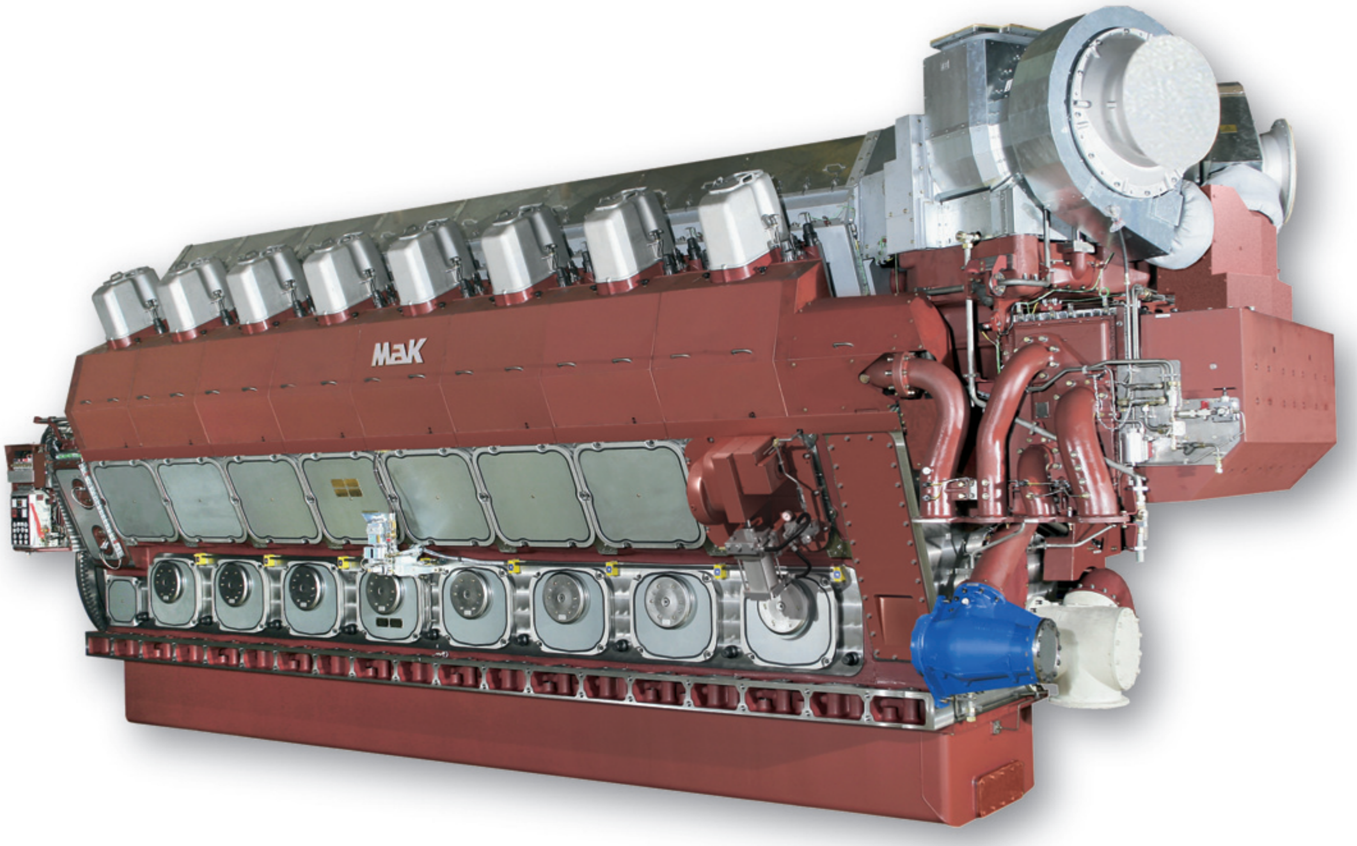
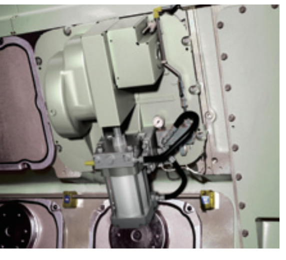
# VM 43 C

## Low Emission Engine



# VM 43 C ▶ Low Emission Engine

**IMO II in sight – MaK Low Emission Engines already in operation**

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 $NO_x$ 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 $NO_x$

The key issue for low $NO_x$ 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, $NO_x$ 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 $NO_x$ emissions, excellent load pick up and invisible soot at all loads.

### A win-win situation for operators and the environment

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. Building upon proven technology residing inside the engine, MaK LEE bears many advantages for vessel owners and operators.

