Service Information

Caterpillar Motoren GmbH & Co. KG product support information for medium-speed engines

Engine platform: all
Engine section: operation media
Engine type: all
Validity: until further notice

No. 0021com • **Issue 1; December 07, 2020**

Information for all recipients of Service Information

Action: for your information

New operation media guideline for diesel and dual fuel engines

With our Service Information No. 0005com, 0006com and 0015com we gave specific recommendations for continuous engine operation with certain fuels in the context of IMO 2020 regulations, new Low Sulphur Fuels etc. With Service Information No.0017com we asked for customer support, sharing engine operation experience with 0.5% S fuels through the CIMAC 2020 Lube Oil Questionnaire.

New fuels and regulations lead to the necessity to reflect these in the engine manuals. The chapter “Operation Media” has been reviewed and all current recommendations and limits are shown.

The following items might be of particular interest:

- Lubrication oil alkalinity

  Regarding Low Sulphur Fuels we often got questions about the lubrication oil alkalinity. In chapter 5.6.2, page 40 we are giving an overview that is intended to assist in selecting an appropriate base number (BN) depending on the Sulphur content of the fuel.

- Low Sulphur Fuels

  Information about the use of Low Sulphur Fuels is shown in chapter 3.13, page 22.

- Viscosity reference temperature

  We want to mention that we are referring to 100°C in relation to viscosity values only. All viscosity values referring to 40°C can be used as rough guidance only (chapter 5.6.1, page 39).

Latest Gas and Crude oil operation media guideline can be provided from your authorized MaK/CM service providers.

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Operating Media

Diesel and Dual Fuel Engines

Revision history

Version	Chapter	Change	Date
1.2		Internet address	2017-01-12
1.3	1	DF engines with MDO	2017-01-25
1.4	Div.	Several changes in the text and the tables	2017-04-10
1.5	Div.	Adjustment to 2017	2017-09-15
1.6	Div.	Tables adjusted	2019-08-20
1.7	Div.	Urea, table adjusted	2020-01-20

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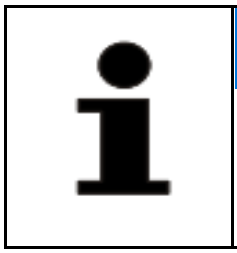
Further information is available on the Internet:

General:	http://www.cat.com
Marine applications:	http://www.cat.com/marine
Mechanical drives:	http://www.cat.com/oilandgas
Power generation:	http://www.catpowerplants.com

1. Introduction



NOTE

Follow the instructions provided below, because readiness for operation and operational reliability of the engine plant essentially depend on the use of proper operating media, their optimal treatment, and monitoring.

The use of appropriate and proper operating media is a prerequisite for readiness for operation and operational reliability of the engine plant.

For this reason the following notes and instructions must be observed.

Warranty

If inappropriate operating media are used or these are maintained improperly, no warranty for trouble-free operation can be assumed.

Product selection

For products not indicated in this document there is no experience available to Caterpillar Motoren GmbH & Co. KG.

Scope

These operating media instructions are applicable to engines according to the current delivery program.

For DF engines special preconditions regarding MDO fuels must be met. Please refer to the specification of the injection fuel module or the specification of the injection fuel interface.

2. Safety Notes

⚠ WARNING

Fire hazard due to combustible operating media!
Improper handling of combustible operating media may cause burns and property damage.

Lubricating oil and fuel vapours may ignite when they come into contact with ignition sources.

- No open fire when working on the fuel system!
- No smoking!
- Fuel and lubricating oil must not come into contact with hot surfaces or ignition sources!

NOTE

Disconnect the power supply before working on the electrical / electronic system and secure the plant against being switched on again without authority.

NOTE

During all work or when handling:

- lubricating oil, hydraulic oil, grease
- fuel (distillate, heavy fuel oil)
- water with corrosion inhibitor, anti-freezing agent
- cleaning agent / solvent
- coolant (CO_2, N_2)
- urea solution

observe the safety instructions/safety data sheets of the product manufacturer!

3. Regulations and Maintenance for Liquid Fuels

For engines, two product groups of liquid fuels are allowed, depending on the equipment status:

- **Distillate fuel**
- **Heavy fuel oil**

Distillate fuel

The fuel should be a high-quality mineral oil product, have good ageing resistance, must not separate due to storage or clog the filters with paraffin exudation and should be free of mineral acids.

There are two different types of distillate fuels:

Pure distillates known as gas oil, marine gas oil, diesel fuel, etc. These are fuels with a relatively low sulphur content and very good ignition characteristics.

Distillates or mixed fuels 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, sulphur content and, in some cases, considerably larger tolerances.

NOTE

Impact on the service life of the catalyst possible!

The SCR system is designed for fuel according to ISO 8217. If this fuel is used, the maximum service life of the catalyst will be achieved. If other fuels are burnt, catalyst poison may lead to a reduced service life of the catalyst material. The same effect may occur when non approved lubricating oils are used.

In order to avoid restrictions in terms of catalyst service life

- do not use fuel that does not correspond to ISO 8217
- only use lubricating oils taking into consideration the permissible percentages of catalyst poison

Caterpillar Motoren does not accept any liability for reduced service life of the catalyst when fuels and lubricating oils are used that are not recommended.

3.1 Customary Specifications for Fuels

Fuel type	Gas oil	Marine diesel oil
ISO 8217 : 2017[1)]	ISO-F-DMA/DFA	ISO-F-DMB/DFB ISO-F-DMZ/DFZ
ASTMD 975:2017	No. 1 D No. 2 D	No. 2 D No. 4 D
DIN EN 590:2017	X	-----
DIN EN 15940:2016	X	-----
Minimum requirement for fuel treatment	Fine filter	Separator, fine filter, preheating to 50 °C

[1)] International specification for marine fuels

3.2 Excerpt from of ISO 8217:2017

Table 1 – Requirements for distillate fuels
Table 2 – Requirements for heavy fuel oil

	NOTE
	The values in this table are either minimum or maximum values for each characteristic. The actual values for different fuel grades may vary within these limits.

This sixth edition reflects important and significant changes. These include substantial amendments to the scope (Clause 1) and to the general requirements (Clause 5).
Changes regarding the distillate fuels include the following:

- Additional grades, DFA,DFZ and DFB have been added with a maximum fatty acid methyl ester(s) (FAME) content of 7.0 volume%.
- The sulphur content of DMA and DMZ has been reduced to a maximum of 1.00 mass%.
- The sulphur content of DMB has been reduced to a maximum of 1.50 mass%.
- Requirements for the following characteristics have been added to winter grades of DMA and DMZ: Cloud point and cold filter point.

Table 1: Distillate fuels for marine use

Characteristics		Unit	Limit	Category ISO-F				Test method
				DMX	DMA/ DFA	DMZ/ DFZ	DMB/ DFB	
Kinematic viscosity at 40 °C		mm^2/s [a]	max.	5.500	6.000	6.000	11.00	ISO 3104
			min.	1.400	2.000	3.000	2.000	
Density at 15 °C		kg/m^3	max.	____	890.0	890.0	900.0	see 6.1 ISO 3675 or ISO 12185
Cetane index		--------	min.	45	40	40	35	ISO 4264
Sulphur [b]		mass%	max.	1.00	1.00	1.00	1.50	see 6.3 ISO8754 ISO 14596
Flash point		°C	min.	43.0	60.0	60.0	60.0	see 6.4 ISO
Hydrogen sulphide		mg/kg	max.	2.00	2.00	2.00	2.00	see 6.5 IP 570
Acid number		mg KOH/g	max.	0.5	0.5	0.5	0.5	see 6.5 ASTM D664
Total sediment by hot filtration		mass%	max.	____	____	____	0.10 [c]	see 6.8 ISO 10307-1
Oxidation stability		g/m³	max.	25	25	25	25 [d]	ISO
Fatty acid methyl ester [e]		volume%	max.	____	--- / 7.0	--- / 7.0	--- / 7.0	see 6.10 ASTM D7963
Carbon residue: micro method on the 10% volume distillation		mass%	max.	0.30	0.30	0.30	____	ISO 10370307-2
Carbon residue: micro method		mass%	max.	____	____	____	0.30	ISO 10370307-2
Cloud point [f]		°C	max.	-16	____	____	____	ISO
Pour point (upper) [f]	winter	°C	max.	____	-6	-6	0	ISO 3016
	summer	°C	max.	____	0	0	6	see 6.11 ISO 3016
Cold filter point [f]		°C	max.	____	____	____	____	see 6.11 ISO 309
Visual check		_____	_____	clear and transparent [g]			c)	see 7.6
Water		volume%	max.	____	____	____	0.30 [c]	ISO
Ash		mass%	max.	0.010	0.010	0.010	0.010	ISO 6245
Lubricity, corrected wear scar diameter (wsd) at 60 °C [h]		µm	max.	520	520	520	520 [d]	ISO 12156-1

a) 1 mm^2/s = 1 cSt.

