abnormalities are encountered, the shipowner should contact the maker.

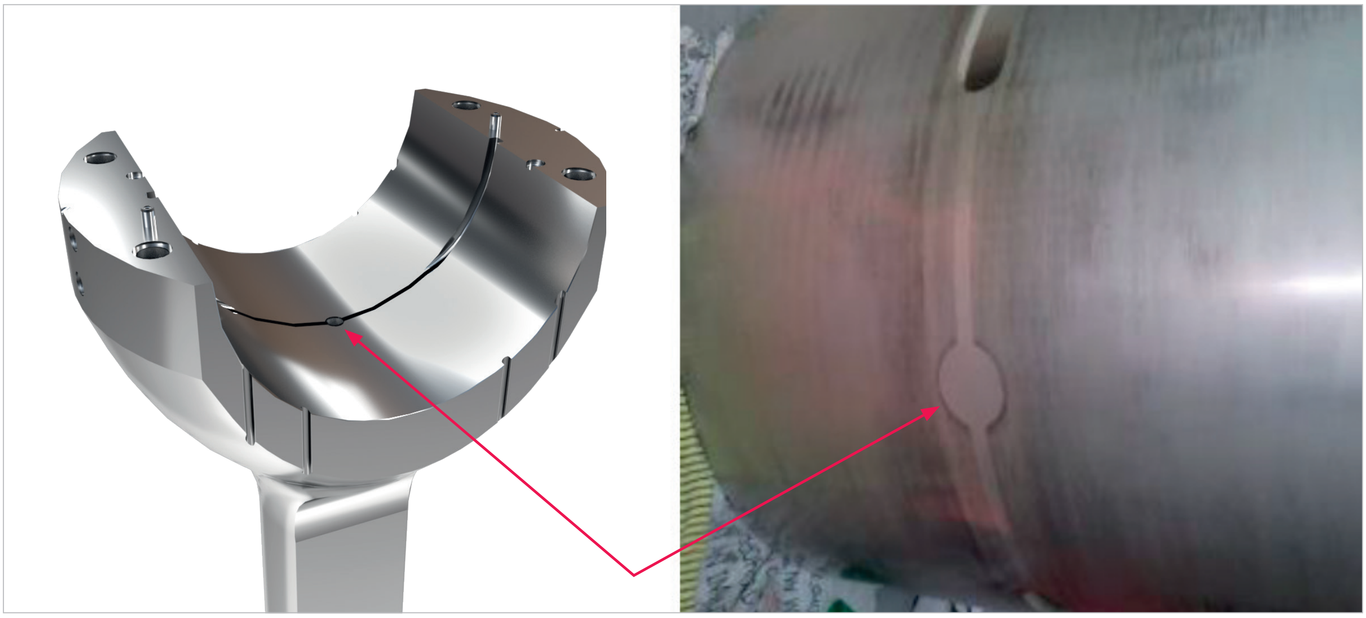


Fig. 42: Design update – smaller lubricating hole in connecting rod

Emission technologies

MAN Energy Solutions has two main technologies for Tier III compliance – exhaust gas recirculation (EGR) and selective catalytic reduction (SCR) – and both technologies have been in service on our engines for more than a decade. The number of vessels with Tier III technologies is increasing fast. In 2022, 80% of new orders included either EGR or SCR – and in 2023 the share is even higher.

How much the EGR or SCR systems are used depends on the trade pattern of the vessels, and the difference is substantial. Some vessels operate 30% of the time in Tier III areas, while others trade in Tier II areas only and never need to run the EGR or SCR system.

Both technologies have proven to be reliable, and the general feedback from owners of vessels with EGR or SCR is good.

In 2018, we introduced the Tier II version of the EGR system, the so-called EcoEGR. By optimising the engine for low-SFOC operation and applying a 10–15% recirculation rate, the NO_X emission level is kept within Tier II limits, see Fig. 43.

Initially, we had only two EcoEGR-test-vessels, and the feedback after 1,000 EcoEGR service hours was good, and the cylinder condition was acceptable after operating continuously on HFO. In 2022, new EcoEGR engines running on gas (ME-GI) entered service.

The amount of sludge and dirt accumulated in the scavenge air receiver increases in EGR operation. This is observed for both EcoEGR on gas and EcoEGR on HFO, but the amount of dirt is significantly higher for HFO operation, see Fig. 44.
The feedback from owners operating continuously with EGR or EcoEGR is that the cleaning interval of the scavenge air receiver has been slightly reduced.

Based on observations and feedback from the 350 EGR engines in service, we have updated the design of the EGR unit to improve the support of the EGR cooler. To achieve a simpler and more

Fig. 44: Sludge and dirt accumulation in the scavenge air receiver when operating on HFO with EcoEGR