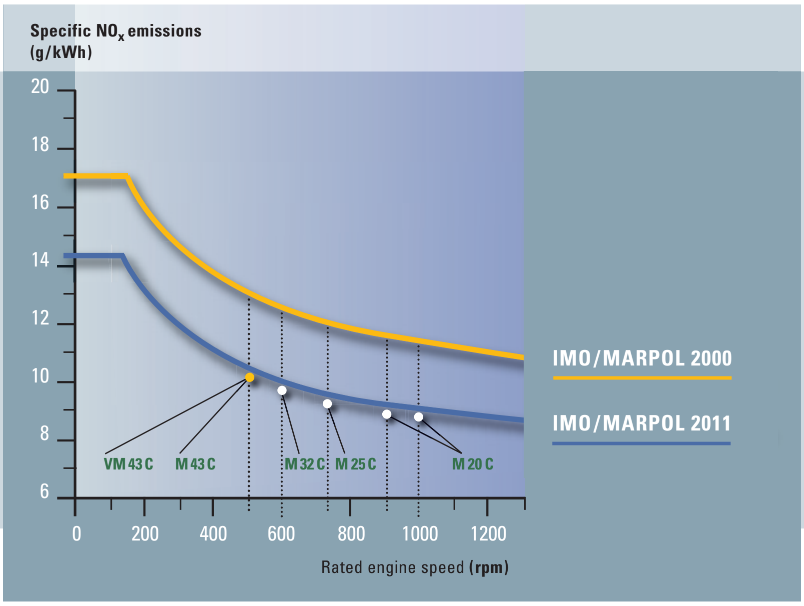
MaK LEE today already provides a power plant complying with expected future IMO emission regulations. This allows shipping companies to increase their reputation for environmental-friendly marine business operations. In addition, the emission levels achieved with MaK LEE enable shipping companies to obtain so-called 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.

### As from 1. 1. 2011 IMO II will become effective

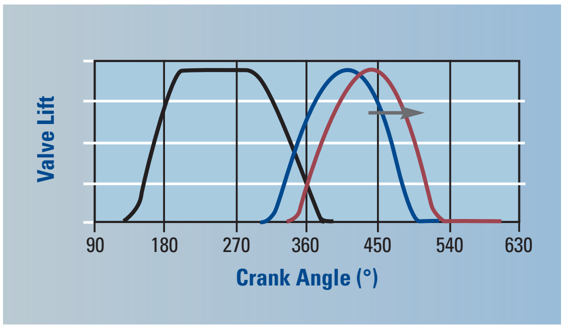
Already today Caterpillar is well prepared to meet these technological requirements. We tested sucessfully engines that meet IMO II emission requirements. The following components have been changed:

– new turbospecification of inner parts,
– new injection nozzle and new plunger design,
– higher compression ratio,
– new camshaft segments,
– FCT system, optional.

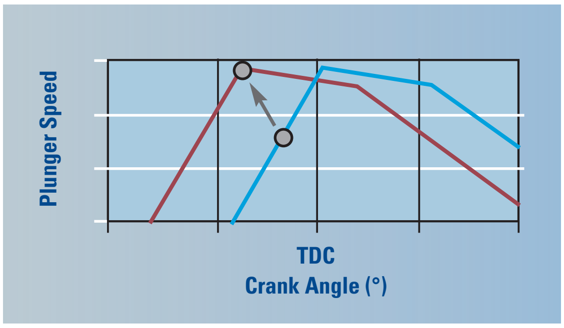
Not possible for fixed pitch propeller drive. Engine equipped with FCT for invisible smoke (FSN < 0.5) in the entire load range in quasi-stationary engine operation and if the ramp-up times according to our project guides are complied with. All these measures are retrofitable between IMO I and IMO II. The pilot engines were introduced into the market in 2008.



# VM 43 C ▶ FCT

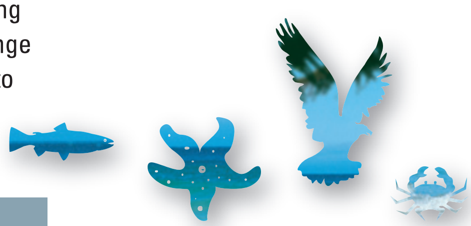



Flexible Camshaft Technology FCT (schematic diagram)




## Flexible Camshaft Technology

Building upon the Emission Reduction System integration concept, FCT achieves synergy between flexible fuel systems and advanced air systems with maximum utilization of the current engine design. While maintaining high fuel injection pressure over the whole operating range, fuel injection and inlet valve timing are load controlled and influenced by a lever shaft which affects injection timing/ pressure and inlet valve events. Valve timing changes at part load to raise effective compression and enhance complete combustion. In addition, shifting the relative position of the lever to the fuel cam increases injection pressure, producing a finer atomization of fuel in a load range where it would otherwise be difficult to control smoke.



