

Field Experience

**L27/38 propulsion engine powering
M/V MARK AMAY**

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Contents:	Introduction	3
	L27/38 – basic engine and performance data	3
	M/V MARK AMAY – principal particulars	4
	Vessel in operation	4
	Status after two years	5
	Local support in Ireland	5
	Engineer on board	6
	20,000 hours of operation	6
	Return from Skagen to the fishing grounds	7
	33,700 hours of operation	7
	46,300 hours of operation – class survey and component inspection	8
	Cylinder liners	8
	Cylinder heads	9
	Pistons and connecting rods	9
	Main and connecting rod bearings	10
	Fuel injection pumps	11
	Other inspections	12
	Future maintenance intervals	12
	Time between overhaul	12
	Continuous development and future perspective	13
	Appendix: Lube oil analysis	14

Field experience

L27/38 propulsion engine powering M/V MARK AMAY

The following paper describes our field experience with MAN Diesel four-stroke propulsion engine type, L27/38, powering the Irish fishing vessel M/V MARK AMAY, built at Karstensens Shipyard in Skagen, Denmark.

Introduction

Since the introduction of the L27/38 series during the year 1999-2000 a large number of engines have been ordered and delivered from the Danish production plants and MAN Diesel licensees.

The L27/38 engine series has reached a high level of success within more market segments, such as marine propulsion plants, marine generating sets and stationary power plants. Today, a total of 2,180 engines are ordered/in operation on different fuels, ranging from marine gas oil (MGO), marine diesel oil (MDO), heavy fuel oils (HFO) – to various biofuels in stationary power plants. Out of that, 370 propulsion engines (a large part operating on HFO) and more than 1,800 generator engines (majority operating on HFO) have been delivered or are in our order backlog.

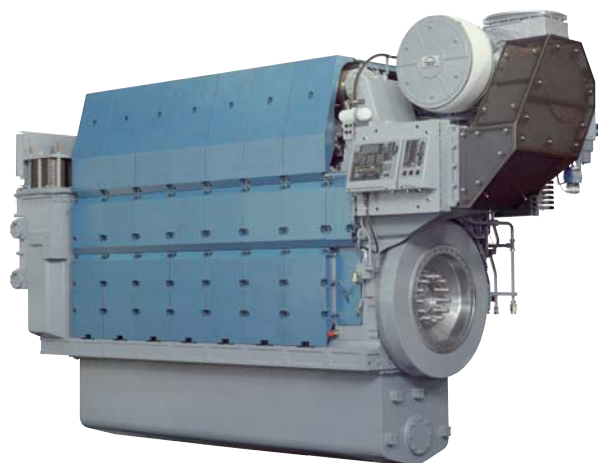


Fig. 1 M/V MARK AMAY after arrival at its homeport at Killybegs, Ireland

This paper will deal with the experience gained from the L27/38 propulsion engines, which can be delivered as in-line engines with 6, 7, 8 and 9 cylinders, covering the power range from 2,040-3,060 kW. Since 2006, this engine type has been delivered with an output up to 3,285 kW.

L27/38 – basic engine and performance data

Bore	mm	270
Stroke	mm	380
Stroke/bore	ratio	1.41:1
Swept volume/cyl	ltr	21.8
Cyl nos	in line	6-7-8-9
Speed	rev/min	800
Mean piston speed	m/s	10.1
Max press	bar	195
SLOC	g/kWh	0.5-0.8
Power range	kW	2,040-3,060
SFOC (mcr *)	g/kWh	182
Bmep	bar	23.5
Output/cyl	kW	340
Fuel	MGO/MDO/HFO	



*) without engine driven pumps at ISO condition, with 5% tolerance and heat release of 42700 kJ/kg

M/V MARK AMAY – principal particulars

The stern trawler was delivered from the building yard in Skagen in December 2000.

