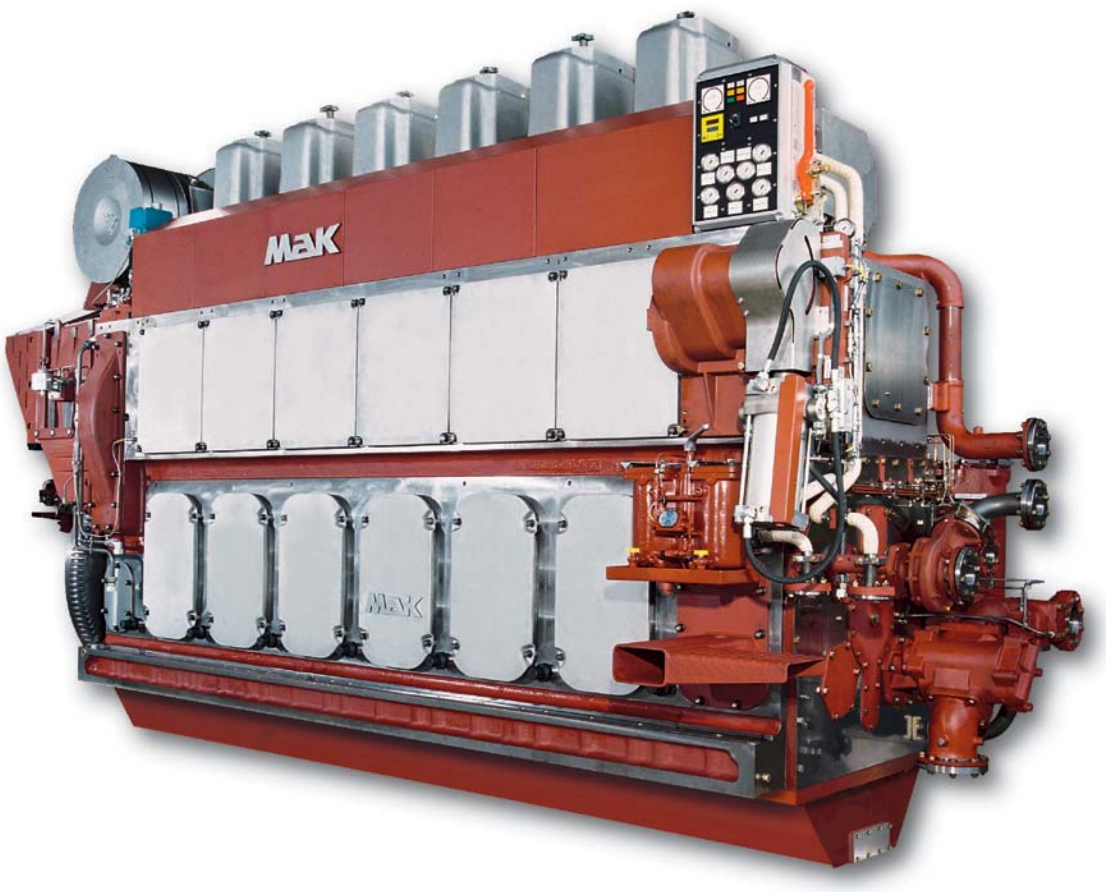
M 32 C

Low Emission Engine



MaK

CATERPILLAR®

M 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.

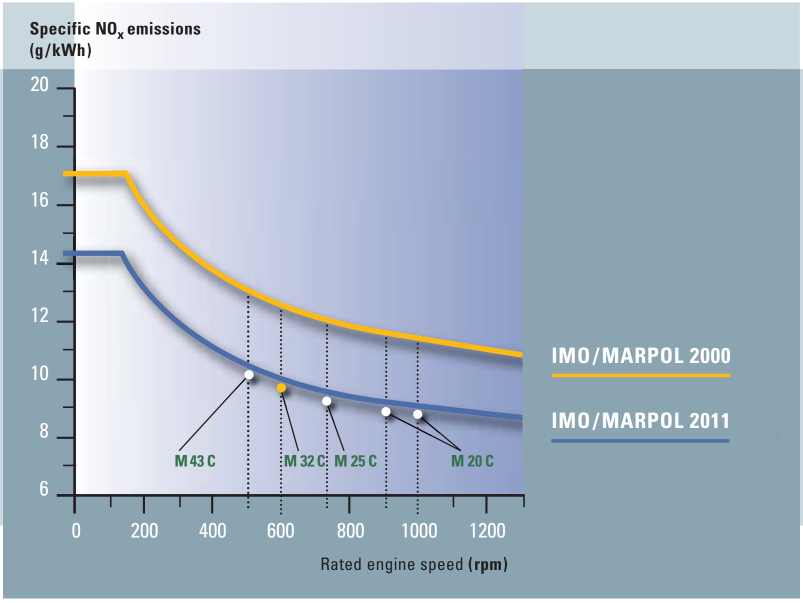
MaK LEE today already provides a power plant complying with expected future IMO emission regulations. This allows shipping companies to increase their reputation for environmental-friendly marine business operations. In addition, the emission levels achieved with MaK LEE enable shipping companies to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

