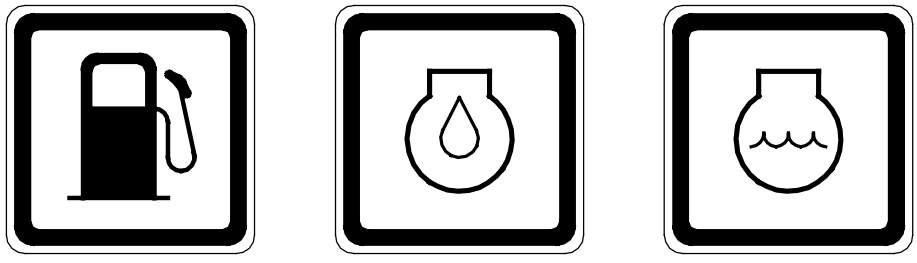
CAT - MaK

Operating media

Betriebsstoffe



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The use of suitable and unobjectionable operating media is an assumption for working readiness and reliability of surface of the engine system.

For that, the following notes and instructions must be observed.

- **Warranty**

  When unsuitable operating media are used or are maintained insufficiently, no warranty for trouble free operation can be guaranteed.

- **Product Selection**

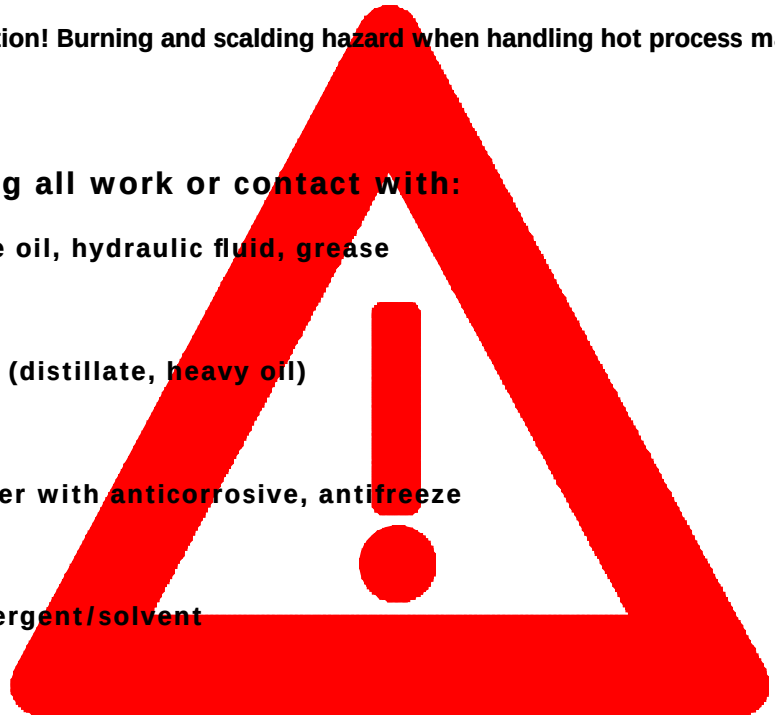
  For not listed products exist not experience at Caterpillar.

- **Scope**

  These operating media instructions are valid for Caterpillar-engines according to the delivery program.

Safety instructions

- **No open fire during work at the fuel system!**
- **No smoking!**
- **Lube oil and fuel vapours may ignite on contact with ignition sources!**
- **Caution! Burning and scalding hazard when handling hot process materials!**



During all work or contact with:

- **lube oil, hydraulic fluid, grease**
- **fuel (distillate, heavy oil)**
- **water with anticorrosive, antifreeze**
- **detergent/solvent**
- **coolant (CO_2, N_2)**

the safety instructions/safety specification sheets of the product manufacturer are to be observed!

<u>California / USA</u>

Proposition 65 Warning

Diesel engine exhaust and some of its constituents are known to the state of California to cause cancer, birth defects, and other reproductive harm.

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Regulations and care

For the Caterpillar / MaK-engines used in shore-based and ship-based operation according to their equipment condition two product groups of fuels are allowed, these are:

- **Destillate fuel**
- **Heavy oil**

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Distillate fuel

The fuel should be a high quality mineral oil product, have good anti-oxidant properties, not separate in storage or block the filters with wax exudation and should be free of mineral acids.

One must differentiate between two types of distillate fuels:

Pure distillates which are known as gas oil, marine **gas oil**, Diesel etc. These are fuels with a relatively low sulfur content and very good ignition characteristics.

Distillates or mixed fuels which are known as **marine Diesel oil (MDO)**, Diesel fuel oil, marine Diesel fuel (MDF) etc.

These types of fuel differ from the former types in general by their higher viscosity, specific gravity and, in some cases, considerably larger tolerances.

Normal specifications for fuels:

Fuel type		**Gas oil**	**Marine Diesel oil**
ISO 8217 : 1996	1)	ISO-F-DMA	ISO-F-DMB -DMC
British Standard MA 100 : 1996 – ISO 8217 : 1996	2)	see ISO 8217	
British Standard 2869 : 1970	3)	Class A 1 Class B 1	Class A 2 Class B 2
ASTMD 975 - 78		No. 1 D No. 2 D	No. 2 D No. 4 D
DIN		DIN EN 590	– – – –
Minimum requirement for fuel preparation		Fine filter	Separator, fine filter, preheating to 50 °C

1) International specification for marine-fuels
2) MA 100 : 1982 was with drawn in September 1989
3) Cancelled

Choice of ISO 8217 : 1996

Table 1 – Requirements for marine distillate fuels

Note

The values in this table are maximum or minimum values for each property. The actual values for any batch of fuel may vary within these limits.

Characteristic	**Test method**	**Limit**	**Designation ISO-F**		
			DMA	**DMB**	**DMC**
Density at 15 °C, kg/m^3	ISO 3675 or ISO 12185	max.	890,0	900,0	920,0
Kinematic viscosity at 40 °C; mm^2/s) 2)	ISO 3104	min. max.	1,50 6,00	– 11,0	– 14,0
Flash point, °C	ISO 2719	min.	60	60	60
Pour point (upper), °C 3) Winter quality Summer quality	ISO 3016	 max. max.	 -6 0	 0 6	 0 6
Carbon residue, (micro carbon) % (m/m) on 10 % destillation bottoms	ISO 10370	max.	0,3	–	–
Carbon residue, (micro carbon) % (m/m)	ISO 10370	max.	–	0,3	2,50
Ash, % (m/m)	ISO 6245	max.	0,01	0,01	0,05
Sediment by extraction, % (m/m)	ISO 3735	max.	–	0,07	–
Total existent sediment, % (mm)	ISO 10307-1	max.	–	–	0,10
Water, % (V/V)	ISO 3733	max.	–	0,3	0,3
Cetane number	ISO 5165	min.	40	35	–
Visual inspection Sulfur, % (m/m)	 ISO 8754	– max.	(see 6,2) 1,5	– 2,0	– 2,0
Vanadium, mg/kg	ISO 14597	max.	–	–	100
Aluminium + Silicium, mg/kg	ISO 10478	max.	–	–	25

2) 1 mm^2/s = 1 cSt

3) Purchasers should ensure that this pour point is suitable for the equipment on board, especially if the vessel is operating in both the Northern and Southern hemisperes.

6.2 Visual inspection

Inspect the sample in good light and at a temperature between 10 and 25 °C. It shall appear clear and bright.

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ISO-F-DMB and -DMC have viscosity limit of 11 or 14 mm^2/s (cSt)/40 °C which is, however, not fully utilized in commercial fuels from the large international fuel suppliers.

Pre-heating of the fuel can be dispensed with if the viscosity of the bunkered fuel at 40 °C is below 7 mm^2/s (cSt).

If this value is exceeded and a pre-heating facility is not installed the next better quality should be bunkered.

The fuel firms recommend that information about the available quality should be obtained in good time from the places where bunkering is itended.

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Heavy fuels

(Viscosity in mm^2/s (cSt) at 100 °C, in the past at 50 °C)

All fuels are called heavy fuels that consits in the main of residual oils from oil refining.

General Requirements:

The fuel must represent a homogenous mixture of hydro-carbon coming from the mineral oil processing. The fuel must not contain other substances (e. g. mineral acids, alcali) if not explicitely noted in the specification. Minor quantities of additives to improve special fuel properties are permitted.