Vessel name	MARK AMAY
IMO Number	921721
Shipyard	Karstensens Skibsværft A/S
Yard number	382
Type	Twin rig trawler
Tonnage	60 GT
Length o.a.	38.3 m
Length p.p	32.8 m
Breadth (mld)	10.5 m
Depth (mld)	6.85 m
Draught	6.2 m
Class	DNV
Notation	+1A1, Fishing Vessel, Ice C

The M/V MARK AMAY is powered by a 6-cylinder MAN Diesel main engine, type L27/38, operated on MGO. The complete MAN Diesel propulsion package consists of:

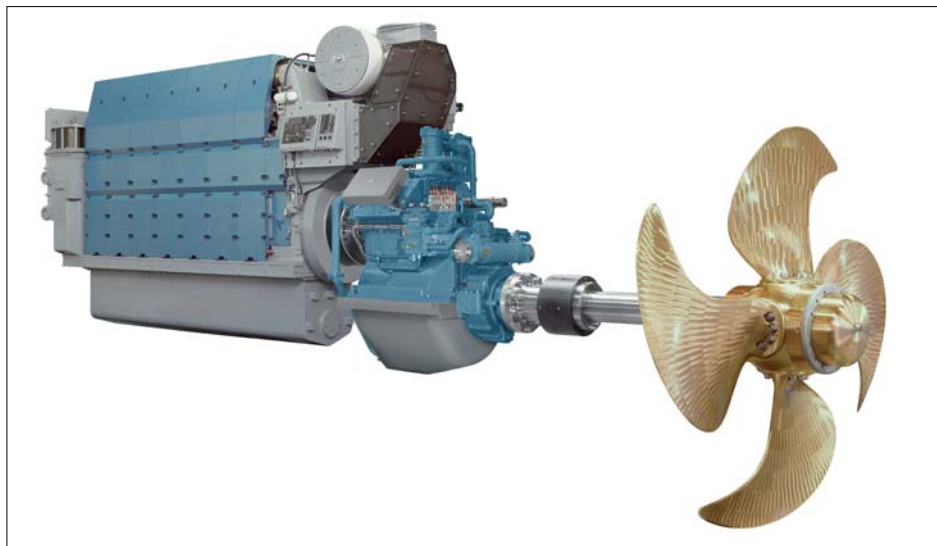


Fig 3. MAN Diesel L27/38 – the complete propulsion solution

- MAN Diesel engine, type 6L27/38, rated 2,040 kW at 800 r/min.
- MAN Diesel gearbox, AMG28 type 52VO27, with a PTO for a 1,200 kW Stamford shaft alternator
- MAN Diesel CP Propeller, type VB860 – 3,400 mm diameter propeller
- MAN Diesel Alphatronic control system, type AT2000

Vessel in operation

In June 2007, the M/V MARK AMAY had accumulated the most running hours for the engine type (totally 46,300 hrs) and we took the opportunity to inspect the engine components in detail due to a parts investigation for TBO (Time Between Overhaul) and a lifetime expectancy analysis, and also to give an objective technical judgement of the engine reliability, strengths and robustness.



Fig. 4 and 5 M/V MARK AMAY on its way to the fishing banks in the Atlantic Ocean

Until June 2006, the vessel had been fishing in the Atlantic Ocean on the west side of Killybegs, which is the home port of the trawler, located in the North-western part of Ireland. In June 2007, the trawler was sold to a new owner from the Faroe Islands and the future working place will be coastal fishing banks. However, the prior shipowner, Mr Shaun Conneely and his chief engineer Mr Féilem O'Muirí (since 2002) have been very helpful providing us with all the necessary information including the daily observations and records from the engine log books.

The engine usually runs with a shaft alternator supplying power to the trawler and main switchboard and powering the hydraulic pumps and stern thrusters during fishing. The average engine load varies between 70-80% during fishing and full load during steaming to and from the fishing place.

This paper will not deal with how fishing has performed, as this is beyond our knowledge, but based on information from crew members the fishing performance has been excellent and expectations have been fulfilled 100%. The voyages of the M/V MARK AMAY have been performed without any interruptions and the entire propulsion plant from MAN Diesel has not caused any off-hire days.