b) Notwithstanding the limits given, the purchaser shall define the maximum sulphur content in accordance with relevant statutory limitations. See Introduction.

c) If the sample is not clear and bright, total sediment determination by hot filtration and testing for water shall be required. See 6.8 and 6.12.

d) If the sample is not clear and bright, the test cannot be undertaken and therefore, compliance with this limit cannot be shown.

e) See 5.1 and Annex A (ISO 8217).

f) Pour point cannot guarantee operability for all ships in all climates. The purchaser should confirm that the cold flow characteristics (pour point, cloud point, cold filter plugging point) are suitable for the ship's design and intended area of operation. See 6.11.

g) If the sample is coloured and not transparent, then the water limit and test method as indicated in 6.12 shall be applied.

h) This requirement applies to fuels with a sulphur content below 500 mg/kg (0.050 mass %).

Table 2 - Residual oils for marine use

Characteristics	Unit	Limit	Category ISO-F											Test method
			RMA	RMB	RMD	RME	RMG				RMK			
			10	30	80	180	180	380	500	700	380	500	700	
Kinematic viscosity at 50 °C	mm2/s a)	max.	10.0	30.0	80.0	180.0	180.0	380.0	500.0	700.0	380	500.0	700.0	ISO 3104
Density at 15 °C	kg/m3	max.	920.0	960.0	975.0	991.0	991.0				1010.0			see 6.1 ISO 3675 or [illegible]
CCAI	-	max.	850	860	860	860	870				870			see 6.2
Sulphur b)	mass%	max.	Legal requirements											see 6.3 ISO 8754
Flash point	°C	min.	60.0	60.0	60.0	60.0	60.0				60.0	60.0	60.0	see 6.4 IS02719
Hydrogen sulphide	mg/kg	max.	2.00	2.00	2.00	2.00	2.00				2.00			see 6.5 IP 570
Acid number c)	mg KOH/g	max.	2.5	2.5	2.5	2.5	2.5				2.5			see 6.6 ASTM D664
Total sediment after ageing	mass%	max.	0.1	0.1	0.1	0.1	0.1				0.1			see 6.9 ISO 10307-2
Carbon residue: Micro method	mass%	max.	2.5	10.0	14.0	15.0	18.0				20.0			ISO 10370
Pour point (upper) e) winter	°C	max.	0	0	30	30	30				30			ISO 3016
Pour point (upper) e) summer	°C	max.	6	6	30	30	20				30			ISO 3016

Table 2 - Residual oils for marine use

Characteristics	Unit	Limit	Category ISO-F											Test method
			RMA	RMB	RMD	RME	RMG				RMK			
			10	30	80	180	180	380	500	700	380	500	700	
Water	vol-ume%	max.	0.30	0.50	0.50	0.50	0.50				0.50			ISO 3733
Ash	mass%	max.	0.040	0.700	0.700	0.700	0.100				0.150			ISO 6245
Vanadium	mg/kg	max.	50	150	150	150	350				450			see 6.14 IP501, IP470 ISO 14597
Sodium	mg/kg	max.	50	100	100	50	100				100			see 6.15 IP501, IP470
Aluminium plus silicon	mg/kg	max.	25.0	40.0	40.0	50.0	60.0				60			see 6.16 IP501 IP471 ISO 10478
Used lubricating oils (ULO): Calcium and zinc; or calcium and phospho-rus	mg/kg	-	The fuel must be free of ULO. A fuel is to be considered as containing ULO, if calcium > 30 and zinc > 15 or calcium > 30 and phosphorus > 15											(see 6.17) IP501 or IP470 IP500

a) 1 mm2/s = 1 cSt
b) The purchaser shall define the maximum sulphur content in accordance with relevant statutory limitations See Introduction.
c) See Annex E
d) The purchaser should confirm that this pour point is suitable for the ship's intended area of operation.

3.3 ISO-F-DMB / DFB

Fuels according to ISO-F-DMB /DFB have a viscosity limit of 11 (cSt) at 40 °C, which is, however, normally not fully utilized in commercial fuels of the big international fuel suppliers.

Pre-heating of the fuel is not necessary if the viscosity of the bunkered fuel is below 7 mm^2/s (cSt) at 40 °C.

If this value is exceeded and no pre-heating equipment is installed, the next better grade shall be bunkered.

The fuel suppliers recommend to obtain information about the available grades in good time from the places where bunkering is intended.

3.4 Heavy Fuel Oil

Heavy fuel oils are defined as essentially consisting of residual oils derived from the mineral oil refining process.

3.5 General Requirements

The fuel must represent a homogeneous mixture of hydrocarbons derived from mineral oil processing. The fuel must not contain other substances (e.g. mineral acids, alkalis), unless expressly indicated in the specification. Minor quantities of additives to improve specific fuel characteristics are permitted.

Depending on whether the fuel features the highest available viscosity or is a mixture with distillates to obtain the required viscosity, the following designations are still frequently used 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)

Due to numerous activities of various boards such as:

- CIMAC–Conseil International des Machines à Combustion
- ISO–International Organization for Standardization

aimed at establishing internationally applicable limit specifications for marine fuels, particularly for heavy fuel oils, the following designations and terms have been introduced to describe fuel characteristics.

3.6 ISO Specification (ISO 8217)

The ISO Specification for marine fuels took effect in April 1987. A revised edition was published in 2017.

A classification according to quality characteristics and viscosities was introduced.

The classes range from

- ISO-F-RM[1] A[2] 10[3]
  to
- ISO-F-RM K 700

1) RM = Residual Marine
2) Quality classification
3) Max. viscosity at 50 °C (mm^2/s)

3.7 CIMAC Specification

On the basis of the ISO Specification, CIMAC has divided the fuels according to their physical and chemical data which are decisive for reliable engine operation.

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

The CIMAC specification does not fully correspond to the ISO Specifications.

The most important differences are the following:

- CIMAC provides for lower density limits for grades A10 - D80.
- Introduction of minimum viscosities with CIMAC.

The CIMAC Specification is the basis for the "Heavy Fuel Oil Specification"

