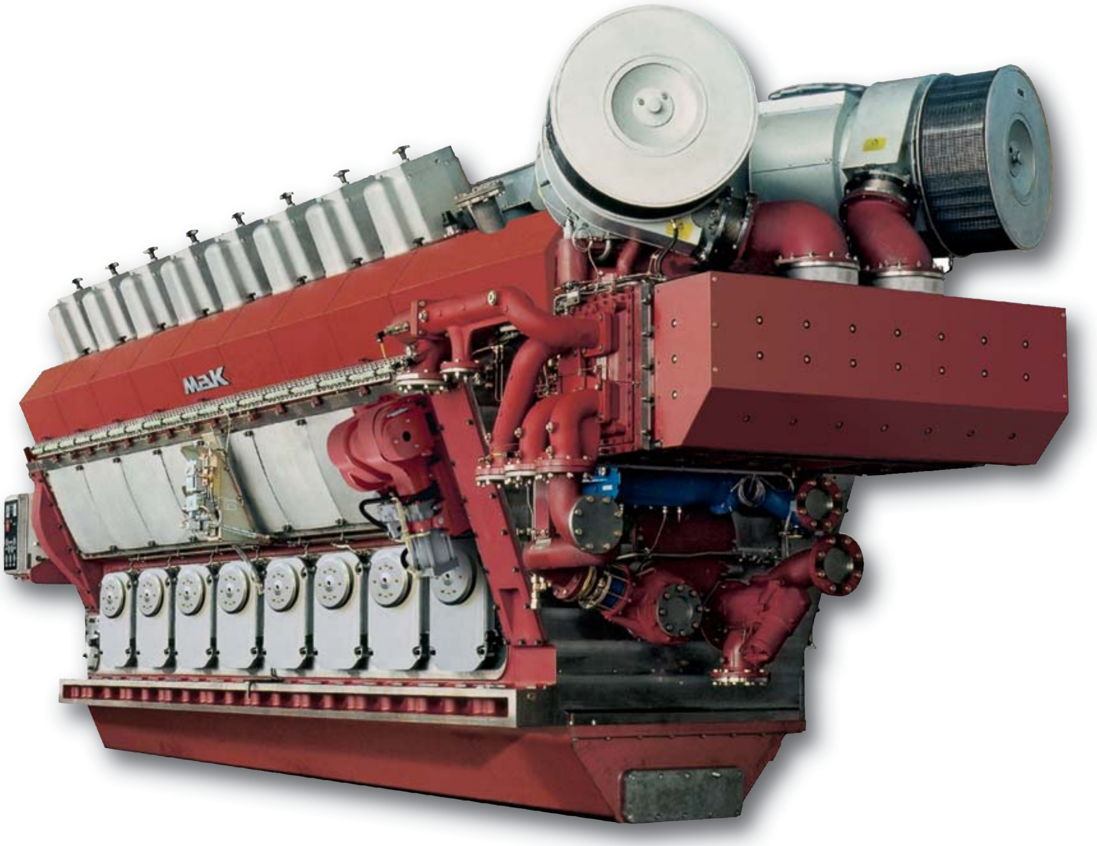
VM 32 C

Low Emission Engine



MaK

CATERPILLAR®

VM 32 C ▶ Low Emission Engine

IMO II in sight – First MaK Low Emission Engine 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.