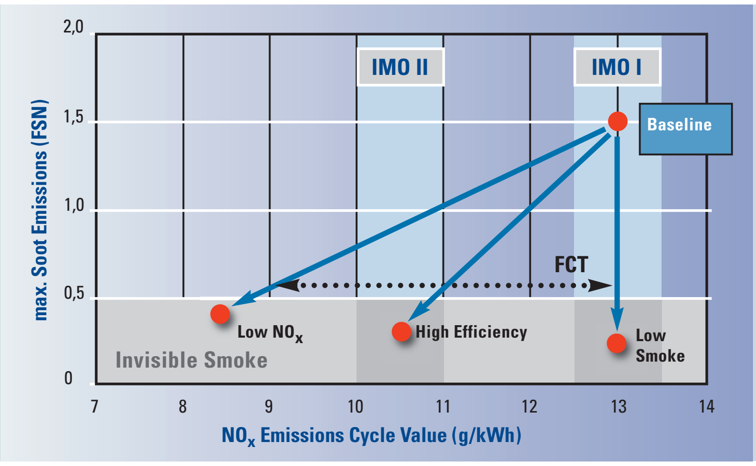
**Customer value sequence and benefits**

**Flexible Camshaft Technology (FCT)**

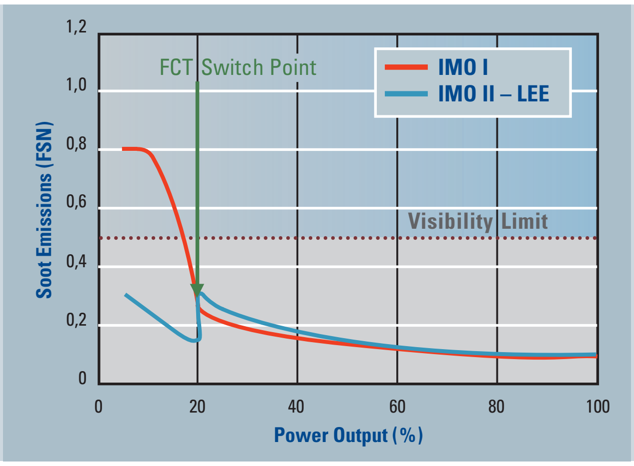
- High potential for $NO_x$ and smoke reduction.
- Hardware changes to prepare for IMO II – sustainable investment.
- Low complexity
- Technically lower risk – application of existing technology.





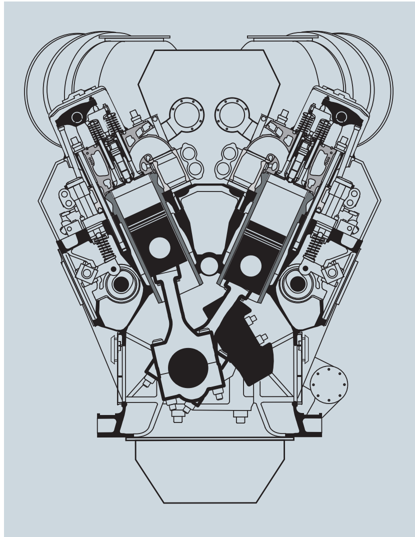



schematic diagram



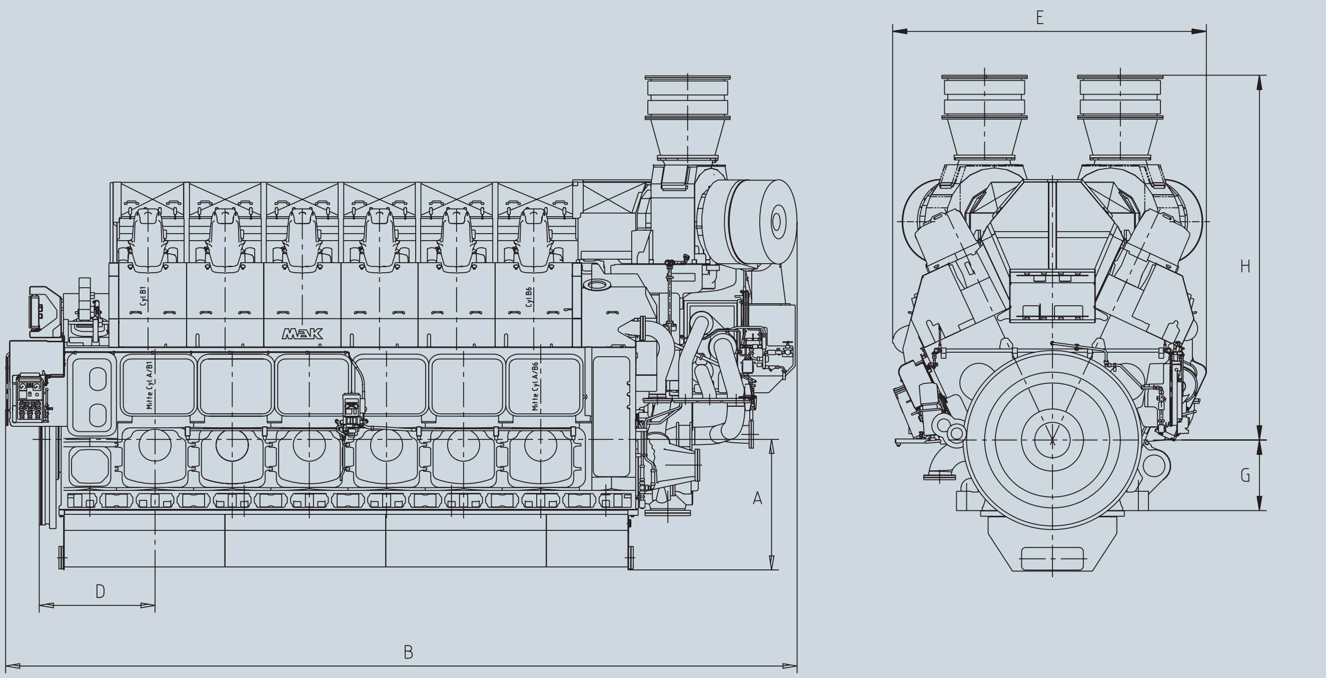
# VM 43 C – Low Emission Engine ▶ Engine Description (Preliminary)