<table>
<tr><th>Characteristics[a]</th><th>Unit</th><th>Limit</th><th>CIMAC A 30</th><th>CIMAC B 30</th><th>CIMAC D 80</th><th>CIMAC E 180</th><th>CIMAC F 180</th><th>CIMAC G 380</th><th>CIMAC H 380</th><th>CIMAC K 380</th><th>CIMAC H 700</th><th>CIMAC K 700</th><th>Test method reference</th></tr>
<tr><td>Density at 15 °C</td><td>kg/m³</td><td>max.</td><td>960.0</td><td>975.0</td><td>980.0</td><td colspan="2">991.0</td><td colspan="2">991.0</td><td>1010.0</td><td>991.0</td><td>1010.0</td><td>ISO 3675 or ISO 12185 (see also 6.1)</td></tr>
<tr><td rowspan="2">Kinematic viscosity at 50 °C</td><td rowspan="2">mm²/s[b]</td><td>max.</td><td colspan="2">30.0</td><td>80.0</td><td colspan="2">180.0</td><td colspan="3">380.0</td><td colspan="2">700.0</td><td>ISO 3104</td></tr>
<tr><td>min.[c]</td><td>22</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>ISO 3104</td></tr>
<tr><td>Flash point,</td><td>°C</td><td>min.</td><td colspan="10">60</td><td>ISO 2719 (see also 6.2)</td></tr>
<tr><td>Pour point (upper) - winter quality</td><td>°C</td><td>max.</td><td>0</td><td>24</td><td>30</td><td colspan="2">30</td><td colspan="3">30</td><td colspan="2">30</td><td>ISO 3016</td></tr>
<tr><td>Pour point (upper) - summer quality</td><td>°C</td><td>max.</td><td>6.0</td><td>24.0</td><td>30.0</td><td colspan="2">30</td><td colspan="3">30</td><td colspan="2">30</td><td>ISO 3016</td></tr>
<tr><td>Carbon residue</td><td>% (m/m)</td><td>max.</td><td colspan="2">10</td><td>14</td><td>15</td><td>20</td><td>18</td><td colspan="2">22</td><td colspan="2">22</td><td>ISO 10370</td></tr>
<tr><td>Ash</td><td>% (m/m)</td><td>max.</td><td colspan="2">0.10</td><td>0.10</td><td>0.10</td><td>0.15</td><td colspan="3">0.15</td><td colspan="2">0.15</td><td>ISO 6245</td></tr>
<tr><td>Water</td><td>% (V/V)</td><td>max.</td><td colspan="2">0.5</td><td>0.5</td><td colspan="2">0.5</td><td colspan="3">0.5</td><td colspan="2">0.5</td><td>ISO 3733</td></tr>
<tr><td>Sulphur[d]</td><td>% (m/m)</td><td>max.</td><td colspan="2">3.50</td><td>4.00</td><td colspan="2">4.50</td><td colspan="3">4.50</td><td colspan="2">4.50</td><td>ISO 14596 or ISO 8754 (see also 6.1)</td></tr>
<tr><td>Vanadium</td><td>mg/kg</td><td>max.</td><td colspan="2">150</td><td>350</td><td>200</td><td>500</td><td>300</td><td colspan="2">600</td><td colspan="2">600</td><td>ISO 14597 or IP 501 (see also 6.8)</td></tr>
<tr><td>Total sediment potential</td><td>% (m/m)</td><td>max.</td><td colspan="2">0.10</td><td>0.10</td><td colspan="2">0.10</td><td colspan="3">0.10</td><td colspan="2">0.10</td><td>ISO 10307-2 (see also 6.6)</td></tr>
<tr><td>Aluminium plus sili-</td><td>mg/kg</td><td>max.</td><td colspan="2">80</td><td>80</td><td colspan="2">80</td><td colspan="3">80</td><td colspan="2">80</td><td>ISO 10478</td></tr>
<tr><td colspan="3">Used lubricating oil (ULO)</td><td colspan="10">The fuel shall be free of ULO. A fuel shall be considered to be free of ULO if one or more of the elements zinc, phosphorus and calcium are below or at the specified limits. All three elements must exceed the same limits before a fuel shall be deemed to contain ULO</td><td></td></tr>
<tr><td>Zinc</td><td>mg/kg</td><td>-</td><td colspan="10">15</td><td>IP 501 or IP 470 (see also 6.7)</td></tr>
<tr><td>Phosphorus</td><td>mg/kg</td><td>-</td><td colspan="10">15</td><td>IP 501 or IP 500</td></tr>
<tr><td>Calcium</td><td>mg/kg</td><td>-</td><td colspan="10">30</td><td>IP 501 or IP 470</td></tr>
</table>

a) See General Recommendations paragraph 3 for additional characteristics not included in this table
b) 1 mm2/s = 1 cSt
c) Fuels with density close to the maximum, but with very low viscosity, may exhibit poor ignition quality. See Annex 6.
d) A sulphur limit of 1.5 % m/m will apply in SOx Emission Control Areas designated by the IMO, when its relevant Protocol comes into force. There may be local variations.
e) See Annex 2 and 3 of CIMAC Recommendations pages 21-22.

3.8 CCAI Limit Curves (M20, M25, M32, M43)

Although generally considered a necessity, an evaluation parameter for the ignition quality has not been specified to date due to a lack of suitable test methods.

The so-called CCAI (CCAI = calculated carbon aromaticity index) is a suitable indicator for assessing the ignition behaviour.

The CCAI is determined from density D (kg/m^3 at 15 °C) of temperature T in degrees °C, at which kinematic viscosity is determined, and viscosity V (mm^2/s or cSt at 50 °C) according to the following equation:

$$\mathbf{CCAI = D - 81 - 141 \log (\log (V + 0.85)) - 483 \log ((T + 273) / 323)}$$

As a basic rule, the following applies: The higher the CCAI, the poorer the ignition quality to be expected.

Furthermore, the following applies: Based on a given CCAI value, there is a higher risk of poorer ignition behaviour at low viscosities.

Since the CCAI is not a measure for the ignition behaviour, but rather an assessment aid, absolute limit values cannot be specified.

The specifications make allowance for these factors:

A lower as well as an upper CCAI limit curve is defined depending on viscosity, type of engine, and equipment status and shown in the "CCAI Limit Curves" chart. The three sub-ranges obtained in this manner have the following meaning:

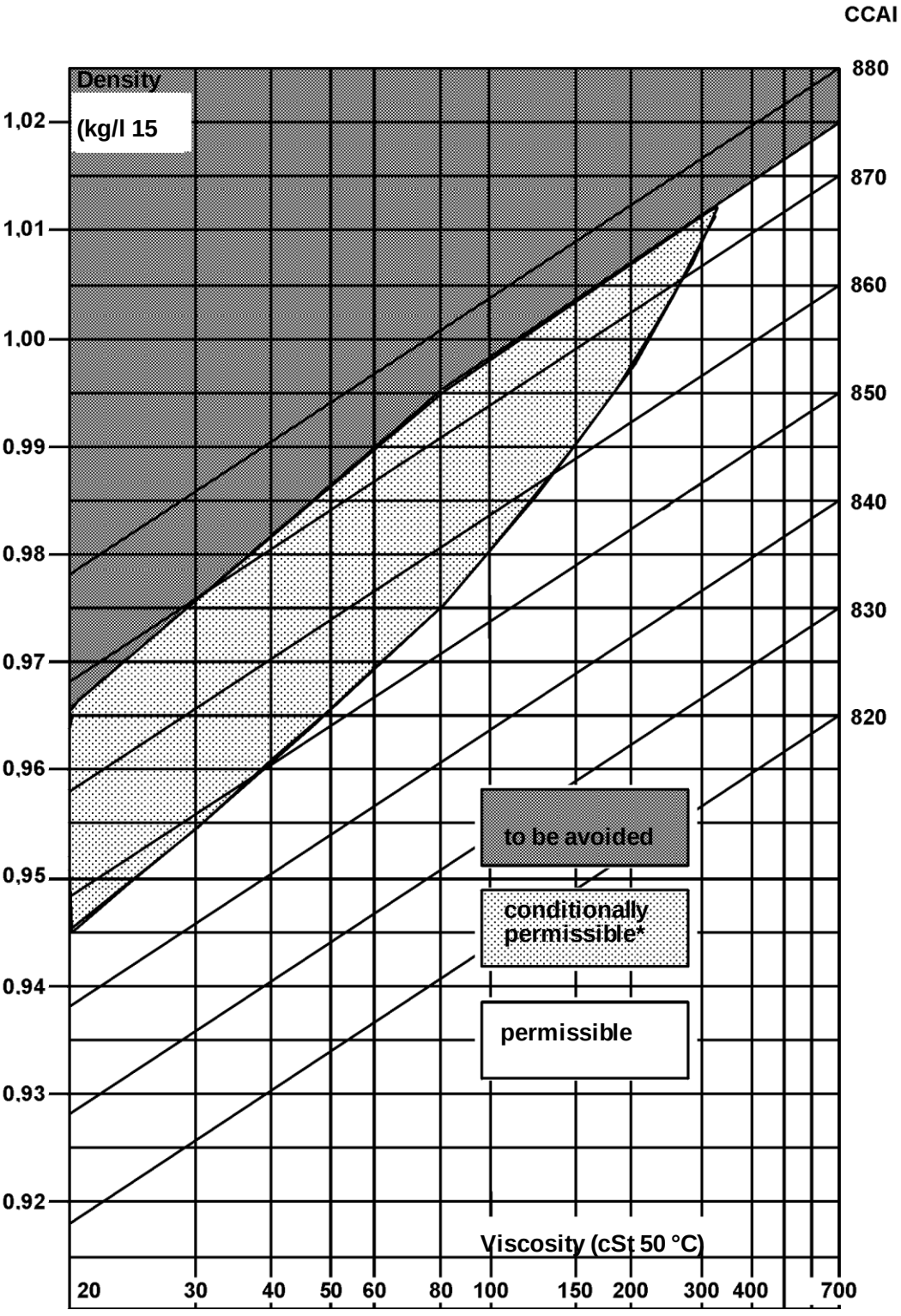
	Range permissible without restrictions. Impairments by insufficient ignition characteristics are not to be expected.
	Ignition characteristics are mostly acceptable. Problematic fuels can, however, not be excluded.
	Range which should be avoided. Impairments and even damage to the engine must be expected.