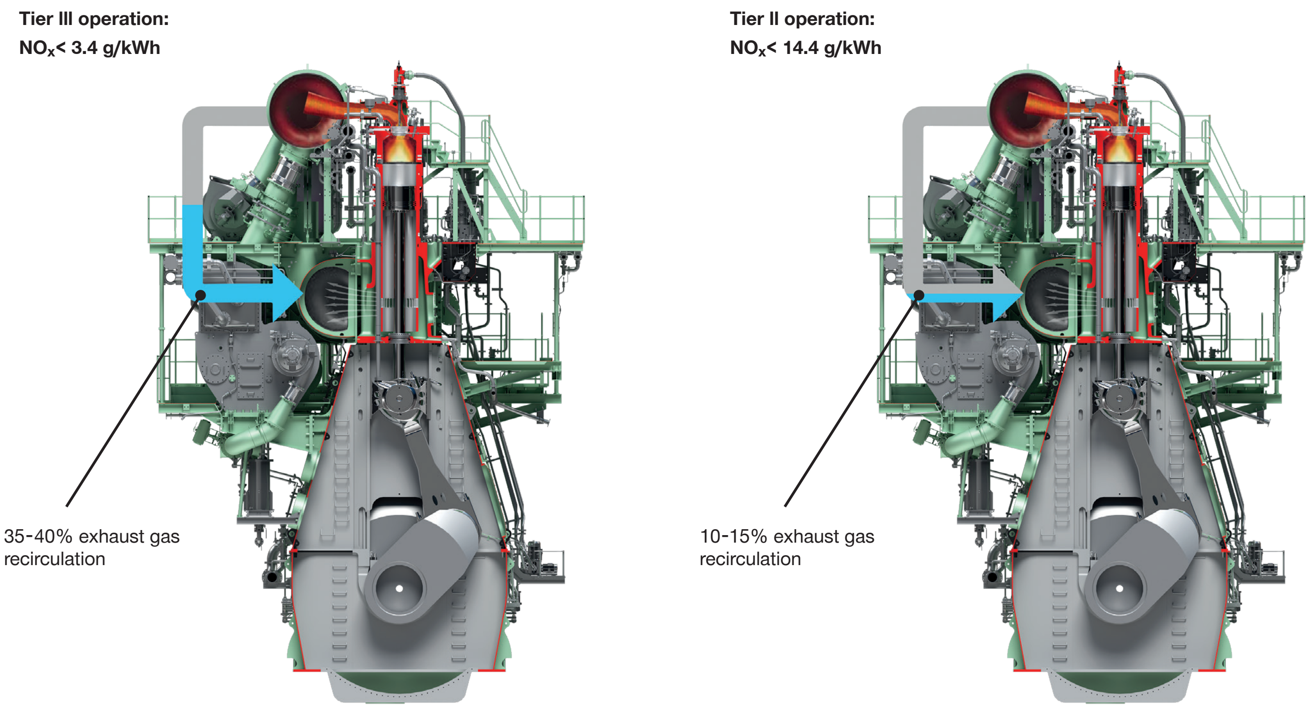


Fig. 43: EGR and EcoEGR

cost-efficient EGR design, we have updated the design:

- oxygen sensor setup
- EGR water handling system
- low-speed EGR blower.

Fig. 45 and Fig. 46 show the condition of ME-GI engines with EcoEGR.

All ME-GA engines have EGR and, like EcoEGR engines, the EGR system will operate continuously.

Based on observations and feedback from the more than 750 SCR engines in service, we have updated the design:

- Pressure equalising valve (PEV) introduced to reduce the air consumption for venting of the reactor and to get a better control of the pressure equalisation between the SCR reactor and exhaust receiver in Tier II operation.
- Pipe size for differential pressure transmitters has been increased to avoid clogging of the pipes.
- Updated control of NO_X sensors for increased lifetime.

There is still a high interest in installation of scrubbers for running on high-sulphur fuels. But most owners choose to install the low-sulphur version of EGR or SCR and run on compliant (low-sulphur) fuel in Tier III areas, and use the scrubber for running on high-sulphur fuel in Tier II areas. Scrubbers are installed in all shipping segments, however, the largest segments are cruise ships, RoRo, bulk carriers, and container vessels. The number of scrubber ships in service by 2023 is more than 5,000 (retrofits around 67%, newbuildings 33%).

Fig. 45: ME-GI with EcoEGR. EGR unit (below EGR-cooler) with no accumulation of dirt or sludge

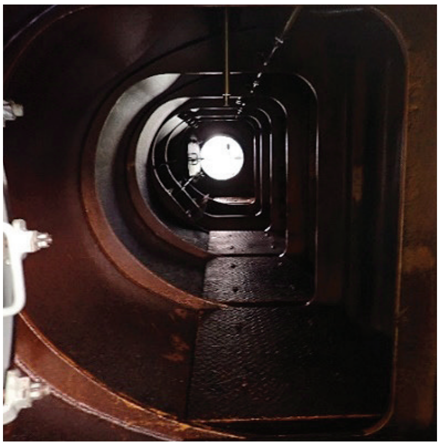


Fig. 46: ME-GI with EcoEGR. Scavenge air receiver coloured by a thin layer of oil and dirt.