Depending on whether it is the highest available viscosity or a mixture with distillates to obtain the required viscosity, the following designations are still used a lot at the present:

Bunker Fuel Oil	(BFO)
Marine Fuel Oil	(MFO)
Bunker C Fuel	
Intermediate Fuel	(IF)
Light Fuel Oil	(LFO)
Thin Fuel Oil	(TFO)

Various organizations, such as:

BSI	–	British Standards Institution
CIMAC	–	Conseil International des Machines à Combustion
ISO	–	International Organisation for Standardisation

are busy to find internationally applicable limit value specifications for marine fuels, especially for heavy fuel oils, and because of their activities new designations will be introduced to describe fuel properties.

ISO-Specification (ISO 8217)

The ISO-Specification for Marine Fuels was issued in April 1987.
A revised edition was published in March 1996.

A classification according to quality characteristics and viscosities was introduced.

The classes difer from

ISO-F-RM[1] A[2] 10[3]	(before, e. g. IF 30 with satisfactory data)

up to

ISO-F-RM H 55	(before, e. g IF 700 with in case using the maximum limit values)

1) RM = Residual Marine
2) Quality classification
3) Max. viscosity at 100 °C (mm^2/s)

(see **A4.05.07.05**).

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CIMAC-Specifications

On the basis of the ISO-Specification, the CIMAC Working Group “Future Fuels” has divided the fuels according to their physical and chemical data, which are decisive for a reliable engine operation.

In accordance with ISO, identical character/figure combinations are used for the identification of quality and viscosity,

e. g. CIMAC-A10 corresponds to ISO-F-RMA 10.

The CIMAC-Specification does not fully agree with the ISO-Specifications.

The most important differences are as follows:

– CIMAC provides fewer density limits for the A10 - D15 classes.
– Introduction of minimum viscosity with CIMAC.

The CIMAC-specification is the basis for the **Caterpillar / MaK heavy fuel specification** (**A4.05.07.05**).

BSI-Specification

The BS MA 100 which came into force in 1982 was with drawn in September 1989. Since then the contents of BS MA 100 conforms with ISO 8217.

The **Caterpillar / MaK Heavy Fuel Specification** indicates the equivalents of the CIMA-Specification and the ISOSpecifications.

The most important change is the limitation of:

Density	(separability)
Carbon residue	(Conradson)(combustibility)
Vanadium	(hot corrosion)
Aluminium + Silicium	(scuffing by catfines)
Pour Point	(pumpability)
Sediments	(stability)

A classification limit about the ignition quality could not be specified up to now in default of suitable test methods.

The so-called CCAI is a useful indicator when assessing the ignition behaviour. (CCI = calculated Carbon aromaticity index).

The CCAI is determined from density D (kg/m^3 t 15 degrees C) and viscosity V (mm^2/s or cSt at 50 degrees C) according to the following equation:

CCAI = D – 141 log log (V + 0,85) – 81

In principle, the following applies: the higher the CCI, the poorer the expected ignition behaviour.

Furthermore, the following applies: When taking a specific CCAI value as a basis, there is more risk of a poorer ignition behaviour if the viscosity is low.

Since the CCAI is **no measurement** for the ignition behaviour, but rather an **assessment aid**, absolute limit values cannot be specified.

The Caterpillar / MaK assessments make allowances for these factors:

A lower as well as an upper CCAI limit curve is defined depending on the viscosity, the type of engine and the condition of the fittings and included in **A4.05.07.03.00** an **A4.05.07.03.01**. The three sub-ranges which develop in this manner mean the following:

	Unrestricted permissible range. Impairments by insufficient ignition characteristics are not expected.
	Ignition characteristics are predominantly acceptable. Problematic fuels can, however, not be excluded.
	Range which should be avoided. Impairments and even damage to the engine can be expected.

The diagrams permit the determination of the permissible and/or maximum acceptable density of a fuel in a simple manner, depending on its viscosity.

100 °C is to be the reference temperature for indicating the viscosity of a heavy fuel. **A4.05.07.05** shows the conversion to 50 °C, 80 °C and Redw. I sec.

The heavy fuel grades permitted for Caterpillar / MaK engines can be found in the table “Permissible limits for heavy fuels to be burnt in Caterpillar / MaK engines” (**A4.05.07.04**).

In so doing, you should ensure that restrictions with regard to the permissible densities are possible, according to the valid CCAI limit curves (**A4.05.07.03.00** or **A4.05.07.03.01**).

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Notes to the specification of the permissible limits:

The equipment of the engine and the fuel treatment system are decisive for the determination of the permissible heavy fuel grade.

There may be restrictions, for instance, if the engine has no cylinder lubrication, the exhaust valve seat rings have no cooling or the pistons are of the monobloc aluminium type. Fuels to CIMAC-A10 are to be used in such cases. Caterpillar / MaK should be contacted if necessary.

A high vanadium content accelerates corrosion on the exhaust valves, and this must be taken into account when fuelling in the Caribbean area.

It will frequently happen in the near future that the limits of the Caterpillar / MaK heavy fuel specification are reached owing to a general change on the fuel market. If it is intended to take such fuels for a lengthy period of time and the owners have no experience with this, we recommend to contact Caterpillar / MaK first.

The sodium and water content should be kept as low as possible after the separator (water less than 0.2 % weight).

The ash content determines the mechanical wear. So preference should be given to heavy fuel with a low ash content.

Mixing of fuel components to obtain the desired viscosity should be done in suitable mixing appliances before bunkering.

A separate filling of the two components into the ship bunker as well as the use of mixed components that are incompatible can cause a great deal of trouble.

If there are mixing facilities on board ship the compatibility of the components must be assured by the supplier.

The technical development in handling of crudes has led to a noticeable increase in the proportion of fuels from new refining processes (catalyst cracking, visbreaking) with which mixing presents more of a problem than with the established heavy fuels. It is therefore preferable to bunker ready mixed fuels.

Note

In the residues from catalyst cracking there can be catfines which lead to extensive engine wear if they are not separated out very carefully.

The flash point of the heavy fuel must be above 60 °C in accordance with the requirements of the classification societies.

In any case a sample of the heavy fuel should be taken while bunkering. Analyses can be carried out by Caterpillar / MaK against payment of costs incurred or by the fuel supplier.

Heavy fuel operation makes necessary the use of a medium alkaline lubricating oil in accordance with our recommendation of lubricating oil brands (**A4.05.08.00**).

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Fuel additives

Two types of fuel additives, classified here according to their main effects, are used in various cases as required:

a) Demulsifying additives (emulsion breakers)

These additives, put in during bunkering, can prevent sludge-like agglomerations and break up stable water-heavy fuel emulsions in heated settling tanks which could not be separated in a simple separating process (mixing proportions 1 : 3000 to 1 : 6000).

Proven additives can be obtained from most oil or additive suppliers.