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

The heavy fuel oil grades permitted for engines can be found in the table "Admissible Limit Specifications for Operation with Heavy Fuel Oil in Engines".

It has to be taken into account, however, that there may be restrictions with regard to the permissible densities according to the valid CCAI limit curves.

CCAI limit curves



3.9 Note Regarding the Limit Specification:

The equipment status of the engine and the fuel treatment system are of key importance for determining the heavy fuel oil grade permissible for the respective plant.

The actual values should, if possible, be significantly lower than all limits indicated in the heavy fuel oil specification.

ISO specification 8217 includes the following note:

"The fuels shall be free from used lubricating oils."

Furthermore, ISO 8217 defines the simultaneous exceeding of the limits for calcium, zinc, and phosphorus as evidence of used lubricating oil in the fuel.

Caterpillar Motoren GmbH & Co. KG has to point out that already individual upper instances of exceeding or even approximations to the limits of the elements calcium and/or zinc may lead to the formation of deposits on the injection pump elements and thus cause jamming pumps.

For this reason it is by no means allowable to add to the fuel any used lubricating oil.

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

The ash content influences mechanical wear. Therefore, preference should be given to heavy fuel oil with a low ash content.

The technical development in the processing of crude oil has led to a noticeable increase in the proportion of fuels from modern refining processes (catalyst cracking, visbreaking) that create even bigger problems for mixing than the established heavy fuel oils. Therefore, only ready mixed fuels should be bunkered.

If the above problems should occur during operation, at least a subsequent examination of the current bunker samples according to CIMAC standard is recommended.

NOTE

Heavy fuel oils (so-called residual fuel oils) from catalyst cracking sometimes contain cat fines that may cause severe engine wear, particularly on the injection elements.
See limits for aluminium and silicon content.
The flash point of the heavy fuel oil must be above 60 °C in accordance with the requirements of the classification societies.
During the entire bunkering process a sample of the heavy fuel oil should be taken in any case (drip sampling method). Analyses can be carried out by the fuel supplier or Caterpillar Motoren GmbH & Co. KG against reimbursement of the costs incurred.
Heavy fuel oil operation requires the use of a medium alkaline lubricating oil according to our Lubricating Oil Brand Recommendation.

3.10 Admissible Limit Specifications for Operation with Heavy Fuel Oil in Engines

	Engine series			
Limit specification	**M 20**	**M 25**	**M 32**	**M 43**
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)

X permissible

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

NOTE

Observe CCAI limit curves!

3.11 Heavy Fuel Oil Specification (Legacy Engines)

	Engine series						
Limit specification	**M601 M601 C**	**M552 M552 C**	**M551**	**M453 M453 C**	**M452**	**M332C**	**M332 M282**
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 permissible

(x) permissible in connection with suitable treatment system only (increased density limit) O upon consultation with Caterpillar Motoren GmbH & Co. KG

* not approved e.g. for "one-fuel ships", special measures are required

NOTE

Observe CCAI limit curves!

3.12 Fuel Additives

Three types of fuel additives, classified here according to their main effects, are used in various cases of need.

However, the benefits of such fuel additives must be assessed on a case by case basis. The results of such an assessment may vary, depending on the application. Therefore, no binding statement regarding effectiveness of certain fuel additives can be made in this document.

Also, no responsibility can be assumed here with regard to possible consequential damage resulting from the use of such additives.

a) Demulsifying additives (emulsion breakers)

These additives, added when bunkering, can prevent sludge-like agglomerations and break up stable water-heavy fuel oil emulsions in heated settling tanks, which cannot be separated in a simple separating process (observe the mixing proportions of the suppliers).

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

b) Additives against high-temperature corrosion

High-temperature corrosion may occur on exhaust valves and turbine blades when burning heavy fuel oil that contains vanadium and sodium.

Caterpillar Motoren GmbH & Co. KG does not require the use of additives against high-temperature corrosion. If such additives are used nevertheless, it must at least be ensured that they are not sensitive to water, compatible with the fuel in any circumstance and do not cause any malfunction in components such as the fuel filters.

c) Homogenizing additives (asphaltene dispersants)

In case of a high asphaltene content (> 5%) of the fuel the use of asphaltene dispersants is recommended (drop test, CCR value >10%). A high asphaltene content manifests itself by an increased formation of sludge in the bunker tanks and separators, reduced service life of filters, coking of the spring chambers of injection pumps, sticking pump plungers, and sluggish control sleeves.

3.13 Use of Low-Sulphur Fuels

International statutory provisions (such as MARPOL Annex 6) and national provisions for special areas (such as California Coastal Waters - CARB) require low-sulphur fuel.

For the operator, this means that a changeover from normal heavy fuel oil to low-sulphur heavy fuel oil or (low-sulphur) distillate fuel has to take place. Both changeover operations may lead to problems that will affect engine operation.

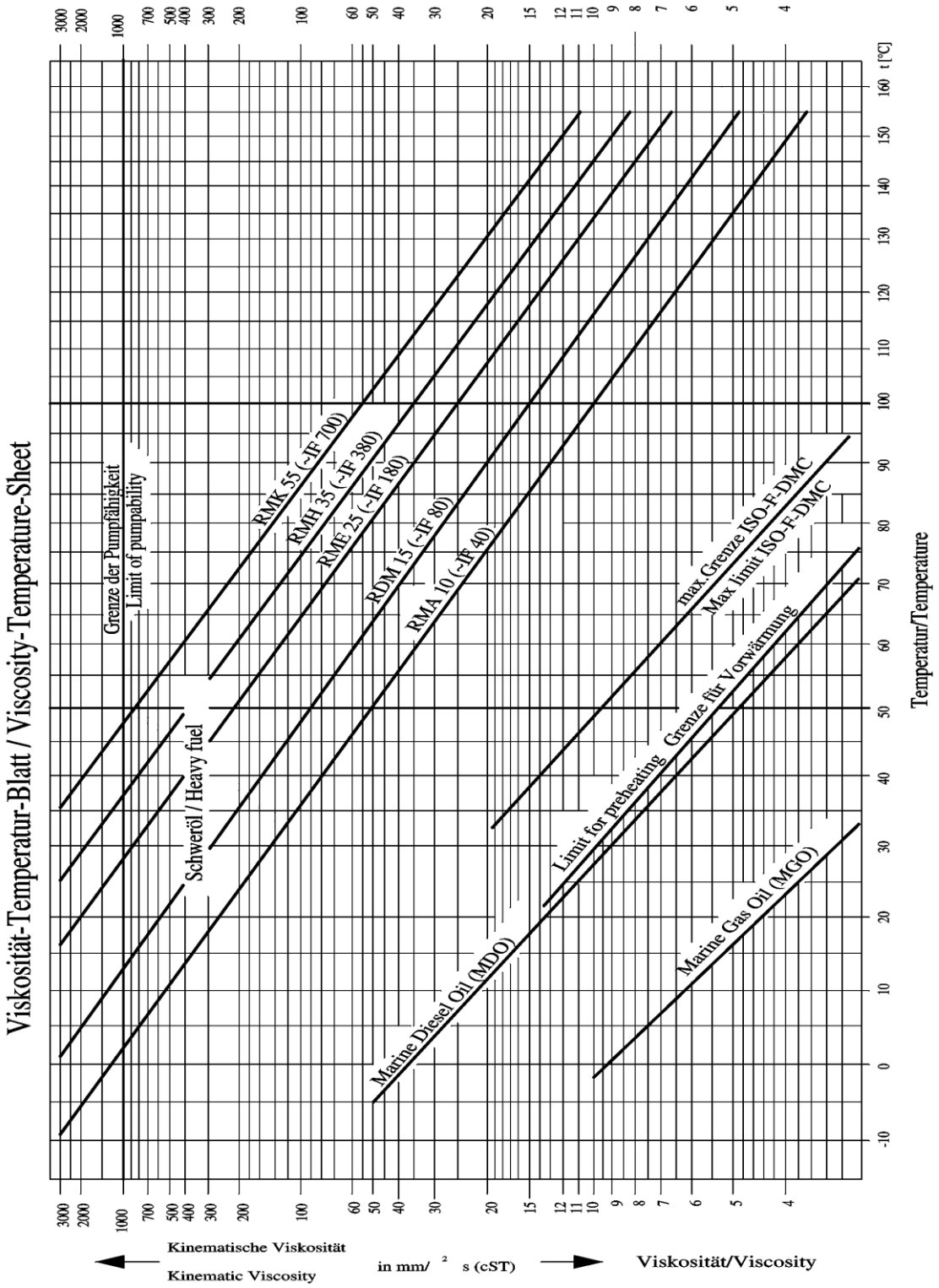
Low-sulphur and normal fuels differ from each other not only in their sulphur content but also in other characteristics such as viscosity and density.

