

For worldwide release: February 28, 2008

Release Number: M02PR08

IMO II in sight – First MaK M 43 C Low Emission Engine already in operation

Hamburg, Germany – “Fure West” is no cruise ship and it is also much smaller than the “Queen Mary 2”. However, this chemical tanker has one of the most advanced medium-speed marine engines available: Its MaK 7 M 43 C Low Emission Engine (LEE) today already meets expected future IMO emission regulations. That makes Fure West not only the first known vessel afloat with an IMO II-compliant engine running on Heavy Fuel Oil (HFO), but also a technological milestone for any future cruise or cargo vessel.

Furetank Rederi AB of Donsö, Sweden, operates five modern product and chemical tankers on European shipping routes. Fure West and its sister ship “Fure Nord” were delivered by Edward Shipbuilding Co Ltd in Shanghai, P. R. China, in 2006 and 2004 respectively. With 144 metres length, 21 metres beam and 9 metres draught, these 16,000 DWT tankers reach a top speed of 15.4 knots. Both vessels have to date relied on IMO-compliant MaK 7 M 43 C main engines rated 6,180 kW at 500 rpm.

However, Furetank owner Lars Höglund places lot of value on environmental-friendly operation and has always been interested in putting innovations into practise as early as possible. “We have committed ourselves to being in the lead when it comes to the preservation and protection of the environment!”, he said.

A strategy for gradual emission reduction

Caterpillar®, for its part, has made sustainable development a bold target of its “Vision 2020” strategy. Having monitored both the development of emission regulations and customer expectations, the company believes that electronically controlled engines will gradually

become the norm. And, with its proprietary simulation and analysis tools for engine combustion, its expertise in fuel system manufacturing and its internal electronic control designs, Caterpillar is well-prepared to set the standard for environmental-friendly diesel engines. Strong evidence for this is provided by Caterpillar's ACERT™ Technology, the product of a \$ 500 million investment structured on the broadest product, application and manufacturing base in the industry.

“The goal for MaK medium-speed marine engines was clearly defined”, comments Dr Udo Schlemmer-Kelling, Manager Research at Caterpillar Motoren in Kiel. “Exceed customer expectations by minimising emissions while maximising product value at the same time. Consequently, our strategy had to comply with the MaK brand reputation: superior reliability in heavy fuel operation, best-in-class fuel efficiency and outstanding durability!”

Back in 2000, Caterpillar Motoren identified three emission levels for the MaK marine product in order to cope with short to midterm emission regulations. These were a base line IMO engine, which fulfils MARPOL 73/78, Annex VI, an IMO-compliant engine with invisible smoke emissions and a Low Emission Engine (LEE) which meets the expected NOx emission range of IMO II and is also invisible in smoke. In addition, this strategy favours inside-the-engine means because of their clear advantage with respect to cost, complexity and maintenance.

LEE for low NOx

The key issue for low NOx emissions is to increase the compression ratio of the base engine. Ten years ago, a compression ratio of 11-12 was standard, for IMO I the ratio was raised to 14-15 and for IMO II ratios of 17 will be needed. Another cornerstone of the MaK LEE concept is the Miller Cycle, i.e. modification of the engine's valve timing to achieve cooler combustion. For IMO I only a small Miller effect of 5% was utilised, however, IMO II requires a Miller effect of 20%. This is a big challenge for the turbo charger, which has to provide boost ratios of 5 in order to maintain today's Mean Effective Pressure (BMEP) values.

By combining increased compression ratio and the Miller effect, NOx emissions can be reduced by around 30% without sacrificing engine efficiency (BSFC). However, such a simple LEE

engine would suffer from poor load pick-up at idle and visible soot emissions at part load. Because of this, the MaK LEE concept uses a “flexible camshaft” to enable both low NOx emissions, excellent load pick up and invisible soot at all loads.

FCT for low soot

Flexible Camshaft Technology (FCT) enables variation of the fuel system and the air system at part load operation. By advancing the start of the fuel injection and increasing injection pressure, combustion is improved and soot emissions are reduced by 50%. Shifted inlet valve timing switches off the Miller Cycle and contributes another 25% reduction in soot. Overall, MaK FCT reduces soot emissions at part load by 75% while improving engine performance at transient operation.

The system essentially consists of a modified lower valve train, a pneumatic adjusting unit and a Programmable Logic Controller (PLC). FCT is a robust mechanical solution, based on an eccentric lifter lever shaft automatically influencing both injection timing, pressure and valve timing. The engine load required to activate the lever can be flexibly set according to the vessel operator’s needs. Either way, visible smoke is eliminated while IMO standards are complied with at all loads. To date, about 80 MaK M 32 C and M 43 C engines equipped with FCT have been sold.

Retrofitting to MaK LEE standard is quick and easy

After comprehensive simulation and prototyping of the MaK LEE technology in 2001-2003 along with some final adjustments and improvements, Caterpillar Motoren, together with Caterpillar Marine Power Systems, was more than willing to put its unique technology to the test. In cooperation with Furetank Rederi, a timetable was agreed to convert the existing MaK 7 M 43 C on Fure West to LEE standard.

During a scheduled vessel stopover in the port of Rostock, Germany, in October 2007, a service crew from Pon Power A/S, Caterpillar’s MaK dealer for Scandinavia, supported by engineers from Caterpillar Motoren facilities in Kiel and Rostock, completed retrofitting, including Marine Classification Society (MCS) approval, in just four days.

Inside this tight time-frame, the team reworked connecting rods, camshaft segments and lower valve trains to cope with advanced LEE requirements. First, a conrod spacer was mounted to lengthen the split-shaft connecting rod, thus reducing combustion volume and increasing compression ratio. As a result, the anti-wear ring needed replacing with a shorter version.