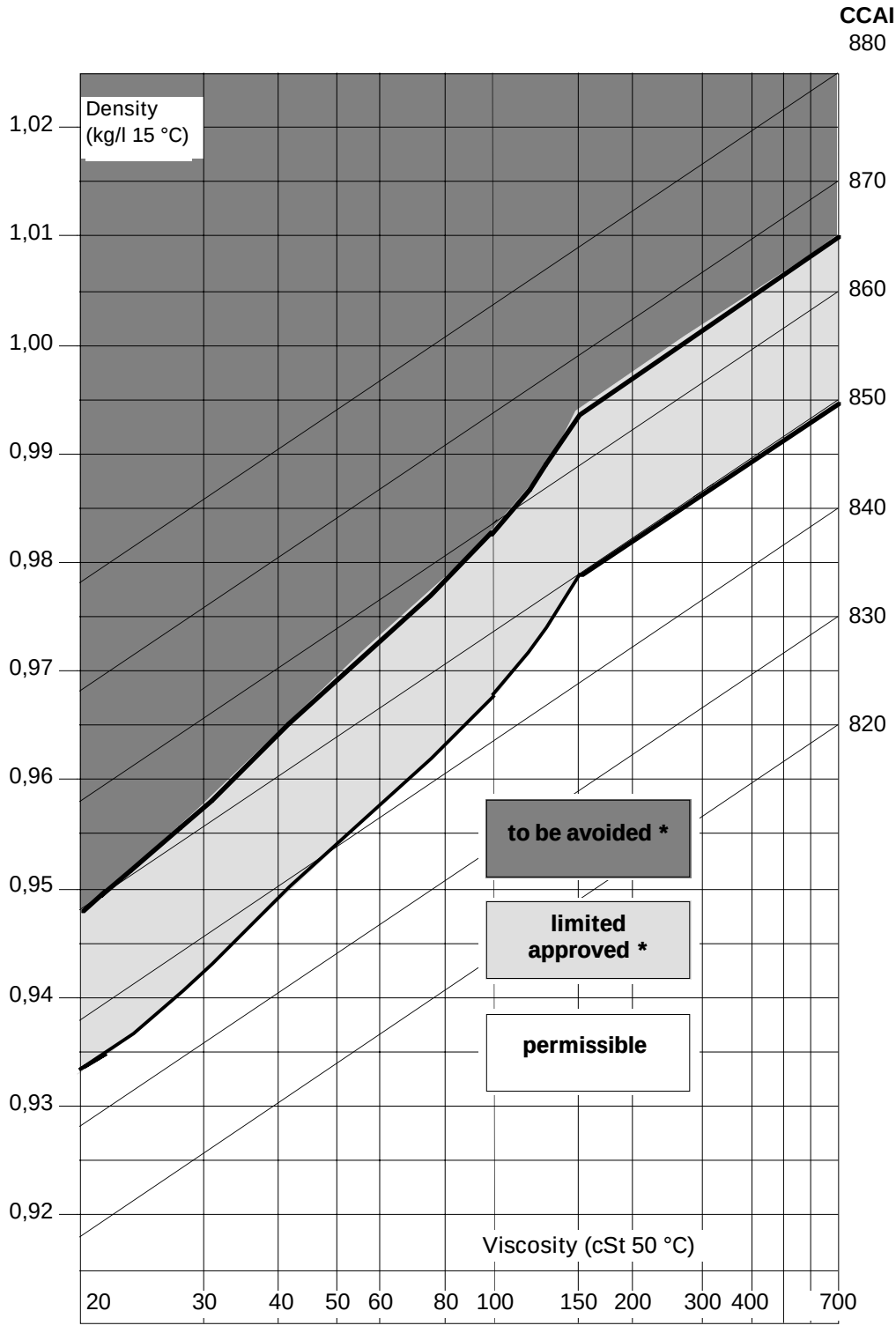
b) Additives against high-termperature corrosion

High-temperature corrosion can occur on exhaust valves and turbine blades when burning heavy fuel containing vanadium and sodium.

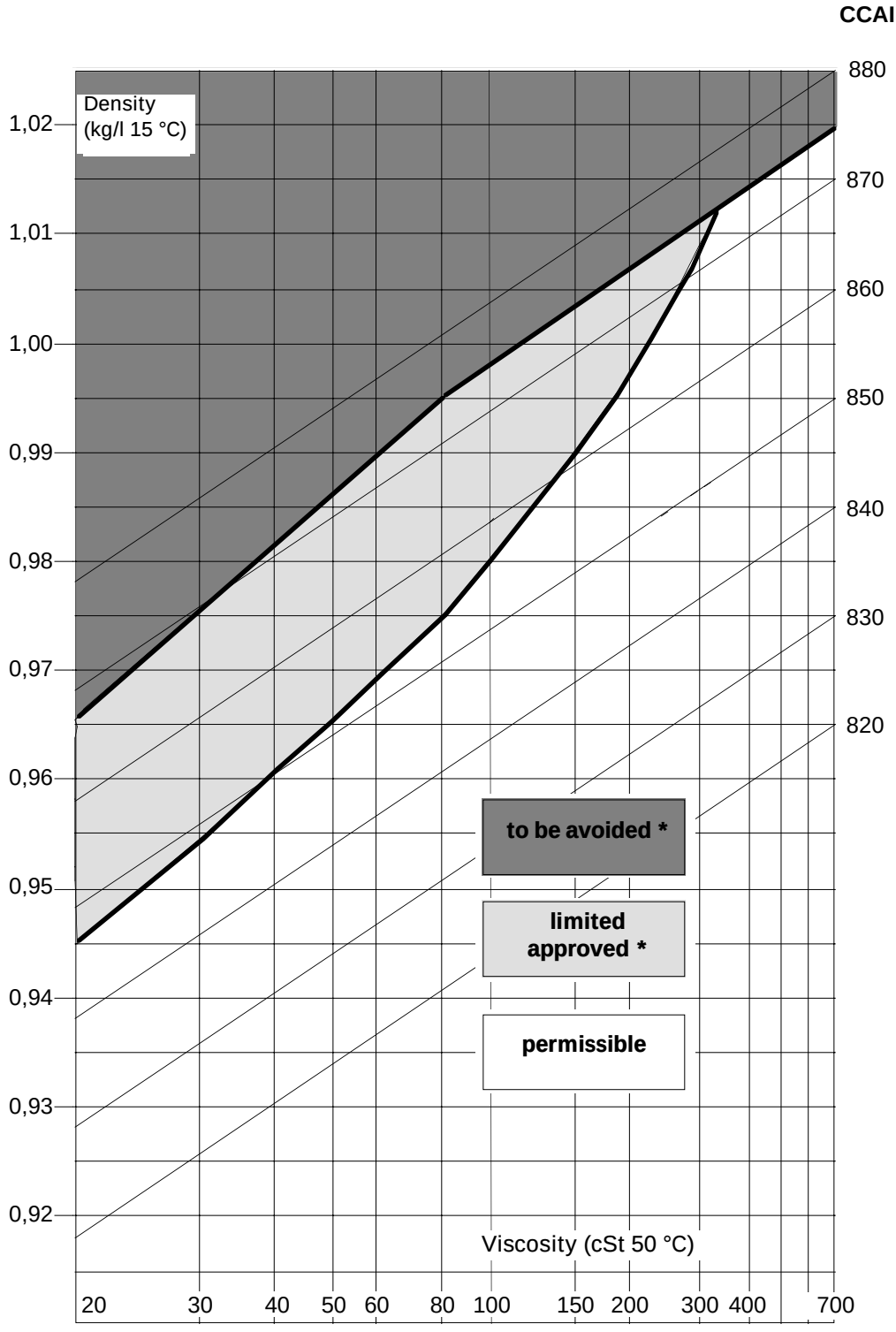
Caterpillar / MaK does not require additives against high-temperature corrosion. Should they be used, however, it must at least be ensured that they are not sensitive to water, compatible with the fuel in any case and no cause of troubles, in the fuel filters, for instance.

M282/M332/M452/M453/M551/M552

CCAI-limit curves, applicable for MaK engines series M282, M332, M452, M453, M551, M552



CCAI-limit curves



M20/M25/M32/M43

Admissible limit specification for the operation with heavy fuel in Caterpillar/MaK engines

Engine series

Limit specification	M 20	M25	M32	M43	
CIMAC A10	X	X	X	X	
CIMAC B10	X	X	X	X	
CIMAC C10	X	X	X	X	
CIMAC D15	X	X	X	X	
CIMAC E25	X	X	X	X	
CIMAC F25	X	X	X	X	
CIMAC G35	X	X	X	X	
CIMAC H35	X	X	X	X	
CIMAC K35	(X)	(X)	(X)	(X)	
CIMAC H45	X	X	X	X	
CIMAC K45	(X)	(X)	(X)	(X)	
CIMAC H55	X	X	X	X	
CIMAC K55	(X)	(X)	(X)	(X)	

X admissible

(X) admissible in connection with? suitable treatment system only (increased density limit)

Caution: **Observe CCAI limit curves (A4.05.07.03.nn)!**

M282/M332/M332C/M452/M453/M453C/M551/M552/M552C/M601/
M601C

Admissible limit specification for the operation with heavy fuel in Caterpillar/MaK engines