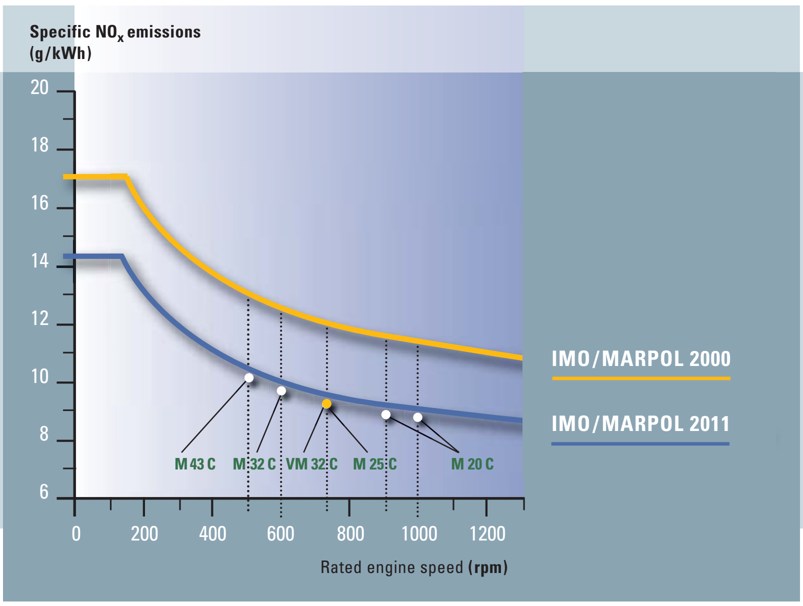
MaK LEE today already provides a power plant complying with expected future IMO emission regulations. This allows shipping companies to increase their reputation for environmental-friendly marine business operations. In addition, the emission levels achieved with MaK LEE enable shipping companies to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

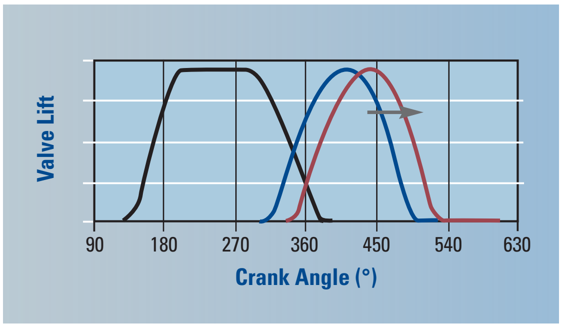
Already today Caterpillar is well prepared to meet these technological requirements. We are currently sucessfully testing engines that meet IMO II emission requirements. The following components have been changed:

- – Turbocharging system
- – injection system
- – combustion chambers
- – longer stroke
- – camshaft
- – FCT system

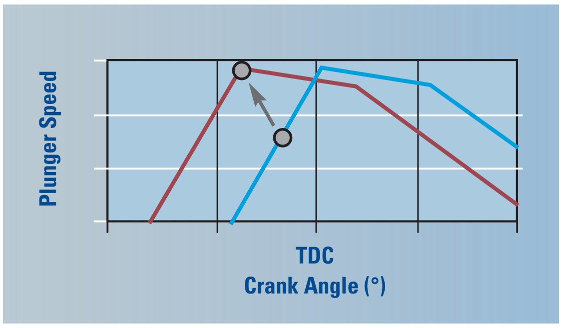
The FCT system is the major building block of the LEE engine concept. The pilot engines will be introduced into the market in 2010.



VM 32 C ▶ FCT

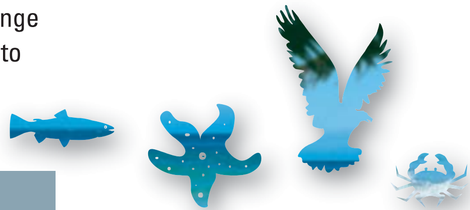


Flex Cam Technology FCT (schematic diagram)