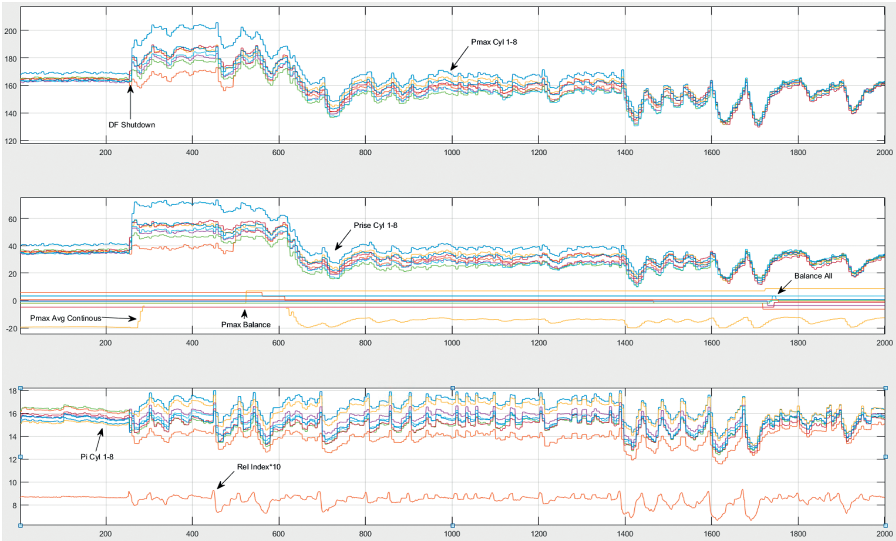
Service experience with ECS

Engine control system

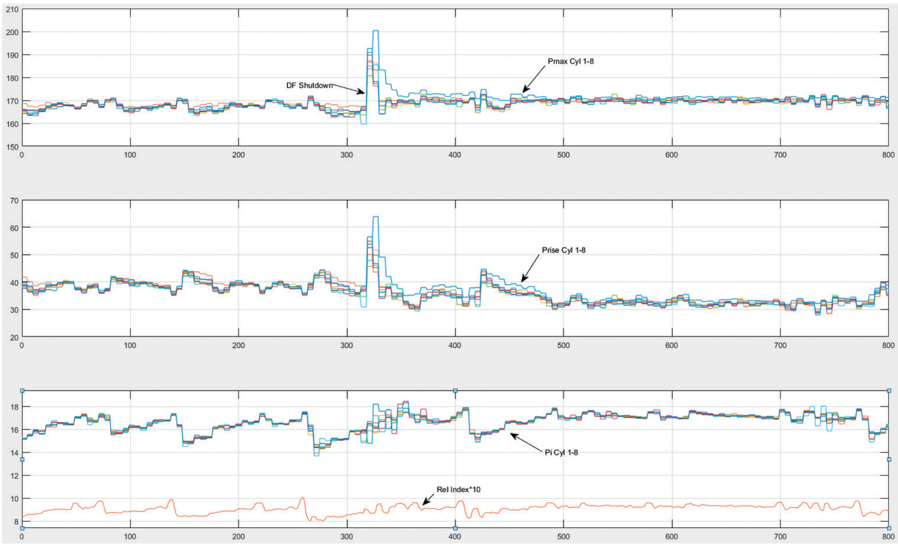
The ME-ECS engine control software is undergoing constant improvements and updates to meet market demands and improve engine performance.

One of the most fruitful improvements has been the adaptive cylinder control (ACCo). ACCo is an improvement of the well-known Autotuning system that has been the standard in ME-ECS for many years. With ACCo, the automatic capabilities have greatly increased, and the system is continuously monitoring and adjusting cylinder pressures. This is a great advantage compared to the previous Autotuning system that would only make automated adjustments to the mean values, but did not ensure a correctly balanced engine performance. The service experience with ACCo is solid and shows that engines with ACCo are adjusted to optimal performance at all times. ACCo is default on selected engine types and it is available for all ME-C engine types. We expect to have a version ready for ME-B in the near future.

The example in Fig. 47 compares a change from gas running to diesel running. The lower side shows that ECS will quickly and without intervention adjust cylinder pressures. In comparison, the Autotuning system needs user intervention to get the balance in place, upper diagram.



Autotuning



ACCo

Fig. 47: Change from gas running to diesel running with Autotuning (top) and ACCo (bottom)

Case story – ACCo solves liner scuffing on 8G95ME-C9.5

From the early introduction, the G95 engines experienced challenges with the piston ring coating quality. The issue led to liner scuffing cases, and various design features were therefore introduced to improve the general cylinder condition and increase the margin against scuffing. The innovative new features incorporated, among others:

- index rate limiter function
- lower second and third piston rings
- improved alu-coating and cermet coating specifications.

The design changes successfully improved the cylinder condition for the G95 engine type.

However, after the 2020 fuel switchover from high-sulphur to compliant 0.5% sulphur fuels, a fleet of G95ME-C9.5 started to experience issues that were similar to the past, whereas the remaining G95 engines continued successfully.

Initially, the investigation led to the introduction of already proven features, such as using 40-BN cylinder oils and modifying older engines to feature one high top-piston ring and two lower piston rings in the second and third ring grooves. Improvements were seen, but the results did not meet expectations.

Further studies of the scuffing incidents and how the crew operated the engine, showed an indicative correlation between the use of CE index limiters and the scuffing incidents. It is believed to result in thermal instability and changes in deformation of the hot components.

To counteract the fluctuations and thermal changes, all vessels were upgraded to the latest versions of ECS and ACCo. The crew were instructed to stop using index limitation and run the engines in torque mode in opposition to the owner's practice of operating in a fixed power mode.

This was implemented while the vessels were in port in Singapore and with the support of engineers from MAN Energy Solutions, and all vessels were upgraded in the period between September and December 2022. A remarkable improvement was immediately noticed by the crews. At the time of writing (end of March 2023), only a single relevant case of liner seizure has been reported, just as the upgrades were finalised at the beginning of December 2022. This makes it the longest period without incidents since the start of 2020. We therefore trust that the issue has indeed been mitigated, and that the superior effect of ACCo has been proved.