| | Output range | | Speed | Mean eff. pressure | Mean piston speed | Bore | Stroke | Spec. fuel consumption | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 100 % | 85 % |
| | kW | mph | rpm | bar | m/s | mm | mm | g/kWh | g/kWh |
| **12 M 43 C** | 11400 | 15500 | 500 | 25.8 | 10.2 | 430 | 610 | 176 | 175 |
| | 11400 | 15500 | 514 | 25.0 | 10.5 | 430 | 610 | 176 | 175 |
| | 12000 | 16320 | 500 | 27.1 | 10.2 | 430 | 610 | 177 | 176 |
| | 12000 | 16320 | 514 | 26.4 | 10.5 | 430 | 610 | 178 | 177 |
| **16 M 43 C** | 15200 | 20670 | 500 | 25.8 | 10.2 | 430 | 610 | 176 | 175 |
| | 15200 | 20670 | 514 | 25.0 | 10.5 | 430 | 610 | 176 | 175 |
| | 16000 | 21760 | 500 | 27.1 | 10.2 | 430 | 610 | 177 | 176 |
| | 16000 | 21760 | 514 | 26.4 | 10.5 | 430 | 610 | 178 | 177 |



Specific lubricating oil consumption 0.6 g/kWh, ± 0.3 g/kWh
LCV = 42700 kJ/kg, without engine-driven pumps, tolerance 5 %

| | |
|---|---|
| Swept volume: | 88.6 l/cyl. |
| Output/cyl.: | 1000 kW |
| BMEP: | 27.1 bar/26.4 bar |
| Revolutions: | 500/514 rpm |
| Turbocharging: | single log |
| Direction of rotation: | clockwise, option: counter-clockwise |




| Dimensions (mm) and Weights (t) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Type** | A | B | D | E | G | H | t |
| **12 M 43 C** | 1625 | 9847 | 1440 | 3890 | 875 | 4524 | 160.0 |
| **16 M 43 C** | 1625 | 11943 | 1440 | 4027 | 875 | 4524 | 220.0 |

Engine centre distance: 4500 mm

Removal of cylinder liner:
in transverse direction 3700 mm

Nozzle position: ask for availability

This engine is only available with dry oil sump

Engine with turbocharger at flywheel end available, ask for dimensions.