Status after two years

Experiences accumulated from the first 12,000 running hours – corresponding to the first two years of the operation period:

- After approx. 1,000 hrs of operation, the lube oil consumption is reported to 1.05 g/kWh, which is 50-60% higher than expected. The bore-scope inspection did not show any abnormalities and honing marks were 100% visible. To avoid any off-hire, it was decided to postpone withdrawal of pistons until the end of the year as fishing and fishing prices were very satisfactory at the time being.
- After 2,100 hrs, a HT water pump failure occurred due to inadequate design of the shaft for tightening the impeller. A preliminary repair took place in May 2001. Consequently, both HT and LT pumps were replaced by an improved version a few months after to avoid further trouble.
- The Engine Operator Panel on the engine failed due to lack of vibration dampers. A new panel with vibration dampers was fitted.
- In October 2001, after 5,900 hrs of operation, the vessel planned to go back to Skagen for a guarantee docking, and it was decided to withdraw all 6 pistons for investigations concerning the excessive lube oil consumption. Cylinder liners were cleaned and slightly honed and a modified ring package was fitted on all 6 pistons.

- A turbocharger breakdown at sea trial on 17 October 2001. A broken flap valve from the by-pass valve entered the turbine due to a design failure on the by-pass valve system. The vessel returned to Skagen with reduced engine load. The turbocharger unit was exchanged and the by-pass valve system was modified, and the failure risk thus totally eliminated. All supplied free of charge.
- A combined relay and control valve for the starter motor failed twice and a new improved version was delivered in December 2001. The engine could be emergency started.
- The air starter turbine was worn out due to inadequate air filtration. A reconditioned air starter and a new modified air filter was sent to the ship (as a gesture of goodwill compensation) in December 2002, after more than 12,000 hrs of operation.

The above-mentioned repair work mainly took place in Killybegs during the unloading of fish or at the planned yard stay in Skagen in October 2001.

Local support in Ireland

Because of the increasing domestic fishing activities and the need for quick support in the western parts of Ireland, we introduced the company Showlin Marine Ltd, Killybegs, which today is an Authorised Repair Shop for MAN Diesel.



Figs. 6 and 7 M/V MARK AMAY engine room – very clean and well maintained

Engineer on board

Also worth mentioning is that a new well-experienced chief engineer Mr Féilem O'Muirei started working on the vessel in the very beginning of 2002. He had a good understanding of operating the plant and kept both engine and the surrounding equipment in a very good and clean condition.

The only concern for the shipowners and chief engineer was the lube oil consumption reported at the end of November 2002, close to 0.9 g/kWh and approx. 25% higher than what MAN Diesel had specified as maximum. The engine had operated a total of 17,000 hrs (11,000 hrs after change of piston rings). Since the lube oil consumption did not elevate dramatically, the shipowner decided to postpone the repair and the engine check until the summer period 2003 when the engine had accumulated 20,000 running hours.

Seen in the engineer's Log Book for the period 27 December 2002 to 19 August 2003, the following work had been carried out by the crew:

14-01-2003: New coupling fitted to engine-driven sea water pump

- 22-02-2003: Modified IR relay valve fitted on the air starter (supplied free of charge as a gesture of goodwill)
- 03-03-2003: Fuel injection pipes fitted on cylinder nos. 3 and 5

20,000 hours of operation

Subsequently, the owner planned to overhaul the engine since it had reached 20,000 hrs of operation. On 19 August 2003, the vessel arrived at Skagen and the following parts were requested to be repaired/maintained:

1 Cylinder heads

The cylinder heads were overhauled at our Service Center workshop in Frederikshavn. Exhaust and inlet valves, seat rings, rotor caps, valve guides, and safety valves were controlled for wear. Four inlet valves and the corresponding seat rings were renewed due to some wear on the inlet valves

2 Fuel valves

The fuel injection valves were overhauled in Frederikshavn

3 Cylinder liners

All liners were replaced due to design changes. Liners were not worn

out at all and the wear rate was not measurable

4 Pistons and piston rings

The pistons were modified and updated to the newest design stage and the piston rings were also renewed to the last development stage. Related costs for the piston modifications were covered by MAN Diesel