Cybersecurity
MAN Energy Solutions has introduced improvements to meet the raising concern for cybersecurity. The MOP computers now have a hardening based on application whitelisting. This means that the MOP computers will only allow applications to be executed if they are approved by MAN Energy Solutions. This greatly diminishes the risk of a ransomware attack or other malware infection. Any software that needs to run on either the energy management system (EMS) on the EMS-MOP, or the engine control system (ECS) MOP (the EC-MOP) must have a unique MAN Energy Solutions signature.

Besides the hardening, steps have also been taken to ensure that only approved service engineers from MAN Energy Solutions have access to modify engine control parameters and make changes to the control system. A "locking" system has been introduced, and a unique password is needed to unlock an EC-MOP. The password is generated by the MOP, but before it can be used, it must be decrypted. The decryption can only be done via a server at MAN Energy Solutions which will only allow selected service engineers to have a password decrypted.

With this setup, it is possible to constantly control who has access to unlock EC-MOP computers, and any password decryption will be logged. To ease the process, the encrypted password is presented as a QR code on the MOP, see Fig. 48. Service engineers can easily access the MOP by scanning the code to receive a password from the server automatically.

ECS parameter updates in service
To ensure that the ECS is easily maintained with the latest parameters, a software tool has been created that allows parameter corrections to be sent to vessels in service. This parameter update tool – referred to as PUT – has been a huge success. Before, even a simple correction to the ECS would normally require attendance by a skilled service engineer, it is now possible for the crew to install this in a safe and reliable way. The tool includes a roll-back feature that will allow the crew to revert the update if it has an unexpected influence on the engine. This is only used on rare occasions, but is a huge advantage because the crew is willing to install an update if they are sure that they can revert to the original setting.

The PUT will work on all electronically controlled MAN B&W two stroke engines. On newer ME-ECS software versions, the installation is handled directly in the MOP GUI like all normal interactions with the MOP, see Fig. 49.