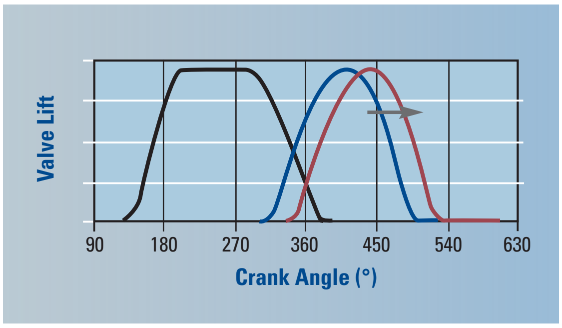
As from 1. 1. 2011 IMO II will become effective

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:

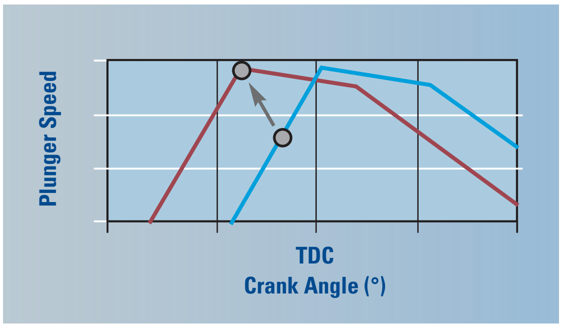
– Turbocharging system
– injection system
– combustion chambers
– camshaft
– FCT system

The FCT system is the major building block of the LEE engine concept. The pilot engines will be introduced into the market in 2009.



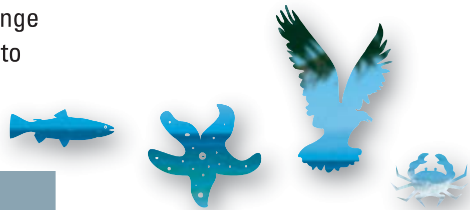


Flex Cam Technology FCT (schematic diagram)



Flex Cam Technology

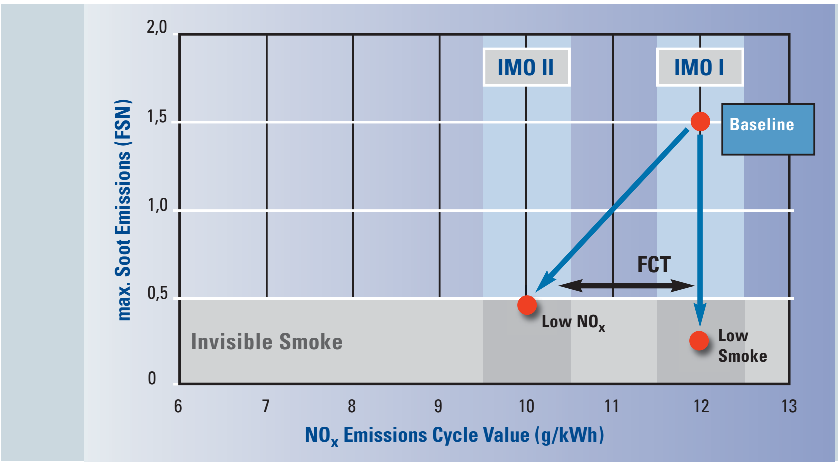
Building upon the Emission Reduction System integration concept, FCT achieves synergy between flexible fuel systems and advanced air systems with maximum utilization of the current engine design. While maintaining high fuel injection pressure over the whole operating range, fuel injection and inlet valve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