Liners, pistons and piston rings were modified/renewed at the request of MAN Diesel, as an updating to the recent design was also in the interest of the company

5 Connecting rod bearings

In order to carry out laboratory investigations, four connecting rod bearings were replaced. The bearings could have continued the operation without concern

6 Main bearings

Main bearing nos. 3 and 5 were renewed and the old bearings were forwarded to the MAN Diesel Augsburg laboratory for investigation. The remaining five main bearing sets continued operation. The extended investigation carried out in our

laboratories later showed, that the bearing set nos. 3 and 5 could have continued operation, and that the selected bearing material was fit for purpose

7 Camshafts

The camshaft sections were inspected and found in perfect condition

8 Turbocharger

The turbocharger was overhauled at our Service Center workshop in Frederikshavn. The rotating elements were controlled for correct balance and nothing was to be remarked. Only soft parts were required

9 Cooling water pumps

LT and HT water pumps were controlled and found in good condition

10 Vibration damper

The vibration damper on the crankshaft was controlled and found in good condition

11 Lube oil filter

The lube oil automatic back-flushing filter was controlled and assembled with new sealing rings

Return from Skagen to the fishing grounds

In September 2003, M/V MARK AMAY left Skagen and returned to Ireland for the fishing season. The fishing continued until August 2005 after 33,700 hrs of operation when the ship returned to Karstensens Shipyard in Skagen. The main engine had operated well and required only normal maintenance according to the standard programme. The engine did not consume any spare parts and only the below three topics/events from the chief engineer's log books are worth mentioning:

Work carried out by the crew
February - 2004:

- Replacement of fuel injection pump no. 6, which seizes after a tremendous amount of water in the service tank. Afterwards, the crew flushed the entire fuel system and replaced all fuel injection filters on main engine and aux. engines as well

April - 2005:

- Replacement of fuel injection pump no 2. with the spare unit, due to leakage on top cover area

May - 2005:

- Exhaust sensor no. 2 renewed

33,700 hours of operation

MAN Diesel service engineers attended the vessel in Skagen, August 2005, and carried out the following work after 33,700 hrs of operation:

- All fuel injectors removed to workshop and reconditioned
- Bore scope inspection of all cylinder units. All were found in good condition
- Lube oil consumption recorded to approx. 0.5-0.6 g/kWh, which is very good

- Main bearing screws and the screws for the counterweights were retightened
- Worked on temporary "Tacho error failure", but did not trace the failure.
- The turbocharger was overhauled

Fuel injection pumps nos. 1, 3 and 5 were exchanged to reconditioned pumps by the ship's crew.

After the very limited repair and maintenance work, the engine operated trouble-free and only daily maintenance work took place until the ship arrived at Karstensens Shipyard in June 2007 for a major overhaul – a new shipowner from Faroe Islands subsequently took over the responsibility of the ship and propulsion plant. The lube oil consumption (after 26,300 hrs of operation after the last overhaul) was still relatively low, but slightly elevated during the last 6 months' operation up to the range of 0.8 - 0.85 g/kWh. The lube oil analysis reports (see appendix) confirm that the oil is in a stable and good condition.



Fig. 8 M/V MARK AMAY at Karstensens slipway

46,300 hours of operation – class survey and component inspection

The engine was repaired/overhauled during the summer 2007, and we followed up on the main components after a total of 46,300 hrs of operation.

Cylinder liners

Cylinder liners were withdrawn and returned to the Service Center repair shop in Frederikshavn with the purpose of measuring the liner wear and also re-honing the liners.

The liners looked fine after 26,300 hrs of operation and the honing marks were visible on the entire liner surface.

The liner diameter was measured before and after the honing. The diameter was still within the tolerance limits of the design drawing. 270H7 \approx Minimum diameter 270.00 and Maximum diameter 270.052. After honing, the diameter reached 270.07 mm, which indicates that the liners have sufficient material for at least another two honing reconditionings, since we can re-hone the diameter up to 270.20 mm.