Low sulphur heavy fuel oil is produced by bunker suppliers e.g. by adding low-sulphur diesel fuel. Mixing of these fuel grades may lead to incompatibilities resulting in the precipitation of asphaltenes. This may create the following problems within the entire fuel system:

- Increased formation of sludge in the bunker tanks
- Reduced heating performance of the preheaters due to formation of deposits
- Reduced service life of separators
- Reduced service life of filters or very frequent backflushing of automatic filters
- Formation of deposits in pump elements with decreased clearance that may even lead to sticking of the pump plungers

Furthermore, the instructions regarding the changeover procedure as detailed above (see Operating Instructions "Changing the Type of Fuel") are to be observed.

3.14 Viscosity/Temperature Sheet



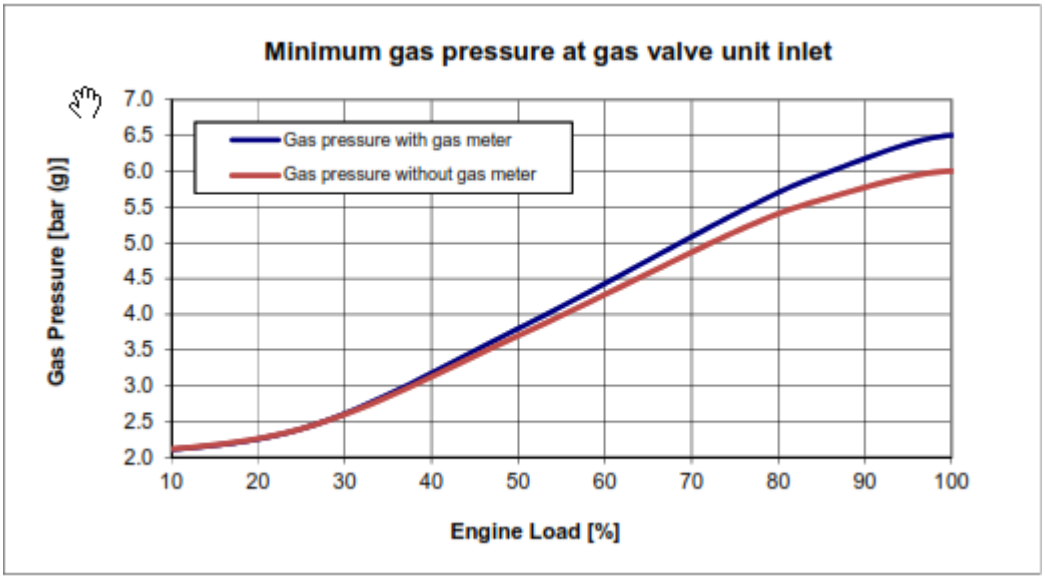
3.15 Gaseous Fuels

Contrary to liquid fuels, there are no established standards for gaseous fuels determining composition, components, ingredients, and contamination of combustion gases. For this reason, combustion gases for DF engines must meet the internal standard VD 9025.

VD 9025
Gas Specification for DF Engines

Gas temperature upstream of engine inlet	°C	0 - 60
Gas pressure upstream of gas valve unit without gas	bar(g)	6 - 9
Gas pressure upstream of gas valve unit with gas flow	bar(g)	6.5 - 9
Maximum permissible gas pressure fluctuation	mbar/s	+/-80
Minimum lower heat value	MJ/m³	28
CAT methane number (for rated power)	MN	80 [1)]
Maximum sulphur content as H2S	mg/m³	20
Maximum ammonia content (NH3)	mg/m³	25
Maximum fluorine content	mg/m³	Σ= 50
Maximum chloride content	mg/m³	
Maximum oil content	mg/m³	50
Maximum particle content	mg/m³	50
Maximum particle size	µm	5
Maximum tar content	mg/m³	10
Maximum silicon content	mg/m³	10
Maximum water content	Water vapour saturated gas or water and condensates at gas pressure control unit are not allowed.	

[1)] At low methane numbers, the maximum power output of the engine will be reduced. Contact Caterpillar for further information.



VD8836
Inert Gas Specification for DF engines

Gas temperature upstream of engine in-	°C	0 - 60
Minimum inert gas pressure	bar(g)	8
Maximum inert gas pressure	bar(g)	10
Allowed gases	- -	Nitrogen >= 95% Carbon dioxide 2.5
Maximum sulphur content as H2S	%	0.05 (= 770 mg/mn³)
Maximum ammonia content	mg/m³	25
Maximum fluorine content	mg/m³	Σ=50
Maximum chloride content	mg/m³	
Maximum oil content	mg/m³	50
Maximum particle content	mg/m³	50
Maximum particle size	µm	5
Maximum dew point	°C	-20

3.16 Ignition Oil

Characteristic	ISO test category	Test
Fuel type	DMA/DFA & DMZ/DFZ	ISO 8217:2017*
Max. particle contamination	25/20/20**	ISO 4406

* The use of other fuels requires the prior agreement of Caterpillar

** If the indicated limit value is exceeded, a significant reduction in service life of the components in the ignition oil system
has to be expected.

4. NOx Reducing Agent - Diesel Exhaust Fluid (DEF) / Aqueous Urea Solution (AUS)

4.1 General

Diesel Exhaust Fluid (DEF) is a liquid that is injected into the exhaust system of engines equipped with systems for selective catalytic reduction (SCR). SCR is used to reduce the emissions of nitrogen oxides (NOx) in the exhaust gas of diesel engines.

There are many varieties of Diesel Exhaust Fluid (DEF) available on the market, including brands with AdBlue or API certification. DEF is also generally referred to as urea.
On engines equipped with SCR emission reduction systema, controlled amounts of DEF are injected into the exhaust gas flow. At the high exhaust gas temperature, the urea in the DEF is converted into ammonia.

In the presence of the SCR catalyst, ammonia chemically reacts with the NOx in the diesel exhaust gas. As a result of this reaction, NOx is converted into harmless nitrogen gas (N2) and water vapour (H2O).

Note: Observe all relevant industrial standards as well as government, environmental and safety guidelines, practices, regulations and directives.
Note: These general recommendations and guidelines regarding the servicing and maintenance of the DEF and DEF storage systems are not meant to be all-inclusive. Consult your DEF supplier to determine the appropriate safety, health, handling and maintenance practices for DEF. The application of these general recommendations and guidelines does not diminish the responsibility of the engine owner and/or DEF supplier to observe all industry standard practices for storage and handling of DEF.

The DEF solution is typically colourless and clear. Changes in colour or clarity are indicators of quality problems.

If DEF is stored and/or handled improperly or not protected from contamination, its quality may be affected. For details, see below.

In case of suspected quality issues, focus on testing urea content, alkalinity as NH3 and biuret content of the DEF. DEF that does not pass all of these tests or is not clear any more, should not be used any more.