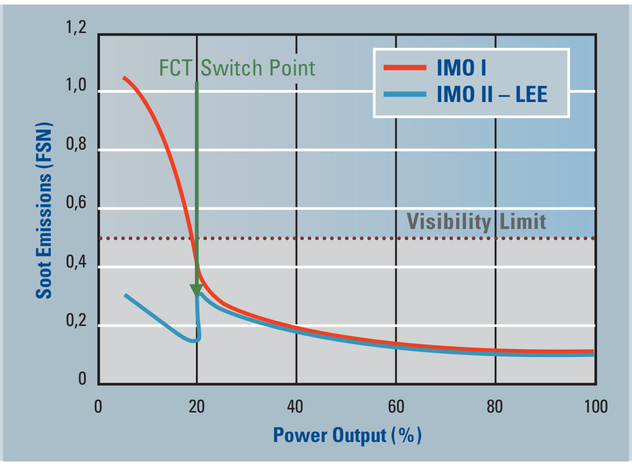


Customer value sequence and benefits

Flex Cam Technology (FCT)

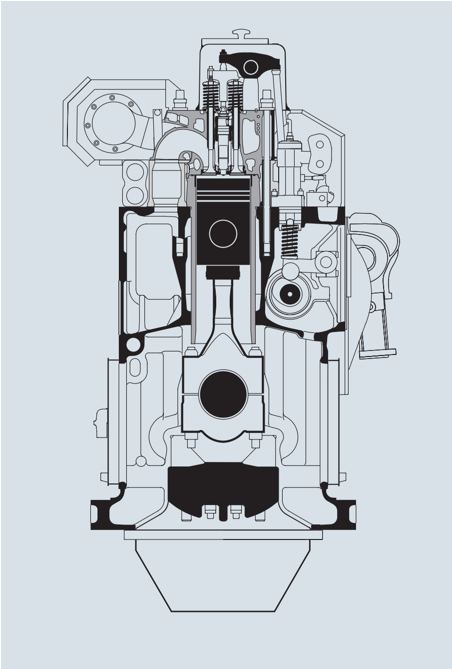
- High potential for NO_x and smoke reduction.
- Hardware changes to prepare for IMO II – sustainable investment.
- Low complexity
- Technically lower risk – application of existing technology.





schematic diagram

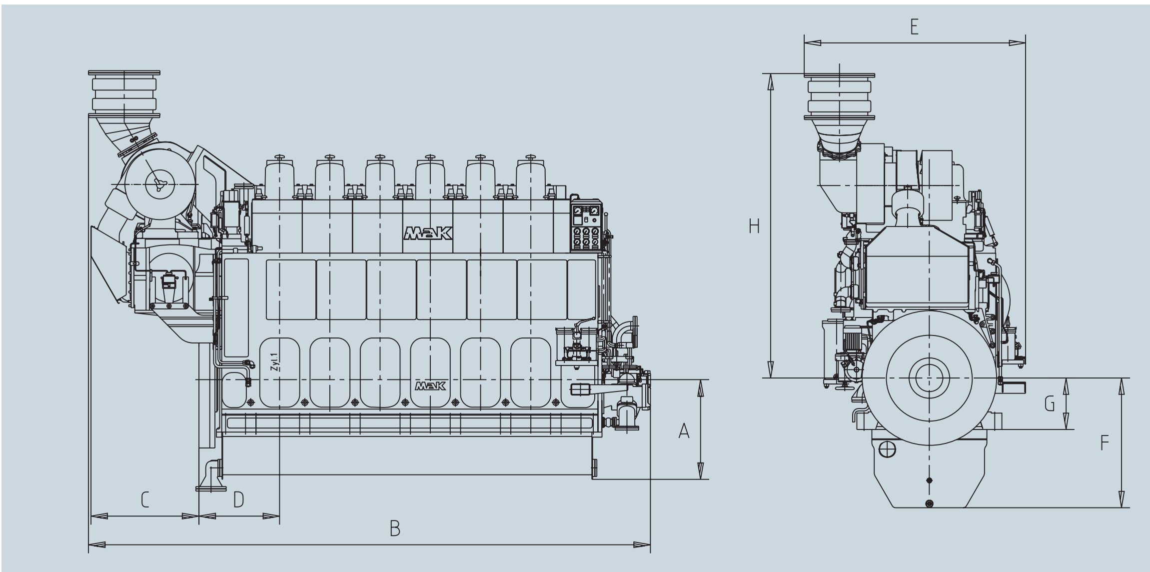
M 32 C – Low Emission Engine ▶ Engine Description (Preliminary)