Flex Cam Technology

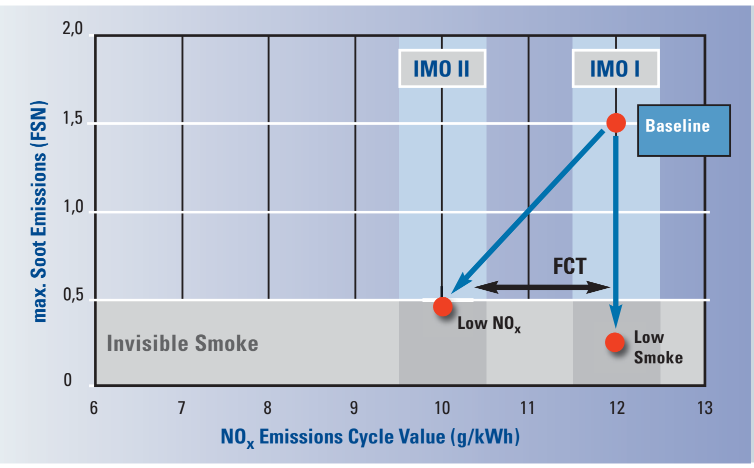
Building upon the Emission Reduction System integration concept, FCT achieves synergy between flexible fuel systems and advanced air systems with maximum utilization of the current engine design. While maintaining high fuel injection pressure over the whole operating range, fuel injection and inlet valve 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.



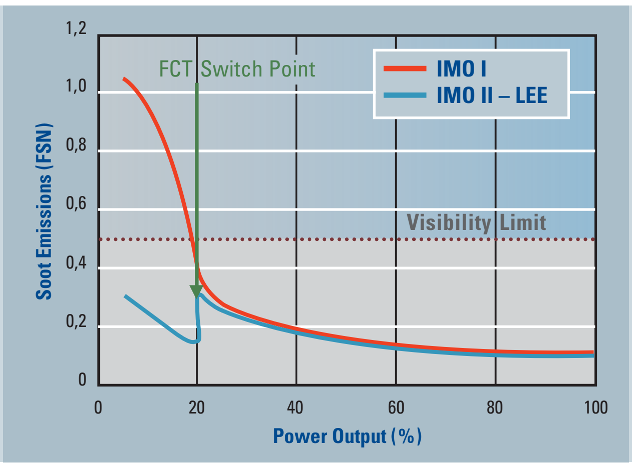
Customer value sequence and benefits

- High potential for NO_x and smoke reduction.
- Hardware changes to be prepared for IMO II – sustainable investment.
- Low complexity due to FCT, Flexible Camshaft Technology
- Technically lower risk – application of existing technology.