Engine series

Limit specification	M 601 C M 601	M 552 C M 552	M 551		M 453 C M 453	M 452	M 332 C	M 332 M 282
CIMAC A10	X	X	X		X	X	X	X
CIMAC B10	X	X	X		X	X	X	X
CIMAC C10	X	X	X		X	*	X	O
CIMAC D15	X	X	X		X	*	X	O
CIMAC E25	X	X	X		X	*	X	O
CIMAC F25	X	X	X		X	*	X	O
CIMAC G35	X	X	X		X	*	X	O
CIMAC H35	X	X	X		X	*	X	O
CIMAC K35	(X)	(X)	(X)		(X)	*	(X)	O
CIMAC H45	X	X	X		X	*	X	O
CIMAC K45	(X)	(X)	(X)		(X)	*	(X)	O
CIMAC H55	X	X	X		X	*	X	O
CIMAC K55	(X)	(X)	(X)		(X)	*	(X)	O

X admissible

(X) admissible in connection with? suitable treatment system only (increased density limit)

O on consultation with MaK, special measures are e.g. required for „one-fuel-ships“

* not admitted

Caution: **Observe CCAI limit curves (A4.05.07.03.nn)!**

Provided the other limits defined by the CIMAC specification are met, the following deviations from the maximum CIMAC viscosities can be admitted in addition:

Visco-sity	100 °C		22	22	22
mm^2/s (cSt)	50 °C		180	180	180

CIMAC – REQUIREMENTS for RESIDUAL FUELS for diesel engines (as delivered)
– ANFORDERUNGEN an RÜCKSTANDS-KRAFTSTOFF für Dieselmotoren (wie geliefert)

	Designation: Bezeichnung:		**CIMAC A 10**	**CIMAC B 10**	**CIMAC C 10**	**CIMAC D 15**	**CIMAC E 25**	**CIMAC F 25**	**CIMAC G 35**	**CIMAC H 35**	**CIMAC K 35**	**CIMAC H 45**	**CIMAC K 45**	**CIMAC H 55**	**CIMAC K 55**
	Related to ISO8217 (96):F–		RMA 10	RMB 10	RMC 10	RMD 15	RME 25	RMF 25	RMG 35	RMH 35	RMK 35	RMH 45	RMK 45	RMH 55	RMK55
Characteristic	Dim.	Limit													
Density at 15 °C Dichte	kg/m³	max	950 [2]	975 [3]		980 [4]	991		991		1010	991	1010	991	1010
Kin. viscosity at 100 °C		max	10			15	25		35			45		55	
Kin. Visk. bei 100 °C	cSt [1]	min	6 [5]				15 [5]								
Flash point Flammpunkt	°C	min	60			60	60		60			60		60	
Pour point (winter) (summer) Stockpunkt	°C	max	0 6		24	30	30		30			30		30	
Carbon Residue (Conradson) Koksrückstand	% (m/m)	max	12 [6]		14	14	15	20	18	22		22		22	
Ash Asche	% (m/m)	max	0.10			0.10	0.10	0.15	0.15	0.15 [7]		0.15 [7]		0.15 [7]	
Total sedim. after ageing Totaler Sedimentanfall nach Alterung	% (m/m)	max	0.10			0.10	0.10		0.10			0.10		0.10	
Water Wasser	% (V/V)	max	0.5			0.8	1.0		1.0			1.0		1.0	
Sulphur Schwefel	% (m/m)	max	3.5			4.0	5.0		5.0			5.0		5.0	
Vanadium	mg/kg	max	150		300	350	200	500	300	600		600		600	
Aluminium + Silicon	mg/kg	max	80			80	80		80			80		80	

1) An indication of the approximate equivalents in kinematic viscosity at 50 °C and Redw. I sec. 100 °F is given below:

Kinematic viscosity at	100 °C	mm²/s (cSt)	7	10	15	25	35	45	55
Kinematic viscosity at	50 °C	mm²/s (cSt)	30	40	80	180	380	500	700
Kinematic viscosity at	100 °F	Redw. I sec.	200	300	600	1500	3000	5000	7000

Eine ungefähre Zuordnung der kin. Viskositäten bei 50 °C sowie in Redw. I sec. bei 100 °F enthält die nachstehende Tabelle:

2) ISO : 975
3) ISO : 981
4) ISO : 985
5) ISO : not limited
nicht begrenzt
6 ISO : Carbon Residue
Koksrückstand 10
7) ISO : 0.20

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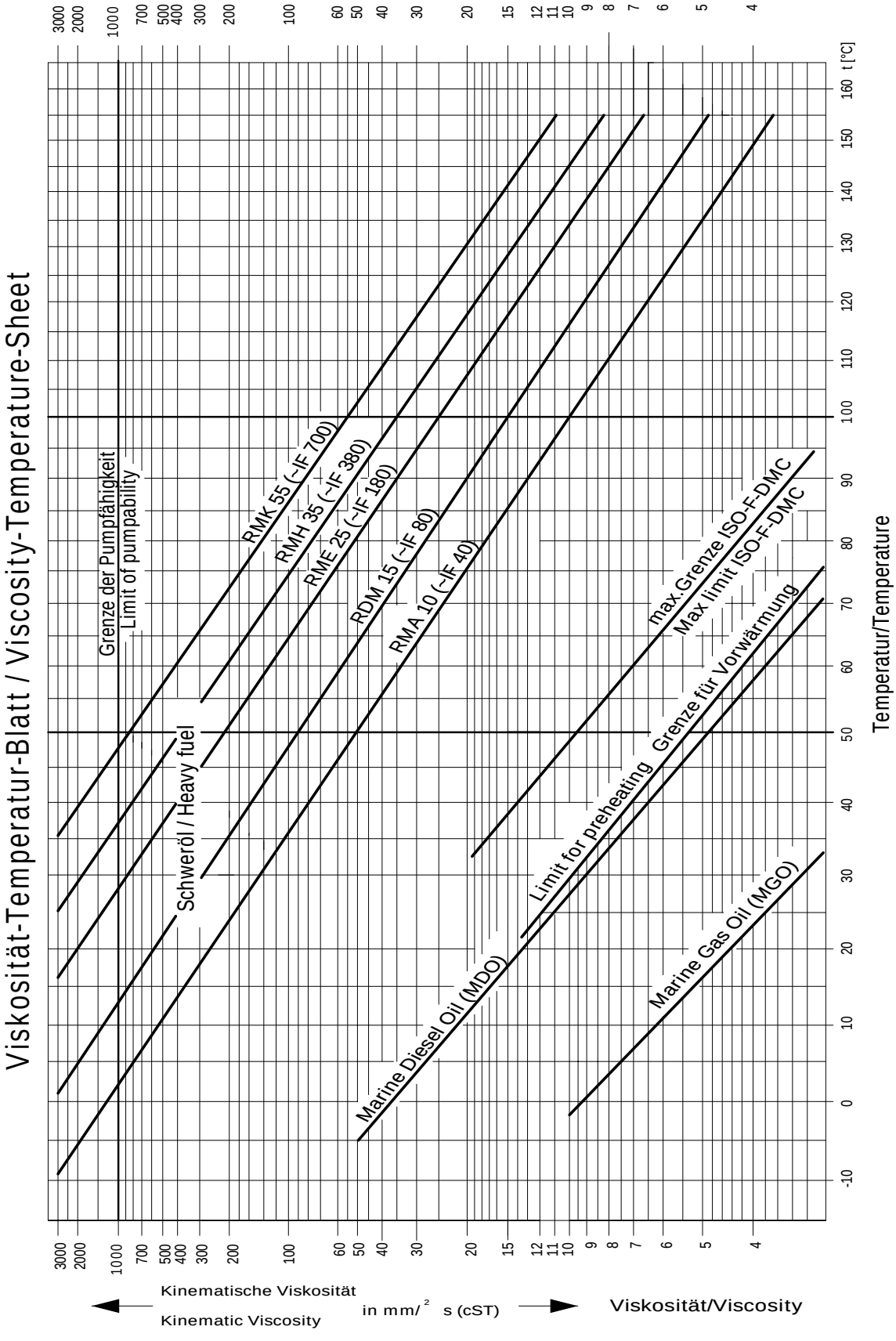
Viskosität-Temperatur-Blatt / Viscosity-Temperature-Sheet
Grenze der Pumpfähigkeit
Limit of pumpability
Schweröl / Heavy fuel
RMK 55 (~IF 700)
RMH 35 (~IF 380)
RME 25 (~IF 180)
RDM 15 (~IF 80)
RMA 10 (~IF 40)
max.Grenze ISO-F-DMC
Max limit ISO-F-DMC
Grenze für Vorwärmung
Limit for preheating
Marine Diesel Oil (MDO)
Marine Gas Oil (MGO)
Temperatur/Temperature
t [°C]
Kinematische Viskosität
Kinematic Viscosity
in mm/² s (cST)
Viskosität/Viscosity

1. Engine Lubricating Oil

The quality of the engine oil has a large influence on the service life and engine efficiency and thus the economical operation.