Number of cylinders	In-line	6, 8, 9	6, 8, 9
Bore	mm	320	320
Stroke	mm	480	480
Cylinder rating	kW	480	500
Rated speed	rpm	600	600
Mean piston speed	m/s	9.6	9.6
Mean effective pressure	bar	24.9	25.9
Cylinder pressure	bar	190	198
Engine power		**kW**	**kW**
	6 M 32 C	2880	3000
	8 M 32 C	3840	4000
	9 M 32 C	4320	4500
Specific fuel consumption* at 100% power		**g/kWh**	**g/kWh**
	6 M 32 C	179	179
	8, 9 M 32 C	178	178
NO_X**		10.1 g/kWh	
Specific lubricating oil consumption		0.6 g/kWh, ± 0.3 g/kWh	

* ISO conditions Hu = 42,700 kJ/kg, without installed pumps, tolerance 5%
** MARPOL 73/78, annex VI, cycle E2, D2

Swept volume: 38.7 l/cyl.
Output/cyl.: 500 kW
BMEP: 25.9 bar
Revolutions: 600 rpm
Turbocharging: single log, option: pulse
Direction of rotation: clockwise, option: counter-clockwise



Propulsion Engine (Dimensions in mm)									
Engine	A	B	C	D	E	F	G	H	t
6 M 32 C	1052	5931	1140	852	2369	1387	550	3258	37.5
8 M 32 C	1052	7135	1279	852	2180	1387	550	3319	46.4
9 M 32 C	1052	7827	1279	852	2180	1387	550	3513	49.4

A: Dry sump (standard)
F: Wet sump (special request)

Engine centre distance: 2800 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 3040 mm
in longitudinal direction 3405 mm