VM 32 C – Low Emission Engine

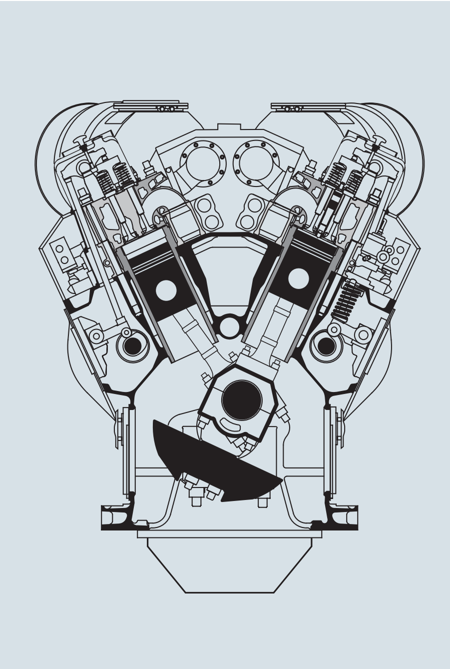


schematic diagram



predicted performance VM 32 C

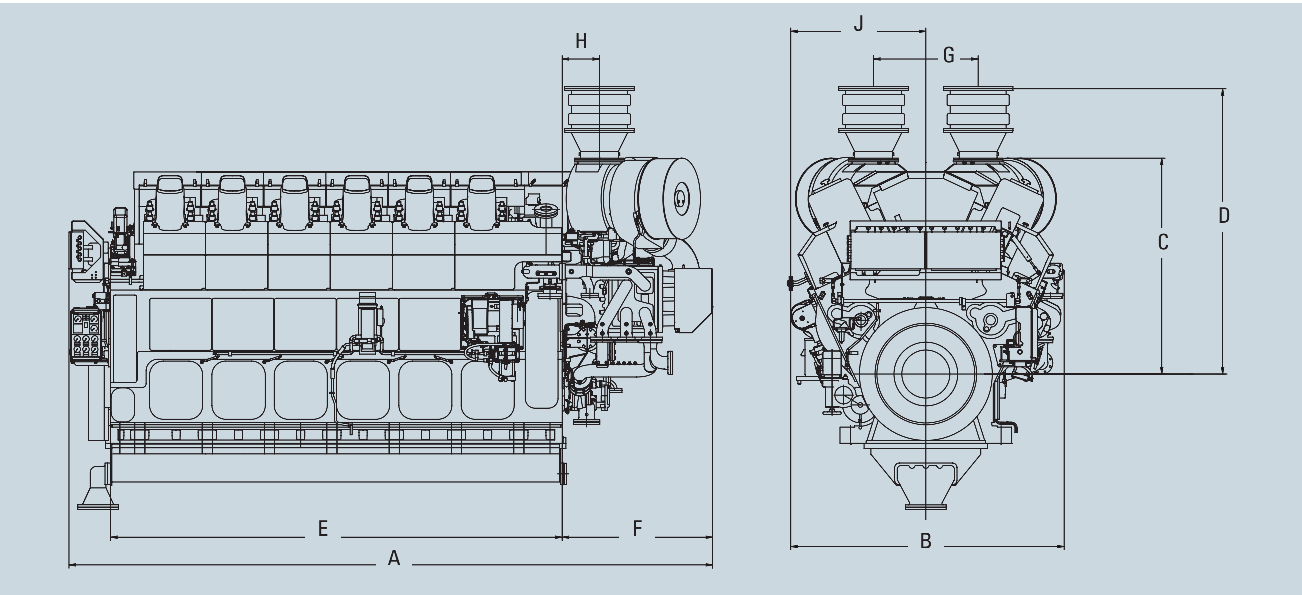
VM 32 C – Low Emission Engine ▶ Engine Description (Preliminary)



Number of cylinders	V-Version	12, 16	12, 16
Bore	mm	320	320
Stroke	mm	460	460
Cylinder rating	kW	480	500
Rated speed	rpm	720	750
Mean piston speed	m/s	11.0	11.5
Mean effective pressure	bar	21.6	21.6
Cylinder pressure	bar	200	200
Engine power		**kW**	**kW**
	12 M 32 C	5760	6000
	16 M 32 C	7680	8000
Specific fuel consumption* at 100% power	**12, 16 M 32 C**	**g/kWh** 178	**g/kWh** 179
Specific lubricating oil consumption			0.6 g/kWh, ± 0.3 g/kWh

* ISO conditions Hu = 42,700 kJ/kg, without engine driven pumps, tolerance 5%

Swept volume:	37.0 l/cyl.
Output/cyl.:	480/500 kW
BMEP:	21.6 bar
Revolutions:	720/750 rpm
Turbocharging:	single pipe system
Direction of rotation:	clockwise, option: counter-clockwise



Dimensions (**mm**) and Weights (**t**)										
Engine	A	B	C	D	E	F	G	H	J	t
12 M 32 C	6972	2961	2339	3091	4891	1630	1133	404	1463	64,4
16 M 32 C	8313	2948	2339	3329	6241	1630	1133	404	1463	81,6

Engine centre distance: 3500 mm*

* If turbocharger is located on opposite coupling side,
the water cover of the charge air cooler must be dismantled.