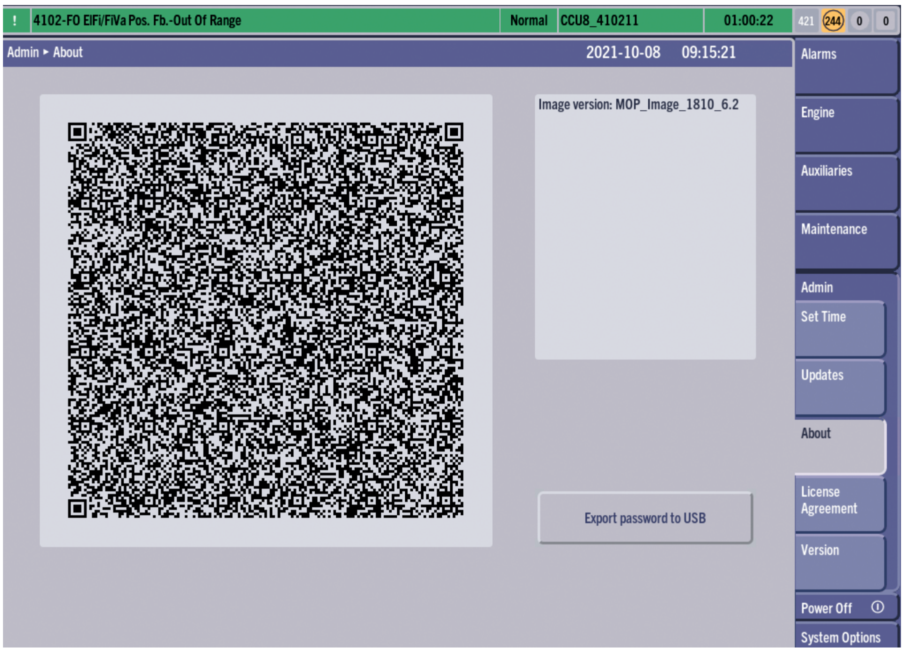


Fig. 48: QR code for EC-MOP unlock

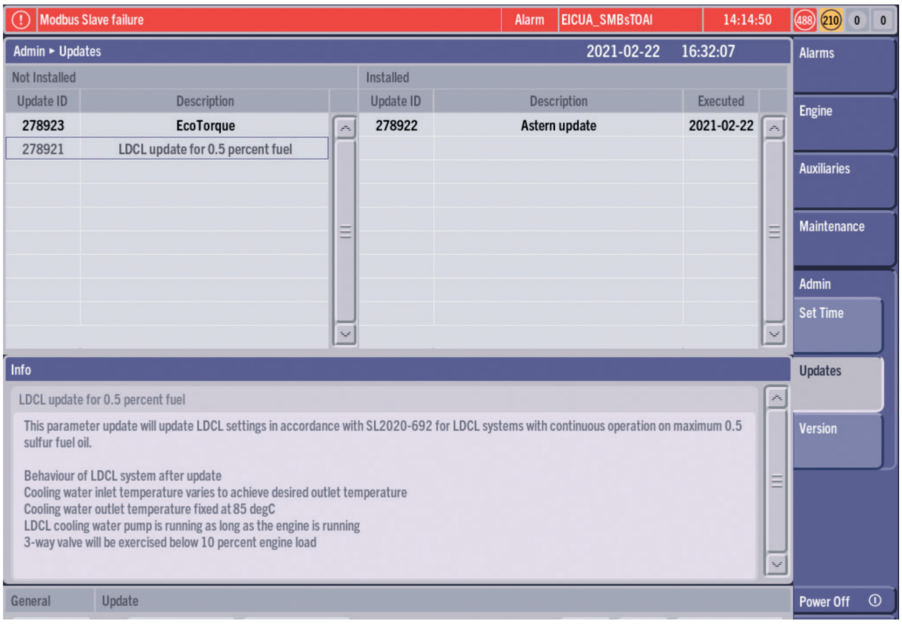


Fig. 49: MOP GUI for PUT

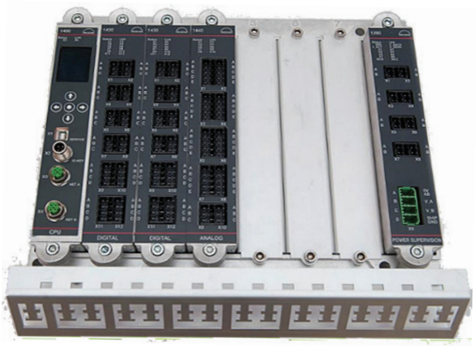


Fig. 50: Triton hardware

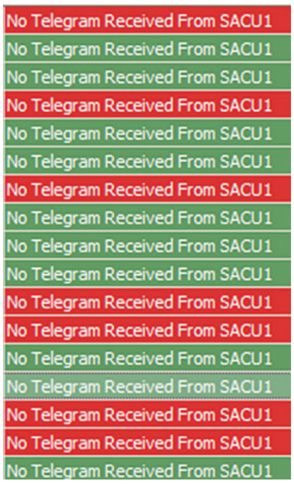


Fig. 51: Missing telegram alarms causing gas shutdown on dual-fuel engines

On older ME-ECS versions, PUT is executed in a stand-alone application.

The ability to create corrections using PUT was recently opened to the licensees. This allows for an even smoother follow-up on parameter settings as licensees will easily be able to ensure that corrections are always updated on all engines in a series. PUT enables MAN Energy Solutions and licensees to react fast to events that can be handled by ME-ECS parameter corrections. Something that would otherwise require travelling, to attend a vessel.

Triton – the new ECS hardware platform

The new hardware platform, see Fig. 50, has seen the light of day and is in use on +100 engines in service. The first engines with Triton began service testing in early 2020. The vessels have operated on Triton since then, even though they were built with both the old multi-purpose controllers (MPC) system and the new Triton system.

Service experience with Triton has been very good. The main obstacle to the success has been the semiconductor shortage that has resulted in a delayed introduction of the hardware and forced the use of MPC on engines that were originally designed with Triton. The hardware itself has proven extremely reliable, the chassis and modules are robust and reliable and have proven the same low claim rates as the well-known MPC controllers, well below 0.5%.

The issues observed and addressed are mainly related to the network and software. Many engines have experienced false alarms, which indicate that network telegrams have not been received as expected. Such false alarms cause gas stoppage on dual-fuel engines and have been the main issue for all dual-fuel engines with Triton, see Fig. 51.

An investigation of software and electric network connections revealed a number of issues.

The most important issue was related to task handling in the software. A phenomenon known as ”priority inversion” meant that a time-critical task in the software was held back by a lower priority task because of a shared resource. The problem was found, and corrected on the SCSU. In 2022, several software releases were introduced with improvements and additional software instrumentation to locate and troubleshoot this issue.
In parallel with the software investigations, the control network components were also thoroughly investigated, and corrections implemented. The control network on Triton is Ethernet-based using the IEEE 1588 Precision Time Protocol to ensure that time-critical information, such as on the fuel injection, is controlled with high accuracy.

It was identified that the network installations were not always made according to the specification that was required to ensure the electrical robustness of the network. Since the high-speed cable work was new to electricians, many installations were made with unshielded cable loops, see Fig. 52.

Also, cables from one manufacturer proved not to deliver the expected performance, and the usage was therefore stopped temporarily.

Substantial changes to the alarm system interface with Triton

The modular design gave the ability to have more input channels in the Triton system compared to the MPC. It means that many signals previously monitored by the alarm and monitoring system (AMS) are now handled directly in the ECS through input channels on the Triton controllers. This is a major improvement because the ECS will now be able to act directly on these signals. The ECS can instantly react to changes in running conditions that could call for reduced cylinder pressure or increased cylinder lubrication.

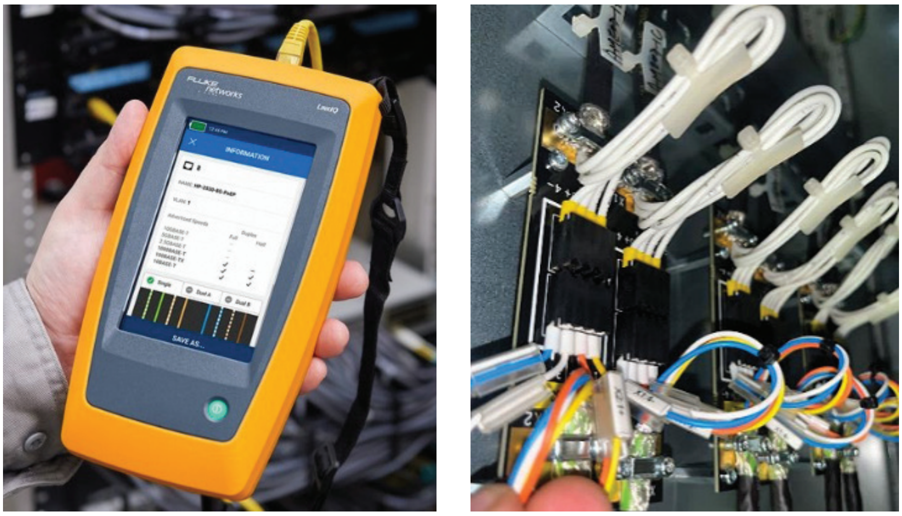


Fig. 52: Installation mistake – unshielded cable loops

Furthermore, it is now possible to set up more intelligent alarm limits for these signals, and the limits and rules can be updated together with the ECS.