In a second step, the camshaft segments were replaced with modified FCT versions, enabling load-dependent variation of the fuel and air system. Lower valve trains, injection pumps and injection nozzles were exchanged accordingly. In addition, specialists from ABB rebuilt the turbocharger for increased loading pressure, replacing the diffuser and nozzle ring. Sea trials with Fure West confirmed the quality of this retrofit as did the final approval given by Germanischer Lloyd.

A win-win situation for operators and the environment

Similar to the retrofitting of Fure West, all existing MaK M 20 C, M 25 C, M 32 C and M 43 C series marine engines afloat can be converted to MaK LEE standard – at about only 15-25% of the cost of a new IMO II-compliant engine. Building upon proven technology residing inside the engine, MaK LEE bears many advantages for vessel owners and operators.

MaK LEE today already provides a power plant complying with expected future IMO emission regulations. This allows shipping companies to increase their reputation for environmental-friendly marine business operations. In addition, the emission levels achieved with MaK LEE enable shipping companies to obtain special environmental classes with Marine Classification Societies, such as DNV Clean Design, GL Green Passport, LR Character N or the German Government's Blauer Engel. These environmental classes not only add to the vessel owner's image but also reduce harbour fees in some parts of the world.

IMO II not a threat anymore

The MaK 7 M 43 C Low Emission Engine has been operating aboard Fure West since October 2007 and has exceeded both the expectations of owner Furetank and Team Caterpillar. The world's first known IMO II-compliant medium-speed HFO-fuelled marine engine afloat, it runs as quietly and reliably as its thousands of MaK predecessors. The big difference, however, is

that emissions have been significantly reduced compared with current standard IMO I-compliant marine engines.

“With NO_x emissions down to 8.3 g/kWh, or 36% below current IMO regulations, and soot emissions reduced to less than 0.5 FSN (Filter Smoke Number) over the whole load range, our MaK LEE technology clearly deserves the name Low Emission Engine”, says Schlemmer-Kelling, highlighting the results of final sea trials with Fure West, achieved with low NO_x trim of the FCT system and determined under ISO E2 cycle conditions. “These achievements also guarantee the future of the MaK long-stroke marine engine design. I am very confident that our technology approach, together with Caterpillar Motoren’s in-house engineering expertise, will also find appropriate ways to cope with even more-stringent potential IMO III regulations.”

Speaking from the owner’s perspective, Höglund notes, “For many years we have trusted the performance and reliability of MaK marine engines. We also have appreciated the excellent service of Pon Power, our local Cat[®] and MaK dealer. In selecting MaK LEE technology for our most-modern tanker, we were convinced this would provide ideal support for our ambitious environmental goals while maintaining the proven durability of the MaK product. And after six months and some 2,500 hours of unrestricted operation, we are more than happy with the results achieved.”

In the next months, more MaK Low Emission Engines will be delivered to customers. Among them are two ship sets comprising 3x 12 M 43 C and 3x 16 M 43 C each for Norwegian Cruise Line’s “F3” newbuildings under construction at Aker Yards in France. These engines will get a customer-specific rating of 950 kW per cylinder, enabling DNV Clean Design compliance and a fuel consumption of 176 g/kWh – which is actually one gram under the 1,000 kW per cylinder IMO I rating of the M 43 C.

By 2010, about half of all MaK M 20 C, M 25 C, M 32 C and M 43 C marine engines built will be of LEE design. Eventually, and once IMO II emission regulations take effect, every medium-speed marine engine produced at Caterpillar Motoren facilities in Kiel, Rostock or Guangdong in the P. R. China will be a state-of-the-art MaK Low Emission Engine.

Characters: 10,542

Pictures available on request:

- 1.) Chemical Tanker Fure West powered by MaK 7 M 43 C Low Emission Engine**
- 2.) World's first known IMO II-compliant medium-speed HFO-fuelled Marine Engine afloat**
- 3.) FCT Unit mounted to MaK LEE Marine Engine**
- 4.) FCT Pneumatic Adjusting Unit for MaK LEE Marine Engine**
- 5.) FCT Camshaft and Lower Valve Train for MaK LEE Marine Engine**
- 6.) Pon Power Service Team arrives at Rostock port**
- 7.) Fure West - Retrofitting MaK 7 M 43 C Marine Engine to LEE Standard 1**
- 8.) Fure West - Retrofitting MaK 7 M 43 C Marine Engine to LEE Standard 2**
- 9.) Fure West - Retrofitting MaK 7 M 43 C Marine Engine to LEE Standard 3**

About Caterpillar Marine Power Systems

Caterpillar Marine Power Systems, with headquarters in Hamburg, Germany, brings together all the sales and service activities for Cat and MaK branded marine products within Caterpillar Inc. This organization provides premier marine power solutions (high and medium speed with outputs from 11 kW to 16,000 kW) and customer service from a single source for the global ocean-going, commercial and pleasure craft markets. The Caterpillar Marine Power Systems sales and service network includes more than 2,100 dealer locations world-wide and is well positioned to support customers wherever they are.

More information is available at www.cat-marine.com or www.mak-global.com.

About Caterpillar

For more than 80 years, Caterpillar Inc. has been making progress possible and driving positive and sustainable change on every continent. With 2006 sales and revenues of \$41.517 billion, Caterpillar is a technology leader and the world's leading manufacturer of construction and mining equipment, clean diesel and natural gas engines and industrial gas turbines.

More information is available at www.cat.com.

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