4.2 Specification

For being used in Cat engines, DEF must meet all the requirements specified in ISO 22241-1.

Characteristics of Urea Solutions			
Characteristic	**Unit**	**DEF 32.5 percent**	**Urea solution 40%**
Urea content		32.5 percent (1)	40 percent (2)
Alkalinity as NH3	Percent	0.2	0.2
Density at 20 °C (68 °F)	g/l	1.087-1.093 (3)	1.108-1.114 (4)
Refractive index at 25 °C (77 °F)		1.381-1.384 (5)	1.394-1.397 (6)
Biuret	Percent	0.3 max	
Aldehydes	mg/kg	5 max	
Insoluble components	mg/kg	20 max	
Aluminium	mg/kg	0.5 max	
Calcium	mg/kg	0.5 max	
Chrome	mg/kg	0.2 max	
Copper	mg/kg	0.2 max	
Iron	mg/kg	0.5 max	
Magnesium	mg/kg	0.5 max	
Nickel	mg/kg	0.2 max	
Phosphate (PO4)	mg/kg	0.5 max	
Potassium	mg/kg	0.5 max	
Sodium	mg/kg	0.5 max	
Zinc	mg/kg	0.2 max	

(1) The permissible range is 31.8 to 33.2 percent
(2) The permissible range is 39 to 41 percent
(3) The desired value is 1.090 g/l
(4) The desired value is 1.112
(5) The desired value is 1.382
(6) The desired value is 1.3956

5. Regulations and Maintenance - Lubricating Oil

The quality of the engine oil has a significant influence on the service life and performance and thus the overall economic efficiency of the engine.

High demands in terms of suitability must, therefore, be made on the lubricants to be used.

The lubricating oil is to be selected depending on the specification of the fuel used to run the engine.

When the engine is operating on heavy fuel oil, the effect of the increased amounts of coke-type and acid deposits which form during combustion due to higher ash and sulphur content must be rendered harmless. For this reason, only lubricating oils are approved which have been specifically developed for heavy fuel oil operation of medium-speed trunk piston diesel engines.

On engines which are equipped with special cylinder liner fresh oil lubrication, the same oil brand is to be used in the circulation system and for liner lubrication.

It is recommended to the check the lubricating oil every 500 operating hours to verify the quality and ensure trouble-free operation of the engine.

	NOTE
	When using fuel with a very low sulphur content, liner lacquering may occur. If this phenomenon occurs in combination with high lubricating oil consumption, special oils should be used after consultation with Caterpillar Motoren GmbH & Co. KG.

5.1 Base Oil

The base oil must be a high-quality solvent refined product from a source suitable for engine lubricating oil and have a good ageing stability as well as a good pressure absorption capability and thermo-stability.

	NOTE
	Regenerated oils are not permitted!

5.2 Additives

The additives contained in the lubricating oil must remain effective and uniformly distributed at all temperatures occurring under normal operation between pour point and 220 °C as well as in storage and also meet the following requirements in engines:

- Have good detergent and dispersant properties (which for heavy fuel oil operation must at least meet the API-CF level) to prevent the depositing of combustion products (coke and asphalt-like compounds) or dissolve and keep them in suspension.
- Have sufficient alkalinity in order to be able to neutralize the sulphur acid compounds generated during the combustion process. This is usually referred to as the Base Number (BN), or as Alkalinity Value (AV) and indicated in mg KOH/g. For engines operating on heavy fuel oil, this value should range between 30 and 40 mg KOH/g for fresh oils, for MDO (depending on the sulphur content) between 12 and 20 mg KOH/g.

5.3 Lubricating Oil Maintenance

The service life of lubricating oil can be extended by means 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.

5.3.1 Lubricating Oil Cleaning (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 Oil Operation.

Prerequisite for good cleaning of the lubricating oil is a low viscosity which requires a correspondingly high temperature. During separation, the temperature should be at least 95 °C.

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

5.3.2 Lubricating Oil Filtration (Main Stream)

In order to cope with the increased amount of contaminants in the lubricating oil during heavy fuel oil operation, an "automatic backflushing filter" must be installed at the engine. If this filter is installed in the external lubricating oil system, an indicator filter designed as duplex filter is additionally required at the engine.

For gas oil or MDO operation, duplex filters that can be changed over manually are sufficient.

- Filter mesh sizes: Automatic filter: 34 µm
  Duplex filter: 80 µm
  Safety filter (if existing): 200 µm

5.4 Lubricating Oil Brand Recommendations – Limitation of Warranty

In most cases, the company 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 Motoren GmbH & Co. KG does not have sufficient experience with the lubricating oil brands listed in column II. Therefore, if such oil brands are intended to be used, prior consultation with the engine builder is required because otherwise the warranty shall lapse.

Caterpillar Motoren GmbH & Co. KG does not have any experience with oils not mentioned in this document. As a basic rule, Caterpillar Motoren GmbH & Co. KG cannot assume any warranty for the lubricating oil used because, for example, recipe and production cannot be controlled by Caterpillar Motoren GmbH & Co. KG. Furthermore, no warranty can be assumed in case of improper engine and lubricating oil maintenance nor if non-approved fuels are used. Proof that a damage is not attributable to the lubricating oil must be provided by the user.

	**NOTE** Viscosity class SAE 40 is required for all engines.

5.4.1 Dual Fuel Operation

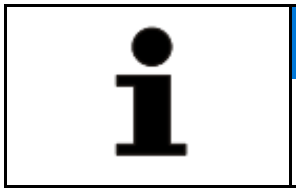
For the engine types M 46 DF and M 34 DF the following lubricating oil brands should be chosen depending on the kind of liquid fuels:

When using distillate fuels, the lubricating oils for distillate operation are to be used.

If heavy fuel oil is used as liquid fuel component, the lubricating oils for heavy fuel oil operation are to be used.

In case of longer operation with heavy fuel oil instead of gas, care should be taken to maintain a sufficiently high base number (at least TBN 18). If the oil is otherwise in a good condition, the base number can be increased by changing part of the oil.

5.4.2 List of Lubricating Oil Brands for Operation with Distillate Fuel



NOTE

Viscosity class SAE 40 is required for all engines.

Producer	Brand	I	II
AGIP	DIESEL SIGMA S		X
	CLADIUM 120		X
BP	ENERGOL HPDX	X	
	40 VANELLUS C3		X
CATERPILLAR	DEO™	X	
CHEVRON, CALTEX, TEXACO	DELO 1000 MARINE 40	X	
	DELO SHP 40	X	
	TARO 20 DP 40	X	
	TARO 20 DP 40X	X	
CASTROL	MARINE MLC	X	
	MHP 154	X	
	TLX PLUS 204	X	
	TLX Xtra 204		X
	HLX 40	X	
CEPSA	KORAL 1540		X
EXXONMOBIL	MOBILGARD 412	X	
	MOBILGARD ADL	X	
	MOBILGARD M430 [1)]	X	
	MOBILGARD 1-SHC [2)]		X
	DELVAC 1640	X	
	MOBILGARD M420		X

Producer	Brand	I	II
SHELL	GADINA S3 40 GADINIA AL ARGINA S2 40 ARGINA S3 [1)]	X X X X	
SINOPEC	TPEO4020 TPEO4012	X X	
TOTAL LUBMARINE	DISOLA M 4015 AURELIA TI 4030 [1)] CAPRANO M40	X X X	
LUKOIL	NAVIGO 12/40 NAVIGO 15/40	X X	
KPC	Q8 Mozart KV	X	

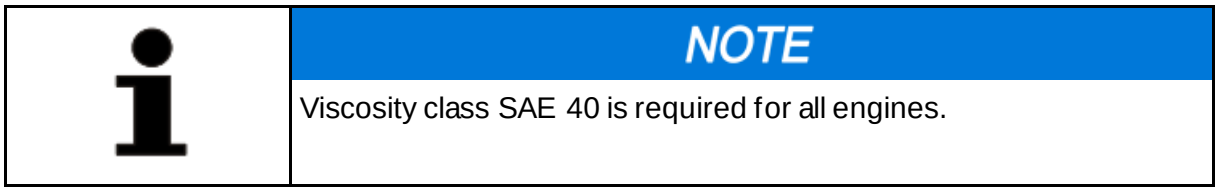
I Proven in use

II Permitted for controlled use. Prior to using these lubricating oils, Caterpillar Motoren GmbH & Co. KG must be informed because at the moment there is insufficient experience available regarding their use in engines. Otherwise the warranty shall lapse.