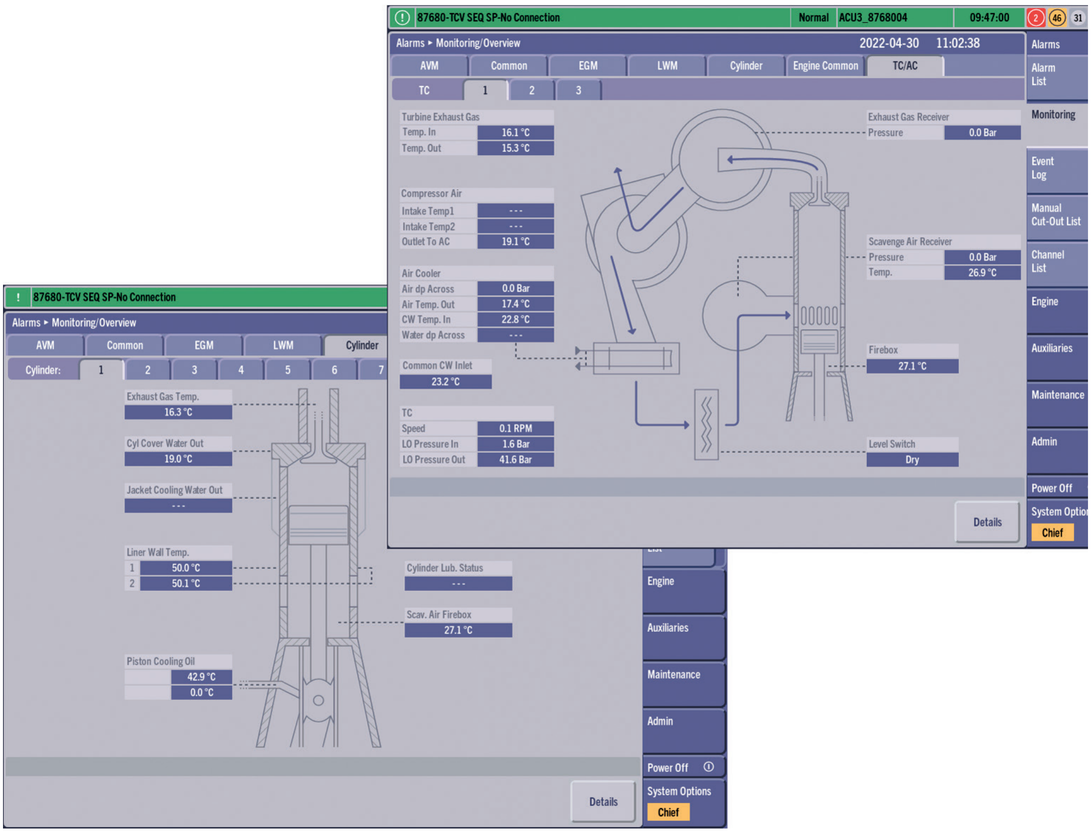


Fig. 53: New MOP GUIs on Triton-controlled engine

This is a challenging task on the MPC, because the alarm limits must be described to all AMS makers, who must then implement the rules.

Consequently, the rules are difficult to change and cannot be differentiated for the engines in the engine programme.

Great effort has gone into making graphical representations to illustrate where signals are measured on the engine, see Fig. 53.

Communicating and understanding this new setup has proven difficult. Situations have been observed where both AMS and ECS have alarms on the same measured value. This is not intended, and any such installation should be corrected. The alarms in the AMS are in these cases based on the non-redundant MODBUS interface, which means that a single failure may cause many alarms to be raised by mistake. The MODBUS interface is intended to be used by the AMS to make a visualisation of the values.

The Triton control hardware has proven to possess the expandability that was desired with the modular design. This has also been proven in connection with the introduction of the ME-GA engine. A Triton module has been designed to drive the micro booster injection valve (MBIV). The 1770 versatile fast injection driver (VFID) module will deliver accurate control of the high voltage and current needed to drive the injection of pilot oil for the Otto process of the ME-GA engine. A similar task was done by the CRISD amplifier for the common rail design, but in this application as an external unit.

Remote access to engines

Online Datgat

A new digital solution has been released for all MAN B&W engines. The Online Datgat offers remote access to all engine data from the Datgat tool.

Historically, the only way to access events, alarms, parameters, line recorder files, etc., was either by asking the vessel to ship the data or by visiting the vessel with a USB stick, see Fig. 54.

We are now introducing a new development where an internet connection enables access to the Datgat data via the MAN CEON cloud.