Removal of cylinder liner:
in transverse direction 2834 mm
in longitudinal direction 3405 mm

Nozzle position: ask for availability

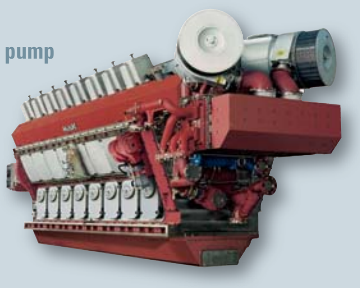
Engine with turbocharger at driving end available, ask for dimensions

VM 32 C – Low Emission Engine ▶ Technical Data (Preliminary)

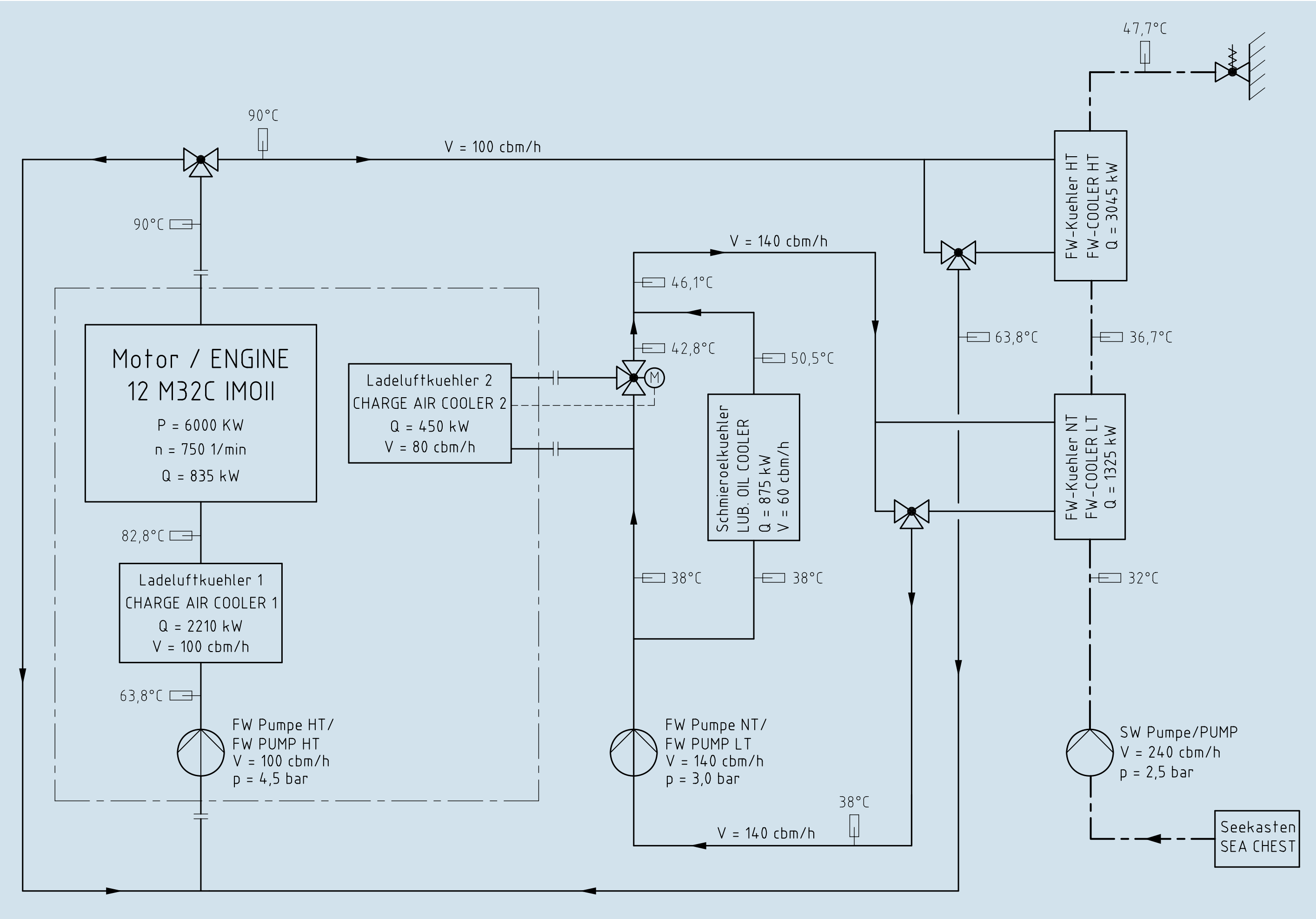
	Cylinder	12	12	16	16
Performance data					
Maximum continous rating acc. ISO 3046/1	kW	5760	6000	7680	8000
Speed	1/min	720	750	720	750
Minimum speed	1/min	420	450	420	450
Brake mean effective pressurebar	21,6	21,6	21,6	21,6	21.6
Charge air pressure	bar	3,25	3,4	3,3	3,5
Firing pressure	bar	200	200	200	200
Combustion air demand (ta = 20 °C)	m^3/h	33025	35005	44290	47050
Specific fuel oil consumption					
Propeller/n = const[1] 100 %	g/kWh	178	179	178	179
85 %	g/kWh	-/178	-/179	-/178	-/179
75 %	g/kWh	-/182	-/183	-/182	-/183
50 %	g/kWh	-/194	-/195	-/194	-/195
Lubricating oil consumption[2]	g/kWh	0,6	0,6	0,6	0,6
NO_x emission[6]	g/kWh	9	9	9	9
Turbocharger type		ABB TPL65	ABB TPL65	ABB TPL65	ABB TPL65
Fuel					
Engine driven booster pump	m^3/h	-	-	-	-
Stand-by booster pump	m^3/h	3.9/10	4.2/10	5.2/10	5.4/10
Mesh size MDO fine filter	mm	0.025	0.025	0.025	0.025
Mesh size HFO automatic filter	mm	0.010	0.010	0.010	0.010
Mesh size HFO fine filter	mm	0.034	0.034	0.034	0.034
Nozzle cooling by lubricating oil system					
Lubricating Oil					
Engine driven pump	$m^3/h/bar$	161.3/10	168/10	161.3/10	168/10
Independent pump	$m^3/h/bar$	120/10	120/10	160/10	160/10
Working pressure on engine inlet	bar	4 - 5	4 - 5	4 - 5	4 - 5
Engine driven suction pump	$m^3/h/bar$	-	-	-	-
Independent suction pump	$m^3/h/bar$	-	-	-	-
Priming pump	$m^3/h/bar$	12/5	12/5	16/5	16/5
Sump tank content/dry sump content	m^3	7.6	8.0	10.0	10.8
Temperature at engine inlet	°C	60-65	60-65	60-65	60-65
Temperature controller NB	mm	125	125	150	150
Double filter NB	mm	125	125	125	125
Mesh size double filter	mm	0.08	0.08	0.08	0.08
Mesh size automatic filter	mm	0.03	0.03	0.03	0.03