High demands must therefore be placed on the lubricants to be used in respect of suitability.

The oil to be used should be selected according to the specifications of the fuel which is used to run the engine.

When using heavy fuel the effect of the increased amounts of coke-type and acid deposits which form during combustion as a result of the high ash and sulfur content, must be rendered harmless and for this reason only lubricating oils which have been developed for medium-speed trunk piston Diesel engines are approved.

On engines which are equipped with special cylinder lubrication the same oil should be used in the circulation system and for the cylinder lubrication.

When using fuel with a very low sulphur content liner lacquering may appear. If there is a high luboil consumption also indicated, a special oiltype should be used after consultation with MaK.

1.1 Base Oil

The base oil should be a high-quality solvent refined product from a source suitable for engine lubricating oil and have a good oxidation stability as well as a good load carrying capacity and thermostability.

Regenerated oils are not permitted.

1.2 Additives

The additives in the oil must remain effective and uniformly distributed at all temperatures occurring in normal operation between pour point and 220 °C as well as in storage and also fulfil the following requirements in Caterpillar/MaK engines:

1.2.1 Good detergent and dispersant properties (which for heavy fuel operation equals at least the API-CF level) to prevent the depositing of combustion products (coke and asphalt-like compositions) or dissolves these deposits and keeps them in suspension.

1.2.2 Have an adequate alkalinity in order to be able to neutralize the sulfur acid compositions which occur during the combustion process. This is usually given as the Base Number (BN), or as Alkalinity Value (AV) and recorded in mgKOH/g. For Caterpillar/MaK engines operating on heavy fuel this value should be between 30 and 40 mg KOH/g for fresh oils.

1.3 Care of lubricating oil

The time between oil changes can be lengthened by the use of separators, oil centrifuges and by-pass filters.

Mechanical filters suitable for filtering blended oils may be used only. Chemically active filters are not permitted.

1.3.1 Lubricating oil filtering (By-pass)

By-pass oil cleaning in separators is specified for heavy-fuel operation because the finely distributed combustion deposits cannot be removed effectively from the oil in any other way. The separator capacity should be designed in accordance with the Instructions for Heavy-Fuel Operation in **A3.04.08.nn**

One stipulation for good separation of the lubricating oil is a low viscosity which requires a correspondingly high temperature. When separating the temperature should be between 90 and 95 °C.

For gas oil or MDO operating by-pass filters can be used instead of separators.

1.3.2 Lubricating oil filtering (full flow)

In order to combat the higher amount of contamination in the lubricating oil when operating on heavy fuel, the installation of an “Automatic back-flush filter” in conjunction with a following indicator filter as double filter is necessary. (See the details in the Instructions for Heavy-Fuel Operation **A3.04.08.nn**)

For gas oil or MDO operation, a double filter with manual change-over is sufficient.

Exception: automatic filters

1.4 **Lubricating oil brand recommendations** – Limitation of warranty

In most cases, the firm’s name is part of the brand designation of the lubricating oil and should, when ordering, be placed in front of the designation to avoid confusion. Caterpillar/MaK has insufficient experience with brands of lubricating oil listed in column II. The intended use of any of these oils must therefore be discussed with the engine manufacturer beforehand as otherwise the warranty is no longer valid.

Caterpillar/MaK has no experience with oils not mentioned here. Caterpillar/MaK cannot give any guarantee for the oil used because, for example, the composition and manufacture cannot be influenced by Caterpillar/MaK. Furthermore no guarantee can be given for poor quality engine and lubricating oil care nor for the use of non-approved fuels. Proof that a defect has not been brought about by the lubricating oil must be provided by the user.

1.4.1 List of brands of lubricating oil for Operation with distillate fuel

The viscosity class SAE 40 is specified for all Caterpillar/MaK engines.

Lubricating oil firm	Lubricating oil brand		I	I I
AGIP	DIESEL SIGMA S			X
	CLADIUM 120			X
BP	ENERGOL DS 3-154		X	
	VANELLUS C3			X
CALTEX	DELO 1000 MARINE		X	
	DELO 2000 MARINE		X	
CASTROL	MARINE MLC		X	
	MHP 154		X	
	TLX PLUS 204		X	
CEPSA	KORAL 1540			X
CHEVRON	DELO 1000 MARINE OIL		X	
	DELO 2000 MARINE OIL		X	
ELF LUBMARINE	DISOLA M 4015		X	
	AURELIA 4030	1)		X
ESSO	EXXMAR 12 TP		X	
	EXXMAR CM+			X
	ESSOLUBE X 301			X
MOBIL	MOBILGARD 412		X	
	MOBILGARD ADL		X	
	MOBILGARD M430	1)	X	
	MOBILGARD 1-SHC	2)		X
SHELL	GADINIA		X	
	SIRIUS FB		X	
	ARGINA S		X	
	ARGINA T	1)	X	
TEXACO	TARO 12 XD		X	
	TARO 16 XD		X	
	TARO 20 DP		X	
TOTAL FINAELF	RUBIA FP			X
	HMA SUPER X 420		X	

I Proven in use

I I Permitted for controlled use.When these lubricating oils are used, **Caterpillar/MaK** must be informed because at the moment there is insufficient experience available in Caterpillar/MaK engines. Otherwise the warranty cover is invalid.

1) See also brand list for lubricating oils for heavy fuel operation.

2) Synthetic oil with a high viscosity index (SAE 15 W/40).For engines under SAE 40-regulation only allowed if the oil inlet temperature can be decreased by 5 - 10 °C.

1.4.2 List of brands of lubricating oil for heavy oil operation

Only the viscosity class SAE 40 is permitted.

Lubricating oil firm	Lubricating oil brand	I	I I
AGIP	CLADIUM 300		X
	CLADIUM 400		X
BP	ENERGOL IC-HFX 304	X	
	ENERGOL IC-HFX 404	X	
CALTEX	DELO 3000 MARINE	X	
	DELO 3400 MARINE	X	
CASTROL	TLX PLUS 304	X	
	TLX PLUS 404	X	
CHEVRON	DELO 3000 MARINE OIL	X	
	DELO 3400 MARINE OIL	X	
ELF LUBMARINE	AURELIA 4030	X	
	AURELIA XT 4040	X	
ESSO	EXXMAR 30 TP	X	
	EXXMAR 40 TP		X
	EXXMAR 30 TP PLUS	X	
	EXXMAR 40 TP PLUS	X	
MOBIL	MOBILGARD M430	X	
	MOBILGARD M440	X	
	MOBILGARD M50	X	
SHELL	ARGINA T	X	
	ARGINA X	X	
TEXACO	TARO 30 DP	X	
	TARO 40 XL	X	
TOTAL FINAELF	HMA SUPER X 430	X	
	HMA SUPER X 440	X	

I Proven in use

I I Permitted for controlled use.When these lubricating oils are used, **Caterpillar/MaK** must be informed because at the moment there is insufficient experience available in Caterpillar/MaK engines. Otherwise the warranty cover is invalid.

1.5 Lubricating oil changing

The oil change interval is dependent to a large extent on the quality of the oil used and is influenced also by the fuel used, the amount circulating in the engine lubricating system, the operating conditions, the engine oil consumption, the lubricating oil care and engine maintenance.

The optimal oil circulation quantity should 1.36 l/kW.

If in special exceptions circulation amounts of at least 0.3 l/kW cannot be avoided, shorter oil change intervals are necessary. In such cases the oil change times given below must be multiplied by the quotient of the actual quantity to the normally required quantity. An oil change must be made every 6 months at the latest.