Cat Common Rail: ask for availability

# VM 43 C – Low Emission Engine ▸ Technical Data (Preliminary)

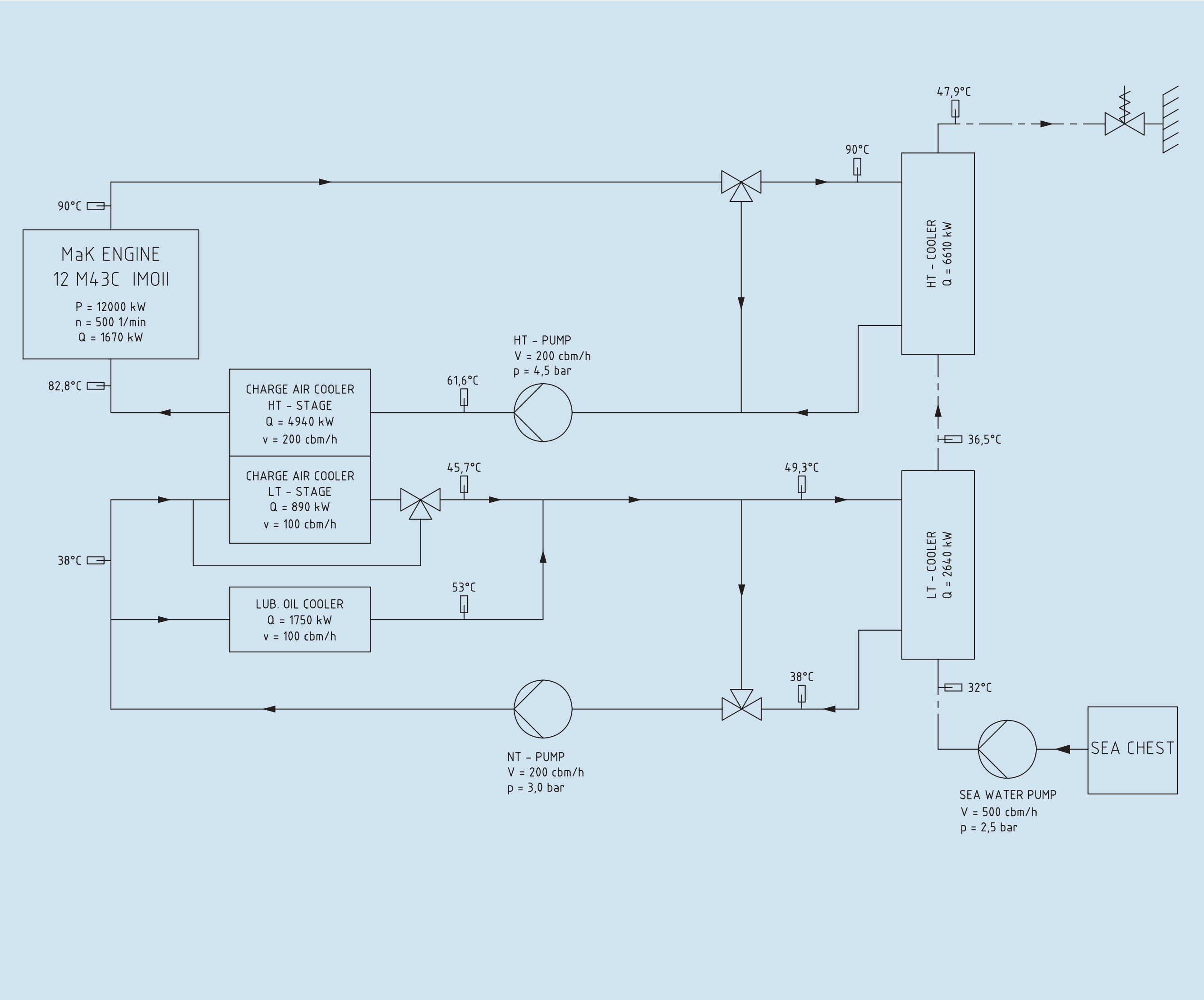
| | Cylinder | 12 | 16 |
|---|---|---|---|
| **Performance data** | | | |
| Maximum continous rating acc. ISO 3046/1 | kW | 12000 | 16000 |
| Speed | 1/min | 500/514 | 500/514 |
| Minimum speed | 1/min | 300 | 300 |
| Brake mean effective pressure | bar | 27.1/26.4 | 27.1/26.4 |
| Charge air pressure | bar | 4.0 | 4.0 |
| Firing pressure | bar | 210 | 210 |
| Combustion air demand (ta = 20 °C) | $m^3/h$ | 70000 | 86700 |
| Specific fuel oil consumption | | | |
| n = const [1] 100 % | g/kWh | 177/178 | 177/178 |
| 85 % | g/kWh | 176/177 | 176/177 |
| 75 % | g/kWh | 178/178 | 178/178 |
| 50 % | g/kWh | 185/185 | 185/185 |
| Lubricating oil consumption [2] | g/kWh | 0.6 | 0.6 |
| $NO_x$ emission [3] | g/kWh | 10.0 | 10.0 |
| Turbocharger type | | 2 x ABB TPL 71-C | 2 x ABB TPL 76-C |
| **Fuel** | | | |
| Engine driven booster pump | $m^3/h$ | -/- | -/- |
| Stand-by booster pump | $m^3/h$ | 8.4/5 | 11.2/5 |
| Mesh size MDO fine filter | mm | 0.025 | 0.025 |
| Mesh size HFO automatic filter | mm | 0.01 | 0.01 |
| Mesh size HFO fine filter | mm | 0.034 | 0.034 |
| Nozzle cooling by lubricating oil system | | | |
| **Lubricating Oil** | | | |
| Engine driven pump | $m^3/h/bar$ | 250/10 | 400/10 |
| Independent pump | $m^3/h/bar$ | 200/10 | 270/10 |
| Working pressure on engine inlet | bar | 4 - 5 | 4 - 5 |
| Engine driven suction pump | $m^3/h/bar$ | -/- | -/- |
| Independent suction pump | $m^3/h/bar$ | 350/3 | 470/3 |
| Priming pump | $m^3/h/bar$ | 30/5 | 40/5 |
| Sump tank content/dry sump content | $m^3$ | 16.3 | 21.8 |
| Temperature at engine inlet | °C | 60 - 65 | 60 - 65 |
| Temperature controller NB | mm | 200 | 200 |
| Double filter NB | mm | 200 | 200 |
| Mesh size double filter | mm | 0.08 | 0.08 |
| Mesh size automatic filter | mm | 0.03 | 0.03 |