	Cylinder	12	12	16	16
Fresh water cooling					
Engine content	m^3	1.4	1.4	1.9	1.9
Pressure at engine inlet min/max	bar	2.5/6.0	2.5/6.0	2.5/6.0	2.5/6.0
Header tank capacity	m^3	0.7	0.7	1	1
Temperature at engine outlet	°C	80 - 90	80 - 90	80-90	80-90
Two circuit system					
Engine driven pump HT	m^3/h/bar	100/4.6	100/4.6	130/4.5	130/4.5
Independent pump HT	m^3/h/bar	100/4.0	100/4.0	130/4.0	130/4.0
HT-Controller NB	mm	125	125	150	150
Water demand LT-charge air cooler	m^3/h	80	80	100	100
Temperature at LT-charge air cooler inlet	°C	38	38	38	38
Heat Dissipation					
Specific jacket water heat	kJ/kW	500	500	500	500
Specific lub. oil heat	kJ/kW	525	525	525	525
Lub. oil cooler	kW	840	875	1120	1167
Jacket water	kW	800	835	1067	1115
Charge air cooler (HT-Stage)[3]	kW	1930	2210	2623	2875
Charge air cooler (LT-Stage)[3]	kW	369	450	481	650
(HT-Stage before engine)					
Heat radiation engine	kW	250	260	333	347
Exhaust gas					
Silencer/spark arrester NB	mm	900	900	1000	1000
Pipe diameter NB after turbine	mm	2*600	2*600	2*700	2*700
Maximum exhaust gas pressure drop	bar	0.03	0.03	0.03	0.03
Exhaust gas temperature after turbine					
(intake air 25 °C)[5]	°C	317	310	311	305
Exhaust gas mass flow (intake air 25 °C)[5]	kg/h	40820	43266	54740	58160
Starting air					
Starting air pressure max.	bar	30	30	30	30
Minimum starting air pressure	bar	10	10	10	10
Air consumption per start[4]	Nm^3	1.2	1.2	1.2	1.2