The oil level must be checked daily (the level must not drop below the minimum mark). It must be topped up at the latest when 20 % of the amount in circulation has been used.

Note:

Modern MaK engines are characterized by low lubricating oil consumption rates of < 1 g/kWh, which in individual cases may even be significantly below this value.

Under such conditions and due to the low refilling requirement the usability limit can already be reached after shorter times depending on the oil grade used (BN) and the influence of the other operating parameters.
Independent of the kind of treatment it is necessary to replenish by adding new oil when the BN limit (item 1.6.2) is reached.

Due to the above-mentioned factors the indicated oil change intervals are guide values only. The essential criterion for determining the time for an oil change is compliance with the limt values specified under item 1.6.

We therefore recommended checking of the lubricating oil by means of regular oil analyses.

These analyses will be carried out by the lubricating oil service of the oil supplier or by Caterpillar/Kiel at cost price. The oil for the analysis must be taken from the oil circuit **before** engine during operation. The amount required is approx. 0,5 to 1,0 l.

Oil change after operating hours (h) based on 1.36 l/kW when fitted with:

Pre- and main filter	– every 1.500 h
Additional by-passfilter or oil centrifuge	– every 3.500 h
Separator	– every 7.500 h

1.6 Limits:

1.6.1 Lubricating oil dilution by fuel

Flash point decrease not below 180 °C (measured according to Penski-Martens DIN 51758) or viscosity decrease for SAE 40 (40 °C) not below 120 mm^2/s (cSt), viscosity increase at 40 °C not above 200 mm^2/s (cSt).

1.6.2 Alkalinity (TBN)

For heavy fuel operation, the total base number of the circulation oil must not fall below 18 mg KOH/g. For engine with cylinder lubrication, the limit value is 15 mg KOH/g.

If the engine is running on gas oil or MDO, the total base number must not fall below 50 % of the value of the new oil.

If only the base number has reached the lower limit and the other analysis values show a satisfactory oil condition, the alkalinity should be increased by the addition of new oil.

1.6.3 Water content

If the water content rises above 0.2 % the cause of the increase should be identified and eliminated immediately. The oil must be separated or it must be changed.

1.6.4 Contamination

When Caterpillar/MaK engines are running on heavy fuel, separators are specified to keep the oil clean. In this way the content of insolubles can usually be kept well below 1 % by weight. If the content increases beyond 1 % weight, the oil must be separated more intensively.

The limit is 2 % by weight.

For gas oil operation as well the pentane or heptane insolubles must not exceed 2 % by weight.

1.7 Lubricating oil for exhaust turbocharger, hydraulic governor and change-over controls

A turbine or hydraulic oil with very good anti-oxidation properties of between 68 and 90 mm^2/s (cSt) at 40 °C should be selected. For highly loaded ABB-turbochargers fully synthetic special oils (see footnote) are recommended.

When selecting the lubricating oil the regulations of the maker such as ABB, Woodward etc. should therefore be noted.

Lubricating oil firm	Lubricating oil brand	
AGIP	OSO 68	
	OTE 68	
	DICREA SX 68	1)
BP	ENERGOL HLP 68	
	ENERGOL THB 68	
	ENERSYN TC-S 68	1)
CALTEX	RANDO HD 68	
	REGAL R & O 68	
	CETUS PAO 68	1)
CASTROL	PERFECTO T 68	
	HYSPIN AWH-M 68	
	AIRCOL SR 68	1)
CEPSA	HD TURBINAS 68	
CHEVRON	EP HYDRAULIK OIL 68	
	OC TURBINE OIL 68	
ELF LUBMARINE	TURBINE T 68	
	BARELF SM 68	1)
ESSO	TERESSO 68	
	TROMAR T	
	COMPRESSOR OIL 68	1)
MOBIL	D.T.E OIL HEAVY	
	RARUS SHC 1026	1)
SHELL	TELLUS OIL T 68	
	TURBO OIL T 68	
	CORENA OIL AS 68	1)
TEXACO	RANDO HD 68	
	REGAL R & O 68	
	CETUS PAO 68	1)
TOTAL FINAELF	PRESLIA 68	
	AZOLLA ZS 68	

1) Fully synthetic special oil for extended oil change intervals in highly loaded ABB-turbochargers with independent lubrication.

1.8 Multi-purpose grease – lithium saponified – consistency number 2 (also suitable for pneumatic control instruments)

Lubricating oil firm	Brand name
AGIP	GR MU 2
BP	ENERGREASE MP-MG 2
CALTEX	MULTIFAK EP 2
CASTROL	SPHEEROL SX 2
CHEVRON	DURA-LITH GREASE EP 2
ELF LUBMARINE	EPEXA 2
ESSO	BEACON EP 2
MOBIL	MOBILUX EP 2
SHELL	ALVANIA R 2
TEXACO	MULTIFAK EP 2
TOTAL FINAELF	MULTIS EP 2

M20-M601C

Recirculating Cooling Water

The cooling system consists of a closed cooling water circuit with a cooling water volume which must be kept constant by topping up, depending on the evaporation loss. The checking of the recirculating cooling water level has to occur at the expansion tank.

Modern Diesel engines put particular requirements on the recirculating cooling water due to the increased power desity and the consequently increased heat to be dissipated.

These requirements can only be met by proper prepared, monitored and maintained cooling water. If the the preperation, monitoring and maintenance work are not carried out properly, even a short period of operation may result in damages due to corrosion.

Three decisive facts are to be considerd for a proper treatment:

- **Suitable fresh water**
- **effective corrosion inhibiting agent**
  - corrosion inhibiting oil, soluble
  - chemical corrosion inhibiting agent (chemicals)
- **exact dosing** of the corrosion inhibiting agent

Requirements for the cooling water

Always use clear, clean water. Suitable are:
- Natural water (deep well-, well water)
- condensate and
- fully de-ionized water.

The values for the fresh water analysis must be within the following limits:

	corrosion-inhibiting oil	Chemicals
total - alkaline earths mmol / l - Hardness * ° dGH	0,5 - 2,2 3 - 12	0 - 1,8 0 - 10***
pH value ** at 20 °C	6,5 - 8	
Chloride ion content mg / l	max. 100	
total chloride + sulphate ions mg / l	max. 200	

*) **Water hardness:**

Water which does not fulfil the above requirements must be hardened or softened.
Water with a hardness of < 12° (10°) dGH must be brought within the specified range by mixing with condensate or fully de-ionized water (by ion exchange), see Diagram I (**A4.05.09.03**).
Condensate and fully de-ionized water should be hardened up to **3° dPH**. Magnesium sulfate (Mg SO_4) should be used for this purpose, if corrosion inhibiting oils are used.

Dosing:
For **1° dPH 21.4 g Mg SO_4 per ton of water** are required.

German total	=	Permanent hardness	+	Carbonate hardness
dGH	=	dPH	+	dKH

Comparison with other values:

1° dGH = 0,18° mmol/l
1° dGH = 1,79° French hardness
1° dGH = 1,25° British hardness
1° dGH = 17,9 USA hardness

) **pH value:

Concentration of hydrogen ions
< 7 = acid, 7 = neutral, > 7 = alkaline.

***) In general, the corrosion inhibiting effect of chemicals shows the best results with low water hardness values (- 0). At higher hardness values and with missing hardness stabilization the chemicals may react with water contents, what may result in precipitations and in reduction of the inhibiting effect.

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1. Treatment of cooling water with corrosion inhibitors

Anticorrosive agents to be used in MaK/CAT engines must have been tested for their effectiveness according to the rules of the “Forschungsvereinigung Verbrennungskraftmaschinen e. V.” (Research Association for Internal Combustion Engines Inc).

MaK/CAT will issue a recommendation on the basis of the results of the test. No liability for the anticorrosive agent used will be accepted because MaK/CAT is unable to control the recipe and treatment.

MaK/CAT has received positive test results for the agents mentioned in 1.1 and 1.2 or they have proven effective over a long period of operation.

Safety note:
<u>No anti-corrosion oil emulsion</u> must be used in case of systems heating living quarters by engine cooling water or in case of shell cooling! In this cases use only chemicals!