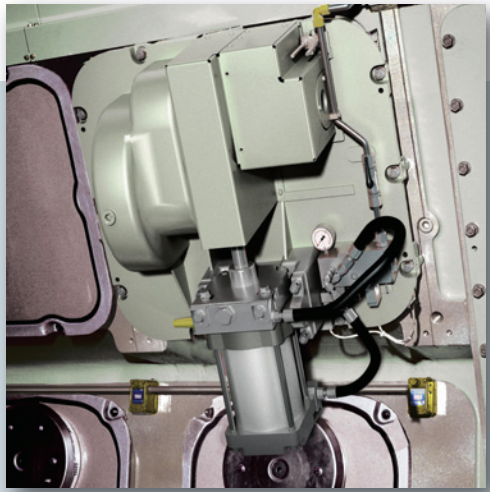
| | Cylinder | 12 | 16 |
|---|---|---|---|
| **Fresh water cooling** | | | |
| Engine content | $m^3$ | 2.8 | 4 |
| Pressure at engine inlet min/max | bar | 4.5/6.0 | 4.5/6.0 |
| Header tank capacity | $m^3$ | 1.5 | 2 |
| Temperature at engine outlet | °C | 80 - 90 | 80 - 90 |
| **Two circuit system** | | | |
| Engine driven pump HT | $m^3$/h/bar | 200/4.7 | 350/4.7 |
| Independent pump HT | $m^3$/h/bar | 200/3 | 350/3 |
| HT-Controller NB | mm | 200 | 200 |
| Water demand LT-charge air cooler | $m^3$/h | 100 | 130 |
| Temperature at LT-charge air cooler inlet | °C | 38 | 38 |
| **Heat Dissipation** | | | |
| Specific jacket water heat | kJ/kW | 500 | 500 |
| Specific lub oil heat | kJ/kW | 525 | 525 |
| Lub oil cooler | kW | 1750 | 2335 |
| Jacket water | kW | 1667 | 2220 |
| Charge air cooler (HT-Stage) [4)] | kW | 4940 | 6390 |
| Charge air cooler (LT-Stage) [4)] | kW | 890 | 1365 |
| (HT-Stage before engine) | | | |
| Heat radiation engine | kW | 511 | 680 |
| **Exhaust** | | | |
| Silencer/spark arrester NB | mm | 1200 | 1500 |
| Pipe diameter after turbine | mm | 2 x 900 | 2 x 1000 |
| Exhaust gas mass flow (intake air 25 °C) [5)] | kg/h | 86520 | 107160 |
| Exhaust gas temperature after turbine (intake air 25 °C) [5)] | °C | 312 | 310 |
| Maximum exhaust gas back pressure | bar | 0.03 | 0.03 |
| **Starting air** | | | |
| Starting air pressure max. | bar | 30 | 30 |
| Minimum starting air pressure | bar | 14 | 14 |
| Air consumption per start [6)] | $Nm^3$ | 3 | 3.5 |

1) Reference conditions: LCV = 42700 kJ/kg, ambient temperature 25 °C
charge air coolant temperature 25 °C, tolerance 5 %, + 1 % for engine driven pump
2) Standard value based on rated output, tolerance ± 0.3 g/kWh
3) MARPOL 73/78, annex VI, cycle E2, D2
4) Charge air heat based on 45 °C ambient temperature
5) Tolerance 10 %, rel. humidity 60 %
6) Preheated engine

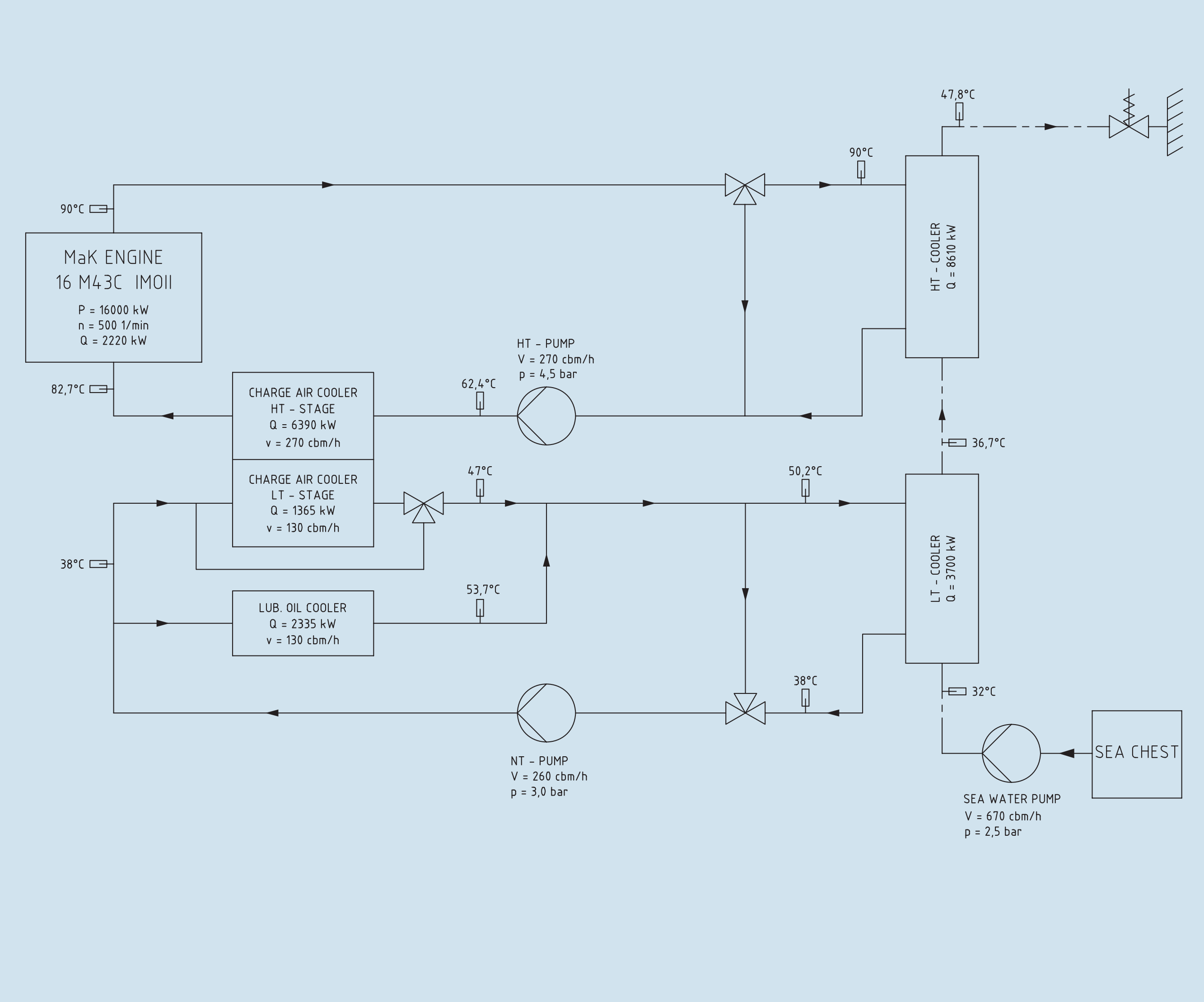
# VM 43 C – Low Emission Engine ▶ Heat Balance (Preliminary)