Calculating the wear rate of the liners, we normally used the key figures by calculating the wear rate in [$\mu\text{m}/1,000$ hrs operation] and in this case we obtained an exceptionally low wear rate of 2 [$\mu\text{m}/1,000$ hrs].

On MGO operation, the liners can reach a total lifetime of 80,000 hrs, which meet our expectations.

With the low wear rate and the consequently good TBO of the liners, we expect that the liners can be reconditioned 3 times in total, before the upper wear limit of 270.4 mm is exceeded, and the liners can meet our 80,000 hrs lifetime expectation.



Fig. 9: Liner no. 4 in the upper TDC point after 26,300 hrs of operation



Fig. 10: Liner no. 3 exhaust side in the upper TDC point after 26,300 hrs of operation



Fig. 11: Cylinder head inlet – and exhaust ring. Coke deposit limited after 26,300 hrs of operation



Fig. 12: Exhaust seat ring – corrosion-damaged due to inadequate cooling water inhibitor



Fig. 13: Exhaust valve after 46,300 hrs of operation



Fig. 14: Exhaust rocker arm bush after 46,300 hrs of operation. Can continue operation

Cylinder heads

All cylinder heads were dismantled for cleaning and repair. Components such as valves, valve seat rings, valve rotators, valve bridges rocker arm shaft and bearing bushes were overall in excellent condition after a total of 46,300 hrs. However, at the end of the repair, we have only renewed 2 inlet valves and 12 exhaust valve seat rings. The exhaust valve seat rings were replaced because of minor water leakages around the 2 seat rings, due to an improper water inhibitor added to the HT water.

All 24 valve rotators (used on both inlet – and outlet valves) could continue service despite our best expectations for a lifetime of 48,000 running hrs, which can be met easily.

Also the pressure safety valves were checked for possible maintenance, which had to be carried out as a matter of routine. However, nothing abnormal was found.

Pistons and connecting rods

The two-part pistons were all dismantled for cleaning and overhaul. The piston skirt (lower part) looked nice and

completely free from glazed areas in the running layer (Molycote threaded) and the lower part of the piston continued operation without any repair.

Owing to MAN Diesel's continuous development philosophy, the piston top and the piston ring design have been modified, since the Mark Amay engine was built. We decided to replace all piston tops, despite of the fact that the wear rate of piston ring grooves could have continued operation. The benefit regarding better "long time" lube oil control and less deposits in the ring

grooves justified our decision of replacing the piston tops.

The new piston top rings fitted were chromium-plated on both flanks in order to minimise the ring groove wear rate, when operating on HFO (Heavy Fuel Oil). Since the introduction of this top ring in 2005, our HFO service experience has shown a 50% reduction of the ring groove wear rate. With this upgrading of the engine, a piston top lifetime of 80,000 running hours could easily be fulfilled before exceeding the scrapping criterion of 6.42 mm.

Main and connecting rod bearings

During our inspection after 20,000 running hours, main bearing nos. 3 and 5 were taken out and forwarded for investigation in our Augsburg laboratory and later by the bearing supplier. The remaining five main bearings continued operation until now, having accumulated a total of 46,300 hrs of operation.



Fig. 15: Piston top crown in good condition after 26,300 hrs of operation since the last withdrawal



Fig. 16: Piston skirt can continue service after reconditioning of the piston steel top



Fig. 17: Main bearing no. 1 after 46,300 hrs of operation



Fig. 18: Close-up photo of main bearing no. 1

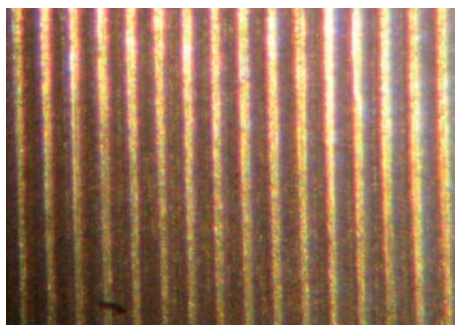


Fig. 19: Main bearing no. 1 after a blow-up (30 times) Miba "Rillenlager" structure in good condition



Fig. 20: Main bearing no. 1 - Back side of lower main bearing shell

The connecting rod bearings had all accumulated 26,300 running hours. All six bearing sets are in good condition, and it was decided to continue operation with the connecting rod bearing sets. However, we emphasised to the new owner of the ship and his engine staff that we strongly require that the maximum safe running period for the large end bearings is to be limited to 36,000 hrs of operation, which meet our expectations to lifetime.