1.1 Anti-corrosion oil

The fresh water is mixed outside the engine with anti-corrosion oil to form a stable emulsion.

For the **initial filling** or after cleaning the coolant circuit a

1.5 % emulsion

should be used and for the subsequent filling a

1.0 % emulsion

should be used.

The following anti-corrosion oils are known to us to be effective (alphabetical order, not complete):

BP:	FEDARO-M
Castrol:	SOLVEX WT3
Esso:	Kutwell 40
Shell:	Dromus B
	Shell Oil 9156

The preparation of the emulsion can generally be carried out as follows:

Add oil to the water (**15 - 25 °C**) and stir vigorously. For initial fillings take so much water that a **10 % emulsion** can be prepared with the required amount of anti-corrosion oil.
This **10 % emulsion** is added to the cooling circuit which is already filled with **75 %** of the necessary cooling water amount, via the expansion tank. Topping up can be done with the engine running.

1.2 Chemical corrosion inhibitors

The chemical corrosion inhibitors have some advantages over the anti-corrosion oils e. g. no danger of sludge formation due to breaking down of the emulsion and are simplier to prepare and control.

Attention:

It is important to avoid too low concentration, because this may result in crevice corrosion!

As far as we know, the following materials are being used in MaK/CAT Diesel engines at the moment:

Manufacturer	Additive	Limit value of nitrite content as NO_2 in mg /l
Bedia	Bedia Liquid BL1	1200 - 1500
Rohm + Haas	Dia-Prosim RD 11	1400 - 2100
	Dia-Prosim RD 25	—
Ashland (Drew Ameroid)	DEWT-NC (Schiff) CWT-110 (Land)	1500 - 2250
	Maxigard	800 - 1100
	Liqui dewt	500 - 700
Maritech	Marisol CW	1000 - 2000
Nalfleet	9-108	750 - 1000
	9-111	750 - 1000
	Nalcool 2000	750 - 1000
Unitor	Dieselguard NB	1500 - 2500
	Rocor NB Liquid	1500 - 2500
Vecom	CWT Diesel / QC2 (D99)	1500 - 2500
Arteco	Havoline XLC	—

Safety note!

Chromates are not recommended despite of their good properties due to their poisonous nature!

Using and checking procedures must be obtained from the manufacturers, taking particular care not to use any poisonous substance it fresh water plants are connected into the cooling circuit.

Note: A chemical anticorrosive agent is added to the delivery scope (fittings) of some stationary engines. In any case, a filling with **this** chemical is to be implemented prior to commisioning.

2. Checking and care of the treated water

2.1 Anti-corrosion oil

A **daily** check of the coolant level in the sight glass on the expansion tank is just as important as checking the **anti-corrosion oil contents** every **750 operating hours**. During prolonged operating breaks, a **monthly** check should be made.

Take the emulsion sample out of the supply line from expansion tank to pump and let it stand for **1 h**. Pour off oil which rises to the surface.

Carry out emulsion test e.g. with hand refractometer (specialist shop laboratory equipment) .

0 %	–	Cooling water change and cleaning necessary, see **A4.05.09.02**
< 0,5 %	–	Emulsion freshening required
0,5 - 1 %	–	Emulsion in order
> 1 %	–	Concentration too high, possibly incorrect measurement

In case the measured values are higher than **1.5 %**, test again with fresh sample water. If the result is confirmed, a correction of the emulsion is necessary.

Emulsion freshening in case of concentration too low
Mix required amount of oil according to diagram II (**A4.05.09.04**) with conditioning water to a highly concentrated emulsion.

Always add oil to water
Fill in the mixed emulsion via the compensator reservoir, also possible with engine running.

Emulsion correction in case of concentration too high
Drain cooling water emulsion according to diagram II (**A4.05.09.04**) and refill the circuit with conditioning water.

2.2 Chemical corrosion inhibitors.

The maintaining of the determined concentration is of decisive importance for a proper corrosion protection.

A concentration check of the chemical corrosion inhibitors under consideration of the limit values (see 1.2) is to be carried out with the relevant testing equipment every 150 h in accordance with the instructions of the supplying companies.

After a freshening up of the concentration mix well with engine running!

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1. Changing the cooling water

1.1 Anti-corrosion oil emulsion

The anti-corrosion emulsion must be changed at the latest every **7500** operating hours, at least **annually** if the **7500** operating hours are spread over a period of more than one year due to long breaks in operation.

1.1.1 Cleaning the cooling water chambers before changing the emulsion

Stop engine and let cooling water cool down to **30 °C**. First drain expansion tank with floating oil then drain the entire system.

Remove water inlets on the crankcase and flush out any sludge which may have formed.

Fill engine with an alkali solution (e. g. P3T 308 from Messrs. Henkel **0.5 %** solution) and run it for approximately **12 hours**. Stop engine and let it cool down to **30 °C**.

Drain the cleaning solution and flush engine thoroughly with fresh water.

Then put in **90 %** of the required amount of water. With the remaining **10 %** and the required amount of anti-corrosion oil (according to diagram II: **A4.05.09.04**) prepare a highly concentrated emulsion.

Attention:
Always add oil to water!

Add the emulsion to system via the expansion tank.

1.2 Chemical corrosion inhibitors

When recirculating cooling water has chemical corrosion protection the cooling water does not need changing.

2. Cooling water with anti-freeze agent

In case of temperatures at or below the freezing point of the cooling water an anti-freeze agent must be added to the coolant.

Only an anti-freeze agent with a corrosion protective effect may be used.

To obtain adequate corrosion protection, a **30 %** concentration is necessary. The highest concentration is **50%.**
This agent must be changed **annually**.

When an anti-freeze agent is used, a reduction in cooling efficiency must be expected. In cases of doubt MaK should be contacted.

For summer operation, it is advisable to drain off the cooling water with anti-freeze in it and replace it with cooling water with chemical corrosion protection in order to guarantee adequate radiator performance at higher ambient temperatures.

3. Cleaning the cooling water chambers

Before badly scaled cooling water chambers can be cleaned, they must be precleaned as described and flushed well with water under pressure. This will remove loose foreign matter such as sand and sludge which may have been deposited at places where the water flow speed is low.
The firm which supplies the anti-corrosion material will usually be able to offer a good cleaning agent for scale, such as:

Drew Chemical:	SAF - ACID
Rohm + Haas:	RD 13 M

Attention:

Keep to the manufacturer´s instructions!Improper use of the cleaning agents may cause damages to your health!

Flush cooling water chambers or cooling system with a **1 %** sodium carbonate solution after draining off the cleaning agent. Afterwards flush the water chambers with fresh water.