Nozzle position: ask for availability

Engine with turbocharger at free end available, ask for dimensions

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

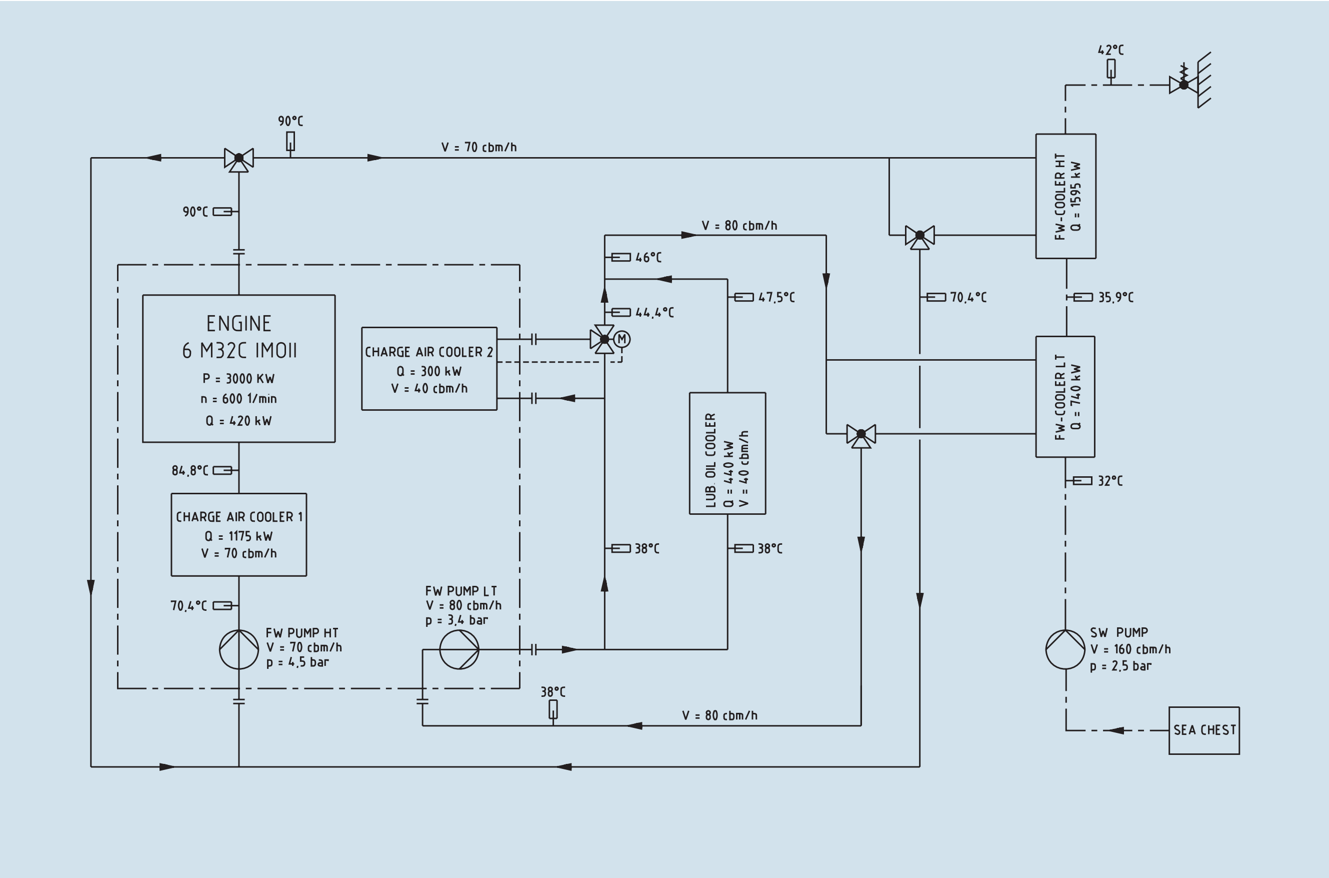
	Cylinder	6	8	9
Performance data				
Maximum continous rating acc. ISO 3046/1	kW	3000	4000	4500
Speed	1/min	600	600	600
Minimum speed	1/min	360	360	360
Brake mean effective pressure	bar	25.9	25.9	25.9
Charge air pressure	bar	3.8	3.8	3.8
Firing pressure	bar	200	200	200
Combustion air demand (ta = 20 °C)	m^3/h	17500	23350	26250
Specific fuel oil consumption				
n = const [1)] 100 %	g/kWh	179	178	178
85 %	g/kWh	178	177	177
75 %	g/kWh	182	181	181
50 %	g/kWh	190	190	190
Lubricating oil consumption [2)]	g/kWh	0.6	0.6	0.6e
NO_x emission [3)]	g/kWh	10.1	10.1	10.1
Turbocharger type		ABB A145	ABB A160	ABB A160
Fuel				
Engine driven booster pump	m^3/h	2.2/5	3.2/5	3.2/5
Stand-by booster pump	m^3/h	2.2/10	2.9/10	3.2/10
Mesh size MDO fine filter	mm	0.025	0.025	0.025
Mesh size HFO automatic filter	mm	0.010	0.010	0.010
Mesh size HFO fine filter	mm	0.034	0.034	0.034
Nozzle cooling by lubricating oil system				
Lubricating Oil				
Engine driven pump	$m^3/h/bar$	118/10	118/10	118/10
Independent pump	$m^3/h/bar$	60/10	80/10	80/10
Working pressure on engine inlet	bar	4 - 5	4 - 5	4 - 5
Engine driven suction pump	$m^3/h/bar$	140/3	140/3	140/3
Independent suction pump	$m^3/h/bar$	65/3	80/3	100/3
Priming pump pressure	$m^3/h/bar$	8/5	11/5	11/5
Sump tank content/dry sump content	m^3	4.1	5.4	6.1
Temperature at engine inlet	°C	60-65	60-65	60-65
Temperature controller NB	mm	80	100	100
Double filter NB	mm	80	80	80
Mesh size double filter	mm	0.08	0.08	0.08
Mesh size automatic filter	mm	0.03	0.03	0.03