Fig. 21: Main bearing no. 2 - Cavitations mark visible



Fig. 22: Main bearing no. 2 – Close-up of the cavitation marks. Visible at the ends of the oil grooves

Fuel injection pumps

The fuel injection pumps were overhauled by the crew, and the lifetime of plungers and barrels seemed to be limited to 30,000-40,000 running hours on MGO. The pump from cylinder no. 4 had the longest operating period of 37,934 hrs, and we took the opportunity to inspect the plunger and barrel.

Inspection of fuel injection pump no 4:

- Minor cavitation marks on the plunger top
- Scratch mark in lengthwise direction on the lower part of the piston
- Severe cavitations at the inlet holes at low pressure side

The above pump element was ready to be renewed and it looked like the TBO for the pump was reached after 36,000 running hrs at MGO, which more than fulfil our guidelines for lifetime.



Fig. 23: Plunger with cavitation



Fig. 24: Cavitation marks at the inlet bore low pressure side



Fig. 25: Detail with inlet bore

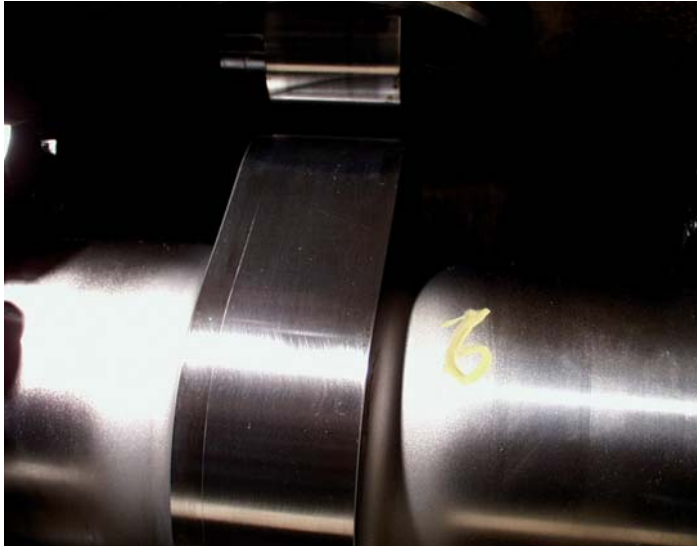


Fig. 26 Fuel cam no. 6



Fig. 27 Valve cams and roller guides for cyl. no. 6

Other inspections

All other inspections during the general overhaul did not reveal any adverse conditions. Special attention was paid to cams, rollers, crankshaft journals and the MAN Diesel turbocharger type NR24/S. The cams and rollers had almost the same appearance, as when the engine left the testbed. A crankshaft check for possible journal wear was carried out and the journals were found to be in excellent condition. The vibration damper (sleeve spring damper type) on the front end of the crankshaft was checked, and nothing irregular was found.

Future maintenance intervals

When the L27/38 engine was introduced, our target was a TBO of 24,000 for a MGO plant for a general overhaul. It has now been proved - after the modifications made to the ring pack and cylinder liners during the first overhaul in August 2003 - that the target has been reached. For pistons, modified piston rings, liners and bearings, we are convinced that a TBO of 30,000 hrs can be reached on this particular plant.

However, it should also be emphasised that the qualified crew on the M/V MARK AMAY has followed our planned maintenance programme and carried out maintenance of the engine regularly, according to the Instruction Manual.