1) See also List of Lubricating Oil Brands for Heavy Fuel Oil 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

5.4.3 List of Lubricating Oil Brands for Heavy Fuel Oil Operation



NOTE

Viscosity class SAE 40 is required for all engines.

Producer	Brand	I	II
AGIP	CLADIUM 300 S	X	
	CLADIUM 400 S	X	
CHEVRON, CALTEX, TEXACO	TARO 30 DP 40	X	
	TARO 30 DP 40X		X
	TARO 40 XL 40	X	
	TARO 40 XL 40X	X	
	TARO 50 XL 40		X
	TARO 50 XL 40X		X
CASTROL	TLX Xtra 204		X
	TLX Xtra 304		X
	TLX Xtra 404		X
	TLX Xtra 504		X
	TLX Xtra 554		X
	TLX PLUS 304	X	
	TLX PLUS 404	X	
EXXONMOBIL	MOBILGARD M430	X	
	MOBILGARD M440	X	
	MOBILGARD M50	X	
	MOBILGARD M420		X
SINOPEC	TPEO4030	X	
	TPEO4040	X	
SHELL	ARGINA S3 40 ARGINA	X	
	S4 40	X	
	ARGINA S4X 40		X
	ARGINA S5 40		X

Producer	Brand	I	II
TOTAL LUBMARINE	AURELIA TI 4030 AURELIA TI 4040	X X	
GULF	SEA POWER 4030 SEA POWER 4040	X X	
LUKOIL	NAVIGO TPEO 40/40 NAVIGO TPEO 30/40	X X	
KPC	Q8 Mozart TM 30 Q8 Mozart TM 40	X X	

I Proven in use

II Permitted for controlled use. Prior to using these lubricating oils, inform Caterpillar Motoren GmbH & Co. KG because at the moment there is insufficient experience available regarding their use in engines. Otherwise the warranty shall lapse.

5.4.4 Special Lubricating Oil Approvals for Operation with MDO / MGO / HFO

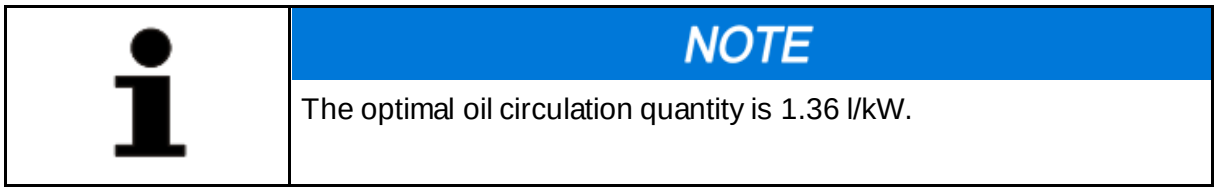
If local engine oils are to be used instead of the engine oils recommended in section "Lubricating Oil Brand Recommendations", the following brands can be used for the engines indicated:

Producer	Brand	Approval accord-	Region	Letter of	Fuel type	Engine type
Aegean	Alfamar 430 Alfamar 440	(2)	Greece	LG	HFO	M35 – M601
Bharat Oil	MaK Marine X 404 (TBN 40)	(2)	India		HFO	M35 – M601 M20 – M43
BP	Vanellus Multigrad 15W40	(1)	(D) (15W-40)		Locomotive applications only	12M282 Locomotive engine
Castrol	TPL 204	(1)	(Russia) (08.00)		MGO/MDO	M35 – M601 M20 – M43
DEA	Cronos Super	(1)	D			M35 – M601 M20 – M43
FUCHS	TITAN UNIC 1040 MC	(1)	(D) (10W-40) (09.04.97)		Locomotive applications only	12M282 Locomotive engine
Petro China	KunLun DCB4030H	(1)	China		HFO	M20 – M43
Petromin (Infineum)	Petropower 1-40	?	Saudi Arabia		MGO/MDO	M35 – M601 M20 – M43
Petromin (Lubrizol)	Petroshield 1-40	(2)	Saudi Arabia		MDO/MGO	M35 – M601 M20 – M43
Pertamina	Medripal 411	(2)	Indonesia	LG	MDO/ MGO	M35 – M601
(Lubrizol)	Medripal 412	(2)		LG	MDO/MGO	M20 – M43
	Medripal 430	(2)		LG	HFO	
	Medripal 440	(2)		LG	HFO	
(Infineum)	Salyx 412	(1)			MDO/ MGO	
	Salyx 415	(1)			MDO/MGO	
	Salyx 420	(1)			MDO/MGO	
Petron Corp.	Petromar XC 4040	(2)	Philippines		HFO	M35 – M601 M20 – M43
Statoil	Dieselway 40	(2)	N		MGO	M35 – M601
	Marway 1040	(2)			MGO	M20 – M43
Valvoline	Valmarin TP 1240	(1)	NL (D) (02/95)		MGO/MDO	M35 – M601 M20 – M43
ZAO Zavod Imeni Shaumyana	M14-D2CE	(1)	Russia		MDO	M20-M43

LG = Letter of Guarantee available.

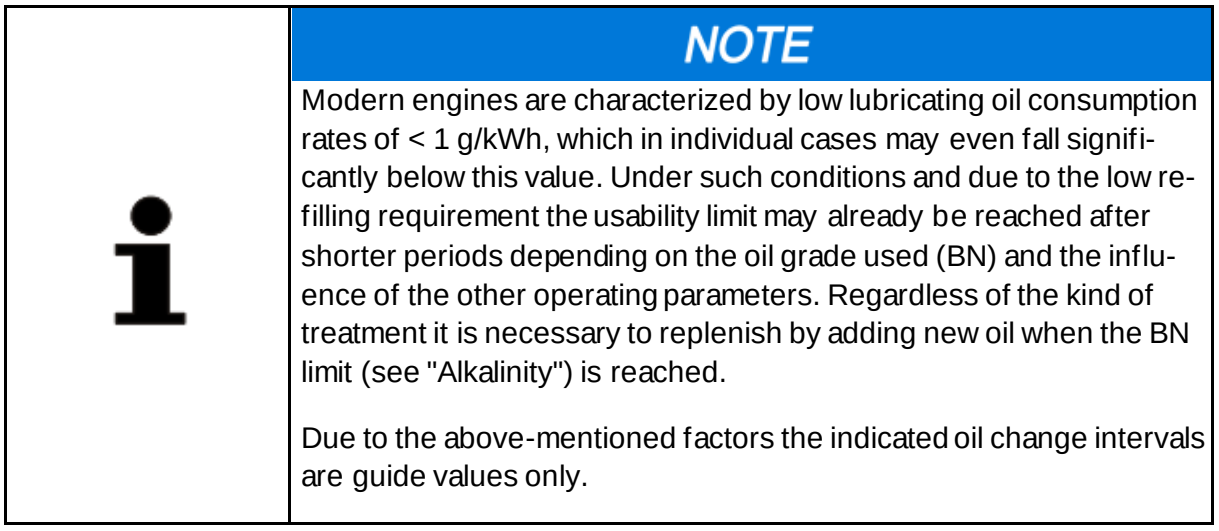
5.5 Lubricating Oil Change

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 and engine maintenance.



If in special exceptions low circulation amounts down to a minimum of 0.3 l/kW cannot be avoided, shorter oil change intervals are necessary. In such cases, the oil change times indicated below must be multiplied by the quotient of the actual quantity to the normally required quantity. However, an oil change must take place latest every 6 months.

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 have been used.