	Cylinder	6	8	9
Fresh water cooling				
Engine content	m^3	0.7	0.95	1.05
Pressure at engine inlet min/max	bar	4.5/6.0	4.5/6.0	4.5/6.0
Header tank capacity	m^3	0.35	0.45	0.55
Temperature at engine outlet	°C	80 - 90	80 - 90	80-90
Two circuit system				
Engine driven pump HT	m^3/h/bar	70/4.5	70/4.5	80/4.5
Independent pump HT	m^3/h/bar	70/4.0	70/4.0	80/4.0
HT-Controller NB	mm	100	100	100
Water demand LT-charge air cooler	m^3/h	40	60	60
Temperature at LT-charge air cooler inlet	°C	38	38	38
Heat Dissipation				
Specific jacket water heat	kJ/kW	500	500	500
Specific lub oil heat	kJ/kW	525	525	525
Lub oil cooler	kW	440	590	660
Jacket water	kW	420	550	625
Charge air cooler (HT-Stage) [4)]	kW	1175	1530	1705
Charge air cooler (LT-Stage) [4)]	kW	300	440	505
(HT-Stage before engine)				
Heat radiation engine	kW	150	190	210
Exhaust				
Silencer/spark arrester NB	mm	600	700	800
Pipe diameter NB after turbine	mm	600	700	800
Maximum exhaust gas pressure drop	bar	0.03	0.03	0.03
Exhaust gas temperature after turbine (intake air 25 °C)[5)]	°C	340	350	350
Exhaust gas mass flow (intake air 25 °C)	kg/h	21630	28860	32445
Starting air				
Starting air pressure max.	bar	30	30	30
Minimum starting air pressure	bar	10	10	10
Air consumption per start [6)]	Nm^3	1.2	1.2	1.2

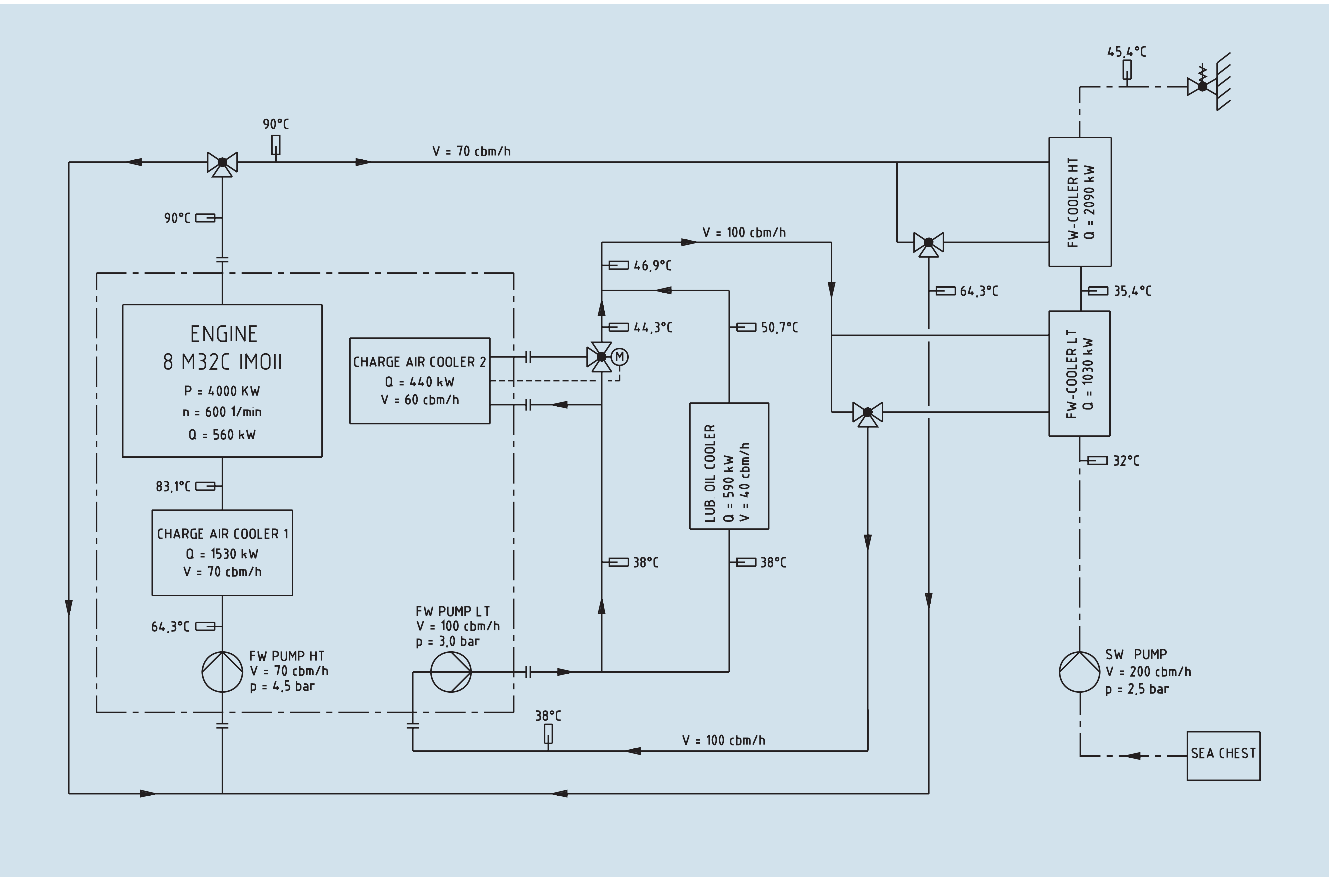
1) Reference conditions: LCV = 42700 kJ/kg, ambient temperature 25 °C
charge air coolant temperature 25 °C, tolerance 5 %, + 1 % for engine driven pump
2) Standard value based on rated output, tolerance ± 0.3 g/kWh
3) MARPOL 73/78, annex VI, cycle E2, D2
4) Charge air heat based on 45 °C ambient temperature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