## 12 M 43 C



## 16 M 43 C



47,8°C
90°C
90°C
MaK ENGINE
16 M43C IMOII
P = 16000 kW
n = 500 1/min
Q = 2220 kW
HT - COOLER
Q = 8610 kW
HT - PUMP
V = 270 cbm/h
p = 4,5 bar
62,4°C
82,7°C
CHARGE AIR COOLER
HT - STAGE
Q = 6390 kW
v = 270 cbm/h
36,7°C
CHARGE AIR COOLER
LT - STAGE
Q = 1365 kW
v = 130 cbm/h
47°C
50,2°C
38°C
LT - COOLER
Q = 3700 kW
53,7°C
LUB. OIL COOLER
Q = 2335 kW
v = 130 cbm/h
38°C
32°C
SEA CHEST
NT - PUMP
V = 260 cbm/h
p = 3,0 bar
SEA WATER PUMP
V = 670 cbm/h
p = 2,5 bar


One Strong Line of World-Class Diesel Engines

## Perfect Solutions for Main Propulsion and On-Board Power Supply

**The Program:** Quality is our Motto

For more than 80 years we have developed, built, supplied and serviced diesel engines – worldwide. Today Caterpillar Marine with its brands Cat and MaK offer high-speed and medium-speed engines with power ratings from 11 kW to 16,000 kW. Many different engine families are available to meet your specific application needs.

Cat and MaK diesel engines are distinguished by high reliability, extremely low operational costs, simple installation and maintenance and compliance with IMO environmental regulations.

The application of engines in main and auxiliary marine power systems varies greatly and extends from high-speed boats and yachts, through tugs, trawlers and offshore vessels to freighters, ferries and cruise liners.

Caterpillar Marine Power Systems

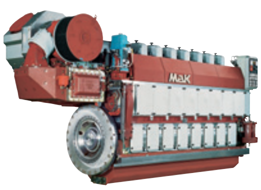
## Sales and Service Organization

Caterpillar has combined the sales and service activities and responsibility of their Cat and MaK brand marine engine business into Caterpillar Marine Power Systems with headquarters in Hamburg/Germany.

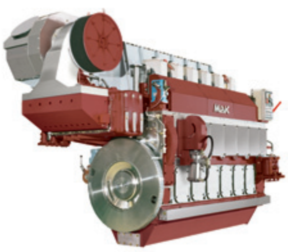
In setting-up this worldwide structure, we have concentrated on integrating the Cat and MaK brand groups into a single, united marine team, which utilises the particular expertise of each group.