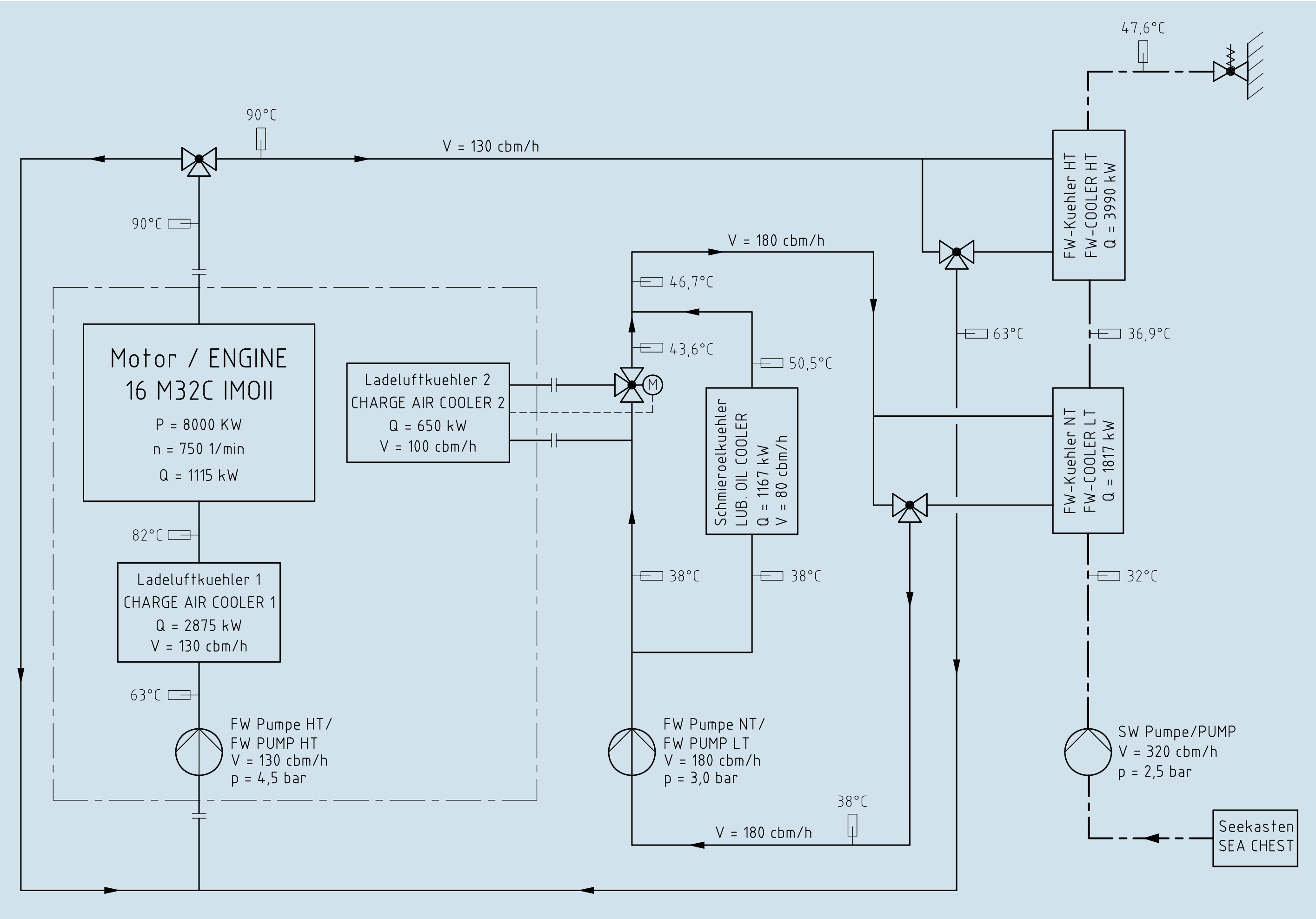
1) Reference conditions: LCV = 42700 kJ/kg, ambient temperature 25 °C
charge air coolant temperature 25 °C, tolerance 5 %, + 1 % for engine driven pump
2) Standard value based on rated output, tolerance ± 0.3 g/kWh
3) Charge air heat based on 45 °C ambient temperature
4) Preheated engine
5) Tolerance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