M 32 C – Low Emission Engine ▶ Heat Balance (Preliminary)

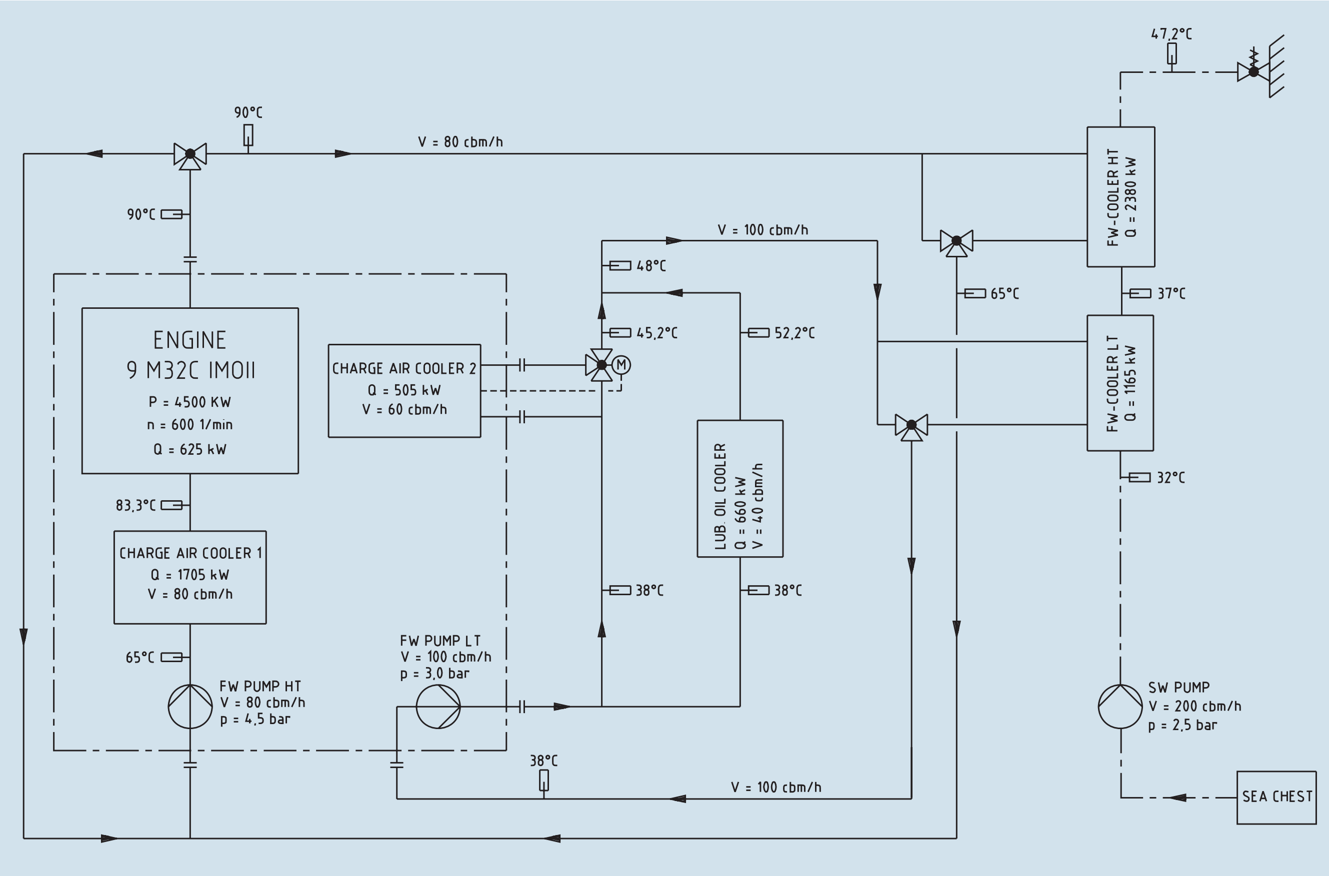
6 M 32 C



8 M 32 C



9 M 32 C


47,2°C
90°C
V = 80 cbm/h
90°C
V = 100 cbm/h
48°C
65°C
37°C
FW-COOLER HT
Q = 2380 kW
ENGINE
9 M32C IMOII
P = 4500 KW
n = 600 1/min
Q = 625 kW
CHARGE AIR COOLER 2
Q = 505 kW
V = 60 cbm/h
45,2°C
52,2°C
M
FW-COOLER LT
Q = 1165 kW
LUB OIL COOLER
Q = 660 kW
V = 40 cbm/h
32°C
83,3°C
CHARGE AIR COOLER 1
Q = 1705 kW
V = 80 cbm/h
38°C
38°C
65°C
FW PUMP LT
V = 100 cbm/h
p = 3,0 bar
FW PUMP HT
V = 80 cbm/h
p = 4,5 bar
SW PUMP
V = 200 cbm/h
p = 2,5 bar
38°C
V = 100 cbm/h
SEA CHEST

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

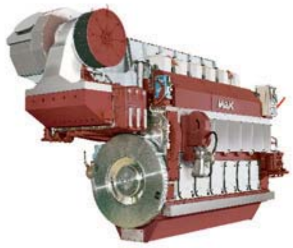
Caterpillar has combined the sales and service activities and responsibility of their Cat and MaK brand marine engine business into Caterpillar Marine Power Systems with headquarters in Hamburg/Germany.