We have built an API that can be controlled remotely via a secure connection. It is possible to check what data is on the asset, order a new Datgat file, and download it over the internet.

Access to Online Datgat data is provided via a web service on the MAN CEON platform, see Fig. 55. The platform can display which engines are online, a Datgat start can be ordered, and the result can be downloaded.

Prerequisites for Online Datgat:
– internet cable to engine firewall (DUN 17.2018)
– EMS MOP HW Cronus 1S/2 (DUN 05.2020)
– engine connected to CEON (DUN 36.2020)
– EMS software release 2203-5 or newer (DUN 27.2022)
– signed data sharing agreement with owner.

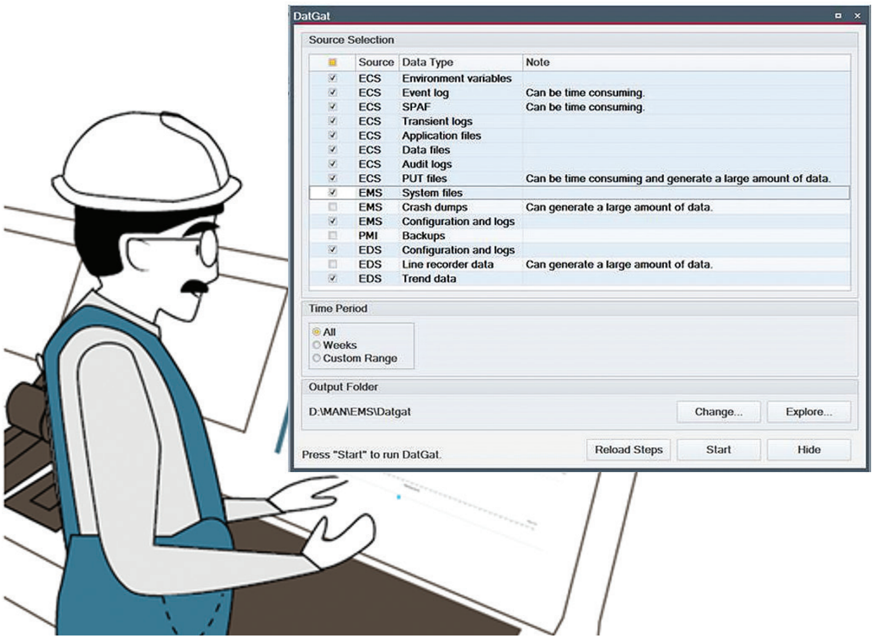


Fig. 54: Current solution on vessels

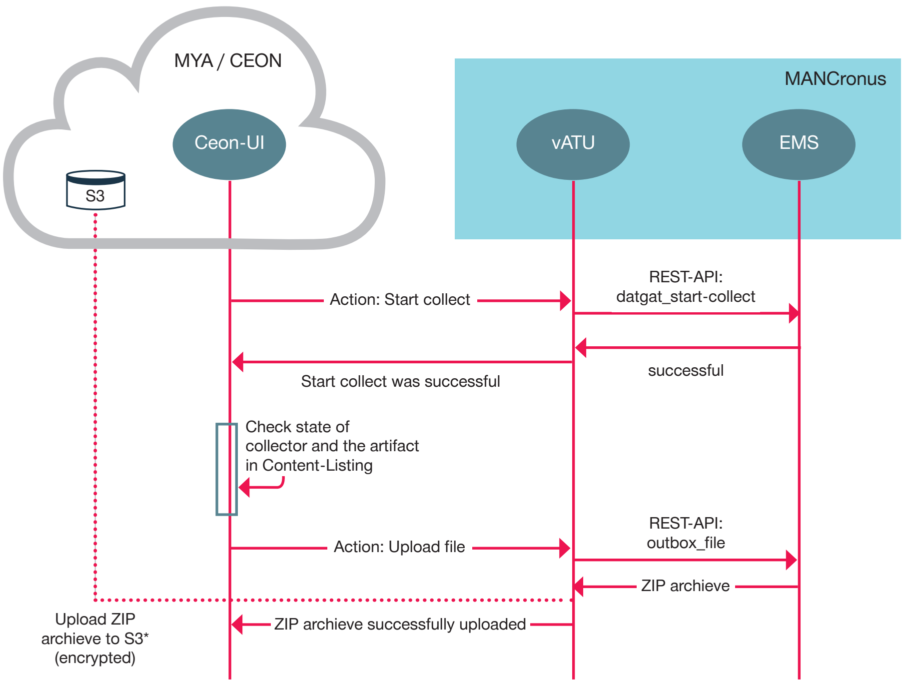


Fig. 55: Working principle of Online Datgat

Engine observation storage

Good management of the wear parts is key for a well-running MAN B&W engine. For MAN Energy Solutions, it is also key to get data feedback on the lifetime of the same components to ensure that we can continuously improve the quality.

The most important data source for keeping track of the component status is the wear measurements and visual observations made by the crew during operation and overhaul.

Engine observation storage (EOS) is a platform that provides a solution for collecting data systematically and use it to the benefit of both the engine owner, engine maker, and designer. Fig. 56 illustrates the input options.

Service engineers have a version that does not require an internet connection, and they must still bring data with them in the field.

Engine owners have two solutions for sharing data, an EOS app on the new app server concept, or a simpler solution where the shipowner submits our templates by e-mail. Fig. 57 shows a mock-up of the EOS app.