■ **12 M 32 C** (V-Version)



16 M 32 C (V-Version)



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

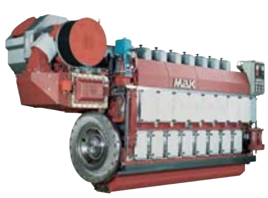
Sales and Service Organization

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,

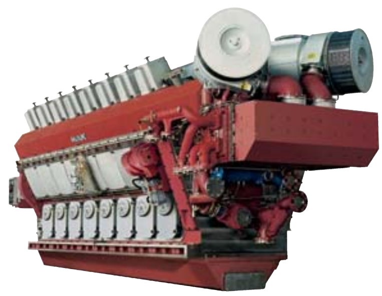
Medium-Speed Engines



M 20 C
6, 8, 9 cylinder
1,020–1,710 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.

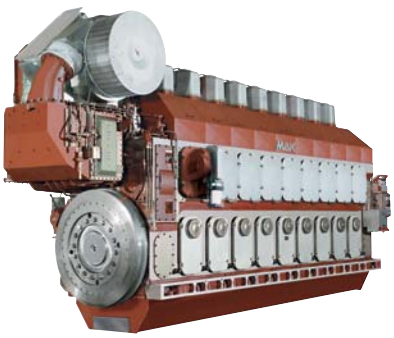
Some of the most advanced manufacturing concepts are used at Caterpillar locations throughout the world to produce engines in which reliability, economy and performance are second-to-none.

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

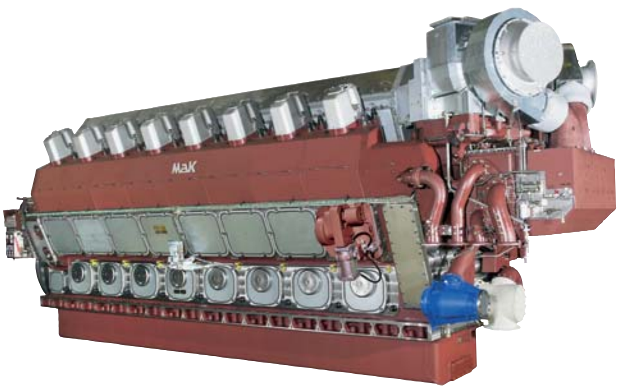
Comprehensive, recognized analysis systems, test procedures and measuring methods ensure that quality requirements are met throughout all the individual manufacturing phases. All of our production facilities are certified under 1:2000 ISO 9001 EN, the international benchmark that is helping to set new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

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MARINE.CAT.COM

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