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,

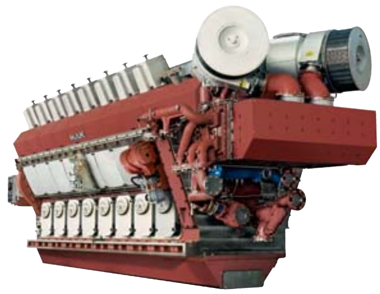
Medium-Speed Engines

● **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.

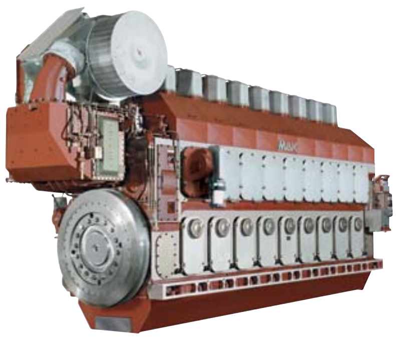
Some of the most advanced manufacturing concepts are used at Caterpillar locations throughout the world to produce engines in which reliability, economy and performance are second-to-none.

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

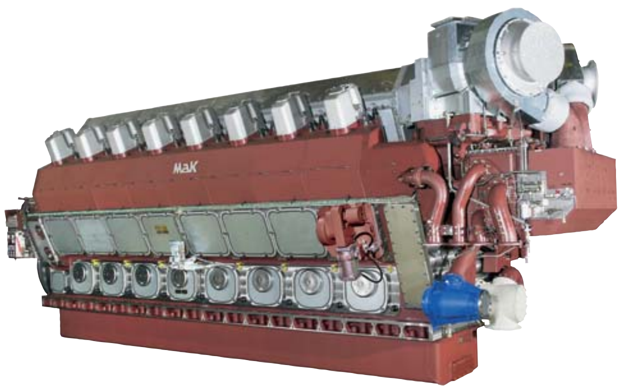
Comprehensive, recognized analysis systems, test procedures and measuring methods ensure that quality requirements are met throughout all the individual manufacturing phases. All of our production facilities are certified under 1:2000 ISO 9001 EN, the international benchmark that is helping to set new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

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