Time between overhaul

After these modifications, the following TBO times can be achieved for MGO operation:

Cylinder liners	30,000 hrs
Piston rings	30,000 hrs
Piston crowns	80,000 hrs
Cylinder covers	30,000 hrs
*Main bearings	48,000 hrs
*Connecting rod bearings	36,000 hrs
Vibration damper	60,000 hrs
Fuel pumps	36,000 hrs
Turbocharger	24,000 hrs
Injectors	6,000 hrs

** Based on component inspection of 1 or 2 units at 24,000 hrs*

The above TBOs are then coinciding with the intermediate survey and control of the machinery.

Continuous development and future perspective

The award-winning MAN Diesel L21/31 and L27/38 design generation has clearly set the new standard for modern medium-speed propulsion diesels. A very visible step forward. Right from the very first glance at the clean-lined exterior – to the closer look at the internal details.

The modular design of the engines – with front-end and aft-end boxes carrying all auxiliary equipment for lube oil and cooling water circuits – gives them an uncluttered appearance. Furthermore, this also leads to practical as well as aesthetic benefits, permitting e.g. removal of each cylinder assembly (cylinder head, piston, connecting rod and liner) as a complete individual unit. This vastly reduces the time required for maintenance or replacement. Additionally, this well conceived design has only a minimal overhead height requirement. However, the necessary lifting height



Fig. 28: L27/38 complete cylinder unit

above the cylinder heads can not always be met on smaller fishing vessels. Therefore, the design also gives the freedom to separate the components in the traditional way by withdrawing first the cylinder heads, piston and connecting rods, and last the cylinder liners.

With the company goal to maintain and improve engine performance, reliability and the market position, the engines undergo MAN Diesel's continuous development philosophy. For instance, engine type L27/38 has been modified/improved with regard to a number of components - first of all with the purpose of making the engine even more attractive, economic, reliable and clean. Nowadays, there is strict legislation on engine designs to meet the environmental requirements of tomorrow. This results in ongoing R&D activities to reduce emissions and particles, without conflicting with the overall requirements, and simultaneously to have moderate investment costs and low operational costs via low specific fuel oil consumption over the entire load range.

Furthermore, new customer-related inquiries have resulted in new developments of the engine and its applications.

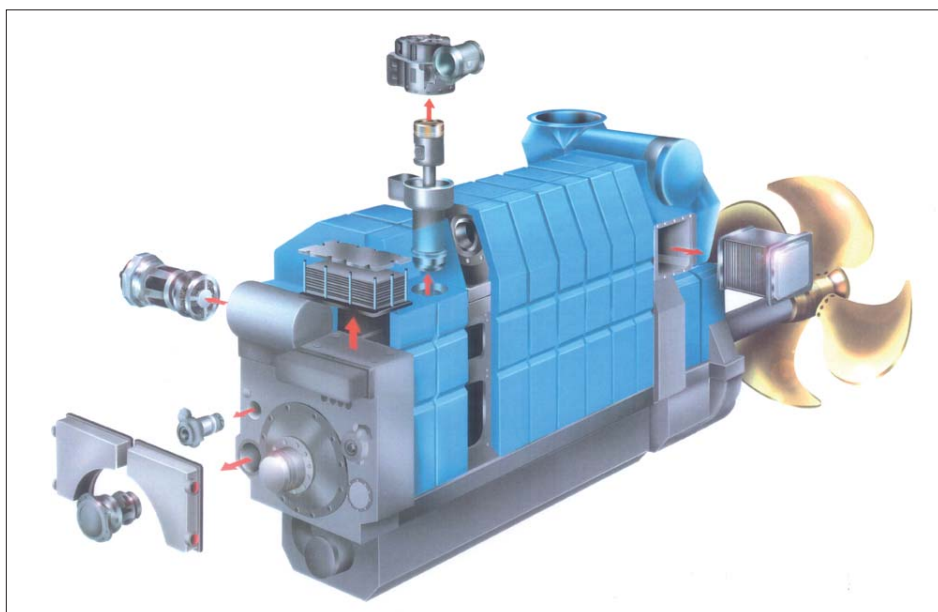



Fig. 29: L27/38 propulsion engine – a service and maintenance-friendly modularised unit concept