Both the app and the e-mail solution will provide feedback to the owner on the current state assessment of the components based on the reported observations. The app will be directly in the program, whereas in the e-mail solution, a report file with submitted data is returned to the mailbox.

Data observation templates supported:

- scavenge port inspection
- exhaust valve
- piston crown
- piston rings
- drain oil
- liner.

EOS on app server

The EOS for the app server is built to support the chief engineer and the crew in their maintenance work. The app reminds them if a report is overdue based on recommendations from MAN Energy Solutions and gives a simple overview of the engine condition based on the data submitted. On the free default version, the recommendations are based on running hours only.

The app can be extended with analysis and recommendations as well as prediction of remaining running hours based on data. Such extensions come at a cost for the shipowner.

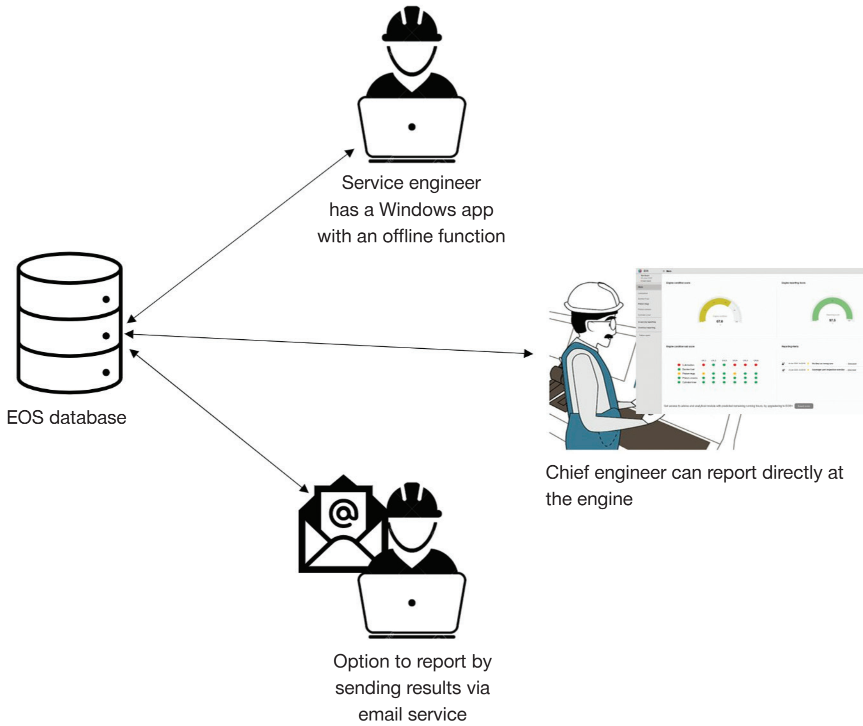


Fig. 56: Principle drawing of input options

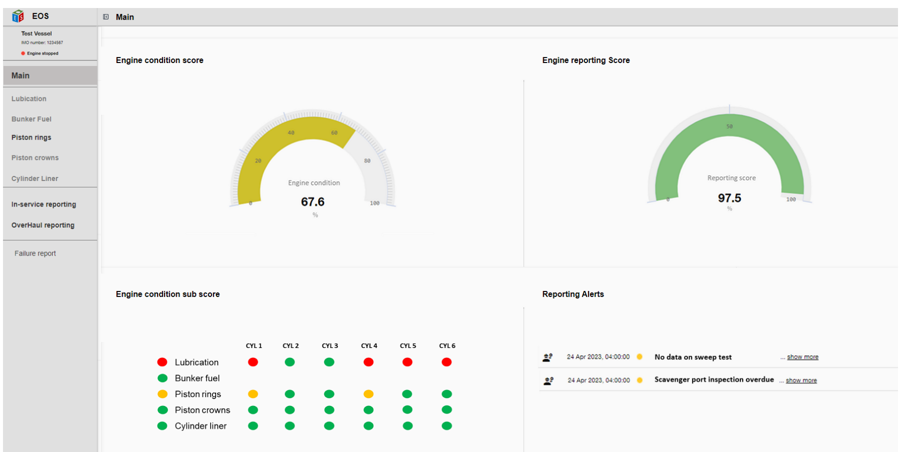


Fig. 57: Mock-up for EOS app version 1

Conclusion

In this paper, we have presented relevant service experience for all MAN B&W two-stroke engines. This goes for both single-fuel engines and the various versions of dual-fuel gas engines.

As the fleet of dual-fuel engines will expand significantly in the coming years to assist the maritime energy transition towards net-zero carbon emissions, we will definitely gain more experience in the near future, and implement more design modifications to follow up on and ensure the reliability of these engines.

Furthermore, to help push the maritime energy transition, retrofitting of single-fuel ME/ME-C engines will also be carried out in the near future. The experience from such retrofit projects will increase the service feedback, and make efficient updates possible.

MAN Energy Solutions
2450 Copenhagen SV, Denmark
P +45 33 85 11 00
F +45 33 85 10 30
info-cph@man-es.com
www.man-es.com

All data provided in this document is non-binding. This data serves informational purposes only and is not guaranteed in any way. Depending on the subsequent specific individual projects, the relevant data may be subject to changes and will be assessed and determined individually for each project. This will depend on the particular characteristics of each individual project, especially specific site and operational conditions.

5510-0275-00ppr Sep 2023. Printed in Denmark.