Commercial marine engine business is split into three geographic regions,
– Europe, Africa, Middle East
– Americas
– Asia-Pacific,

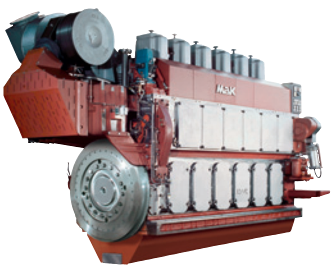
**Medium-Speed Engines**



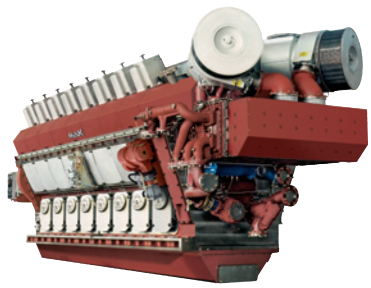
**M 20 C**
6, 8 cylinder
1,020–1,520 kW



**M 25 C**
6, 8, 9 cylinder
1,800–3,000 kW



**M 32 C**
6, 8, 9 cylinder
2,880–4,500 kW



**VM 32 C**
12, 16 cylinder
5,760–8,000 kW



Main Propulsion Engines

## Production Facilities

which manage all sales and product support activities. They have direct responsibility for achieving the ambitious growth targets set for the Cat and MaK brands and for providing our customers and dealers with complete marine solutions.

Caterpillar's global dealer network provides a key competitive edge – customers deal with people they know and trust.

Cat dealers strive to form a strong working relationship with their customers, offering comprehensive and competent advice from project support to repair work.

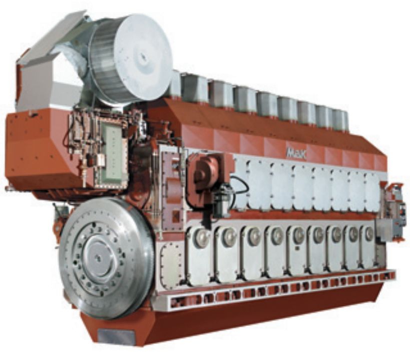
Some of the most advanced manufacturing concepts are used at Caterpillar locations throughout the world to produce engines in which reliability, economy and performance are second-to-none.

From the production of core components to the assembly of complete engines, quality is always the top priority.

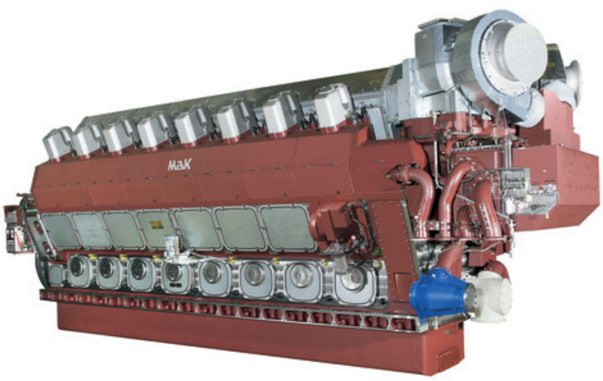
Comprehensive, recognized analysis systems, test procedures and measuring methods ensure that quality requirements are met throughout all the individual manufacturing phases. All of our production facilities are certified under 1:2000 ISO 9001 EN, the international benchmark that is helping to set new quality standards worldwide.

In addition to product quality, our customers expect comprehensive service which includes the supply of spare parts throughout the life of the engine.

Caterpillar Logistics Services, Inc., located in Morton, Illinois, is the largest parts distribution facility within the Cat Logistics network and is also the headquarters for all the worldwide distribution centres. Morton utilises sophisticated material handling, storage and retrieval systems to support Caterpillar's customer service goals.




**M 43 C**
6, 7, 8, 9 cylinder
5,400 – 9,000 kW




**VM 43 C**
12, 16 cylinder
10,800 – 16,000 kW

MaK LEE will soon be part of all MaK engines!

# Caterpillar Marine Power Systems


**Headquarters**

**Caterpillar Marine Power Systems**
Neumühlen 9
22763 Hamburg/Germany

Phone: +49 40 2380-3000
Telefax: +49 40 2380-3535

**Europe, Africa, Middle East**

**Caterpillar Marine Power Systems**
Neumühlen 9
22763 Hamburg/Germany

Phone: +49 40 2380-3000
Telefax: +49 40 2380-3535

**Americas**

**MaK Americas Inc.**

3450 Executive Way
Miramar Park of Commerce
Miramar, FL. 33025/USA
Phone: +1 954 885 3200
Telefax: +1 954 885 3131

**Asia Pacific**

**Caterpillar Marine Trading (Shanghai) Co., Ltd.**
25/F, Caterpillar Marine Center
1319, Yan'an West Road
200050 Shanghai/P. R. China
Phone: +86 21 6226 2200
Telefax: +86 21 6226 4500

**Caterpillar Marine Asia Pacific Pte Ltd**
14 Tractor Road
Singapore 627973/
Singapore
Phone: +65 68287-600
Telefax: +65 68287-624


**For more information please visit our website:**
**MARINE.CAT.COM**


Subject to change without notice.
Leaflet No. 249 · 08.10 · e · L+S · VM3



© 2010 Caterpillar All Rights Reserved. Printed in Germany. CAT, CATERPILLAR, their respective logos, ACERT, ADEM, „Caterpillar Yellow“ and the POWER EDGE trade dress, as well as corporate identity used herein, are trademarks of Caterpillar and may not be used without permission

Caterpillar Marine Power Systems is committed to sustainability. This document is printed on PEFC certificated paper.