In the following summary, the most important design modifications, features and benefits for the L27/38 propulsion engine have been listed:


- 1 Improvement/modification of piston and piston ring pack for improvement of the TBO
- 2 Modification of cooling water jacket for equal temperature in the liner top circumference
- 3 Modification of cylinder liners to “free hanging” version for improving the TBO for cylinder units
- 4 Improvement of fuel injection pumps in order to minimise the risk of cavitations / erosion in the pipe system.
- 5 Design of engine control system for operation with Munters SCR converters, which can reduce the NO_x emissions to a level below 2 g/kWh.
- 6 Uprating of the engine by strengthening / improving some components enabling us to increase BMEP to 25.2 bar. Engine load elevated from 340 kW/cyl. to 365 kW/cyl. in order to reach a new customer demand
- 7 Introduction of the new MAN Diesel turbocharger generation type TCR. The main purpose was to ensure faster engine response during manoeuvring and additionally to improve the turbocharger and overall plant efficiency and reduction of the NO_x
- 8 Introduction of new fuel injection atomisers “low sack” version for optimising combustion behaviour and reducing soot and particle emission in order to come closer to the restrictive EPA Tier2 legislation
- 9 New low “dry sump” oil pan (as customer option) suitable for plants with separate oil tank
- 10 Special insulation of hot surfaces (as customer option) to meet the demand to ensure all surface temperatures be kept below 100°C

Within its power range, the L27/38 is the most attractive and safe engine investment today. An engine design with high safety margins offering lots of potential for the future.

Appendix: Lube oil analysis



Shell e-Quip



Shell e-Quip number : 00332735/AMOT
this number is mandatory on the label of your next sample

Customer number (Internet login) : SIR00035

MARK AMAY FISHING CO LTD

Sample Number : 03855887

Lubricant in use : MDCO THE GLEBE
 Equipment Reference : SHELL GADINIA 40 KILLYBEGS
 Equipment description : MAIN ENGINE ME DONEGAL
 Component description : MARK AMAY KILLYBEGS
 MAIN ENGINE IRELAND

SHELL CONTACTS

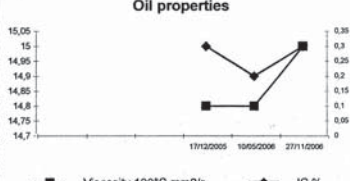
JACK CONDON Shell Web site :
 00353866783928 www.shell-equip.com

COMMENTS Sample 03855887 GREEN

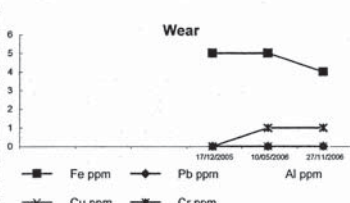
The overall results are satisfactory.

RESULTS			
Sample Number	03572173	03855884	03855887
Sampling date	17/12/2005	10/05/2006	27/11/2006
Equipment life (Km or Hours)	35801	38224	42436
Oil life (Km or Hours)	35801	38224	42436
Viscosity 100°C			
Viscosity 100°C mm2/s	14.8	14.8	15.0
Water			
Water content %	0.0	0.00	0.00
Flash point			
Flash point °C	>190	>190	>190
TBN			
TBN ASTM D 2896 mgKOH/l	11.5	11.3	11.1
Chromatography			
IC %	0.3	0.2	0.3
MD	91	95	72
DP	2	0	8
Spectrometry			
P %	0.04	0.04	0.03
Zn %	0.05	0.04	0.04
Ca %	0.40	0.43	0.37
Ba %	0.00	0.00	0.00
Mg ppm	31	30	27
Al ppm	3	1	1
Fe ppm	5	5	4
Cr ppm	0	1	1
Mo ppm	1	1	1
Cu ppm	0	0	0
Pb ppm	0	0	0
Sn ppm	0	0	0
Si ppm	11	10	11
Na ppm	14	11	12
B ppm	1	1	4
V ppm	0	0	0
Ni ppm	0	0	0
Comments	GREEN	GREEN	GREEN

Oil properties



Wear



Pollution