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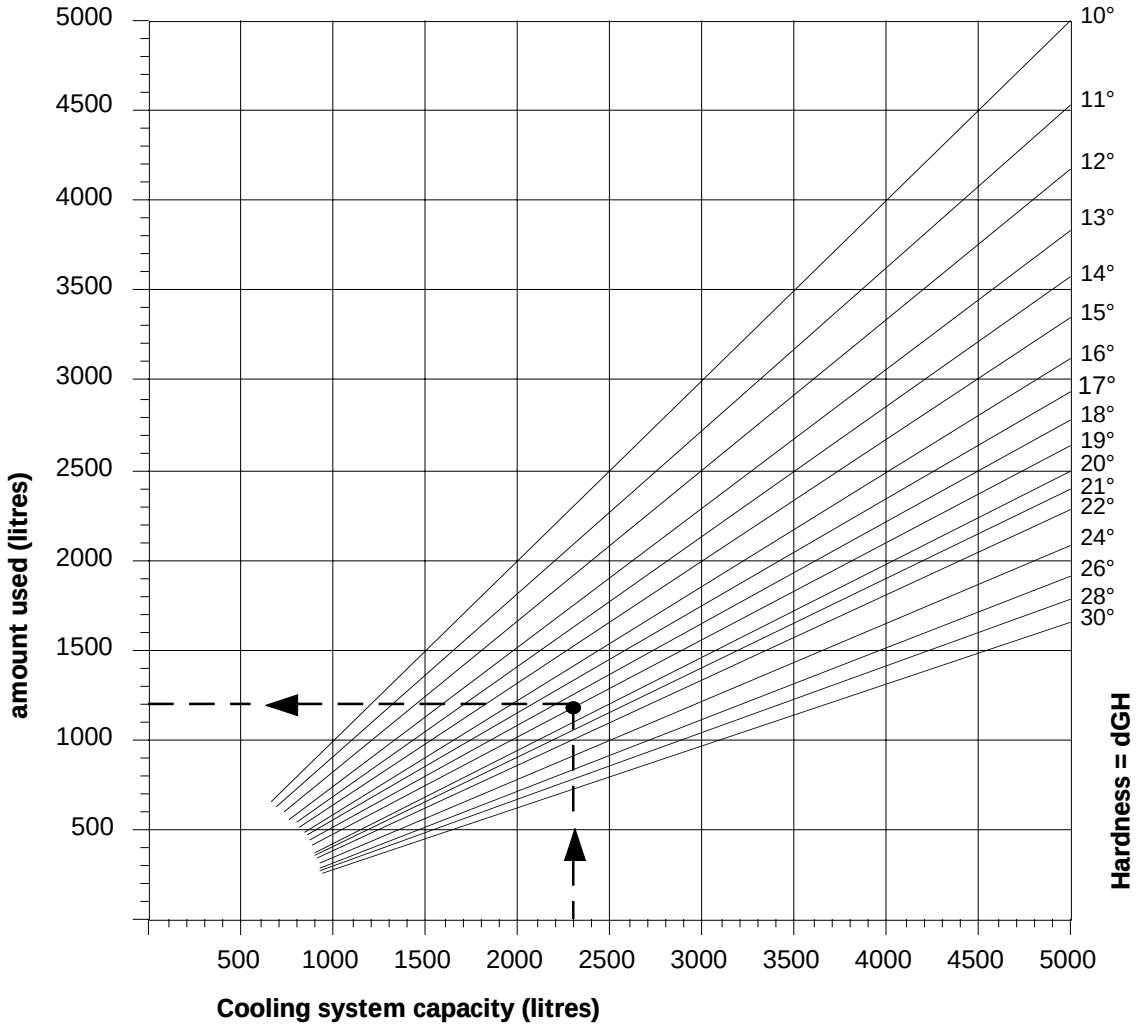
Diagram I
Determining the cooling water mixture for 10° dGH



Example:

Cooling system capacity:	2300 l
Hardness of available fresh water:	19° dGH

To determine the fresh water mixture, proceed from the abscissa “Cooling system capacity” (2300 l) via the intersection of the 19° dGH line to the ordinate “Amount used” and read off the amount of water with 19° dGH which is to be used and which is to be mixed with the difference of 2300 - 1200 = 1100 litres of condensate or fully de-ionized water.

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Diagram II
Emulsion freshening for weak concentration

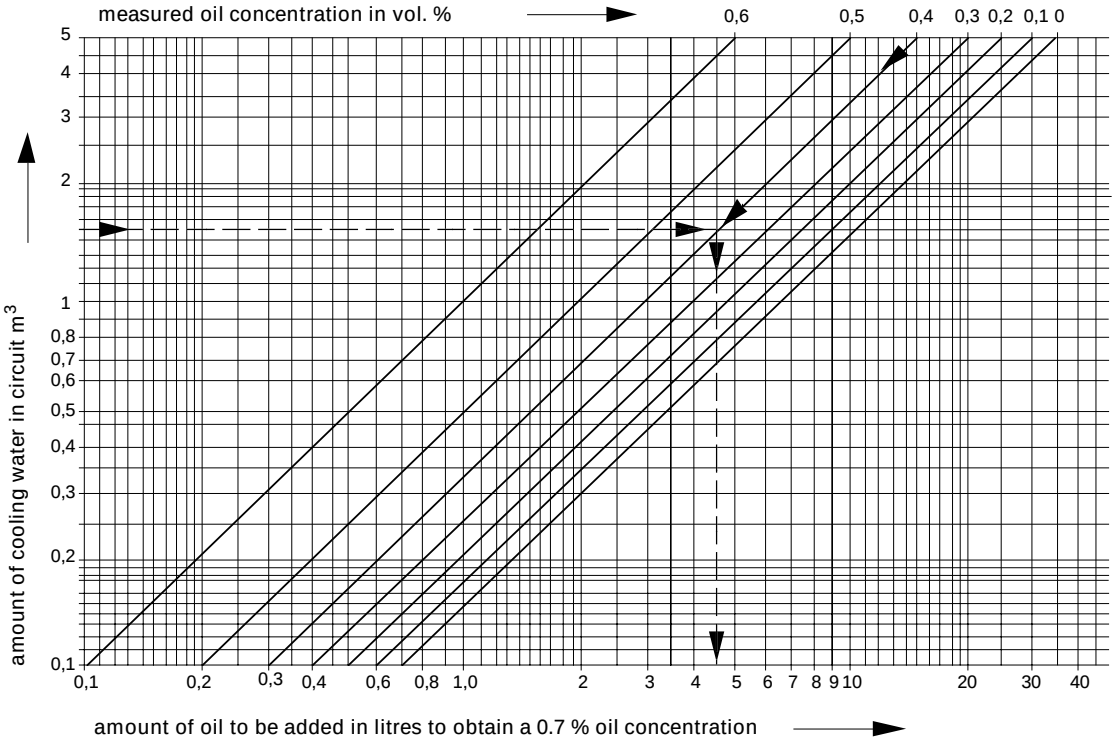
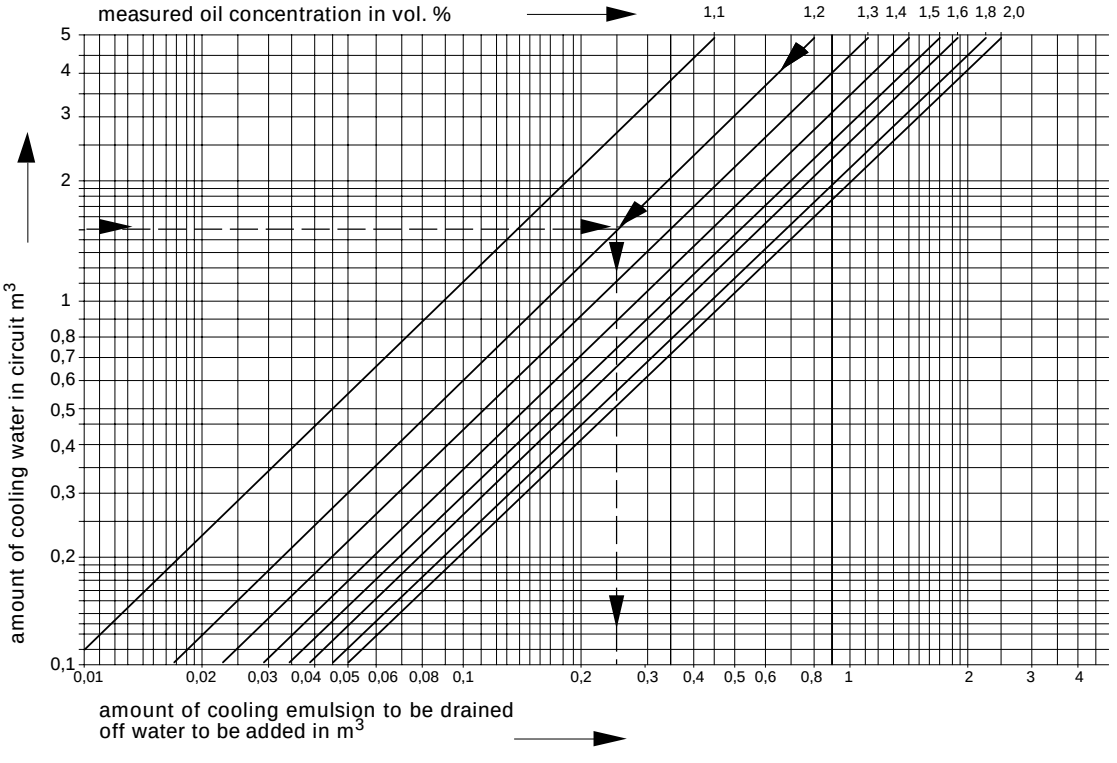


Diagram III
Emulsion freshening for weak concentration



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