It is, therefore, necessary to check the lubricating oil continuously by means of regular oil analyses. These analyses will be carried out by the lubricating oil service of the lubricating oil supplier or Caterpillar Motoren GmbH & Co. KG against reimbursement of the costs incurred. The oil for such an analysis must be taken from the oil circuit upstream of the 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 equipped with:

- Pre- and main filter every 1,500 h*****
- Additional by-pass filter or oil centrifuge every 3,500 h*****
- Separator every 7,500 h*****

***** valid for engines with oil consumption ≥ 1 g/kWh
and a sulphur content of ≤ 1.5% for distillate or ≤ 3% for HFO

5.6 Limits

	NOTE
	When reaching the limits, change at least 25% of the oil filling! If the limits are still not complied with as per specification, notify your authorized dealer.

5.6.1 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 not below 12.5 mm^2/s (cSt) at 100 °C, viscosity increase not above 17.6 mm^2/s (cSt) at 100 °C, vanadium content not higher than 150 ppm, asphaltene content not higher than 1%.

Category	Limit
Flash point	180 °C
Viscosity min (100 °C)	12.5 mm^2/s (cSt)
Viscosity max (100 °C)	17.6 mm^2/s (cSt)
Vanadium	150 ppm
Asphaltene content	<1%wt

Note: The maximum and minimum viscosity values at 40 °C may only be used as indicators for marine use.

The minimum viscosity at 40 °C is 120 mm^2/s (cSt).
The maximum viscosity at 40 °C is 200 mm^2/s (cSt).

5.6.2 Alkalinity

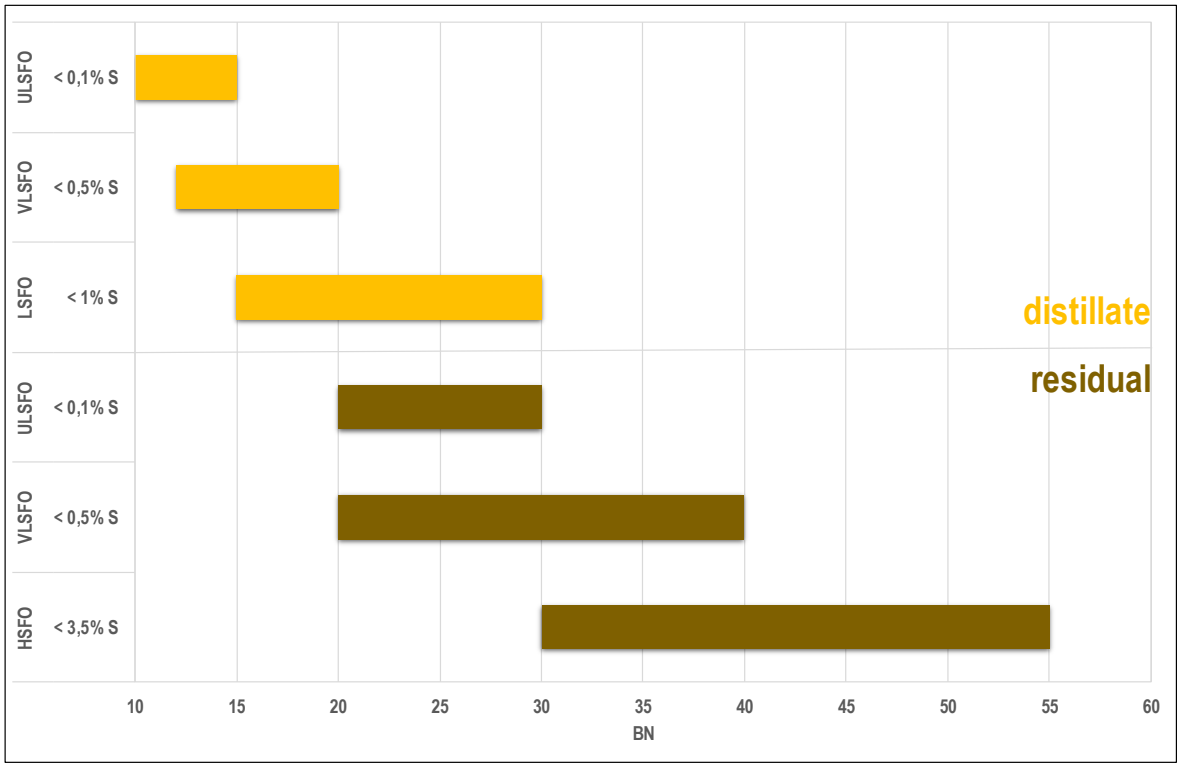
If the engine is running on heavy fuel oil, the base number of circulating oil the must not fall below a value of 18 mg KOH/g For engines with cylinder lubrication, the limit value is 15 mg KOH/g.

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

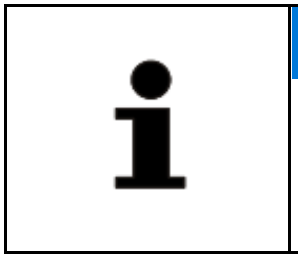
If only the base number has reached the lower limit and the other analysis values show a satisfactory oil condition, the alkalinity should be increased by adding new oil.

Engine type	Limit
HFO engines without cylinder lubrication	18 mg KOH/g
HFO engines with cylinder lubrication	15 mg KOH/g
MDO engines	50% of the value of new oil

The following overview is intended to assist in selecting an appropriate base number (BN) depending on the sulphur content of the fuel.



5.6.3 Water Content



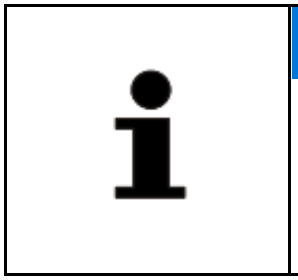
NOTE

If the water content rises beyond 0.1%, identify the cause of the high water content, check the settings of the separator and decrease the water content below 0.1% again. If the water content rises beyond 0.2% shut down the engine immediately.

5.6.4 Contamination

When engines are running on heavy fuel oil, separators are required to keep the oil clean. This way the content of solid foreign particles (asphaltenes and soot) can be kept well below 1% by weight. When this value is exceeded, check the treatment system and carry out a partial oil change.

If a value of 2% by weight is exceeded, we advise against continuing to operate the engine. Check the treatment system and carry out a partial oil change to obtain values within the limit range.



NOTE

In case of a contamination of 1% by weight, check the treatment system and change 25% of the oil filling.
In case of a contamination of 2% by weight, change at least 50% of the oil filling.
The tribological system may already have been affected.

Also for gas oil operation, the gasoline or heptane insolubles must not exceed 2% by weight.

6. Other Lubricants

6.1 Lubricants for Turbochargers, Governors, and Barring Gears

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

When selecting the lubricating oil brand the regulations of the equipment manufacturers such as ABB, Woodward, etc. shall be taken into account!

For RE governors use SAE 40 engine oil and for Woodward governors HLPD 46 hydraulic oil.

Producer	Brand
AGIP	OSO 68 OTE 68 DICREA SX 68 [1)]
CHEVRON, CALTEX, TEXACO	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
MOBIL	D.T.E OIL HEAVY RARUS SHC 1026 [1)]
SHELL	TELLUS OIL S2 VX 68 TURBO OIL T 68 CORENA OIL S4 R 68[1)]
TOTAL LUBMARINE	PRESLIA 68 AZOLLA ZS 68 TURBINE T 68 BARELF SM 68 [1)] DACNIS SH 68 VISGA 68

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

6.2 Multi-Purpose Grease - Lithium Saponified – Penetration Grade 2

Producer	Brand
AGIP	GR MU 2
CHEVRON, CALTEX, TEXACO	MULTIFAK EP 2
CASTROL	SPHEEROL SX 2
ESSO	BEACON EP 2
MOBIL	MOBILUX EP 2
SHELL	GADUS S2 V100 2
TOTAL LUBMARINE	CERAN AD PLUS

6.3 Barring Gears

Choose a transmission oil with a viscosity of 460 cSt at 40 °C, e.g.:

Producer	Brand
BP	Energol GR-XP 460
Exxon Mobile	Mobilgear 634
ESSO	Spartan EP 460
SHELL	Omala S2 GX 460

7. Cooling Water

7.1 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 recirculating cooling water level has to be checked at the expansion tank.

Modern diesel engines make high demands on the recirculating cooling water due to the increased power density and related increase in heat to be dissipated.

These requirements can only be met by properly prepared, monitored and maintained recirculating cooling water. If the preparation, monitoring and maintenance work is not carried out properly, corrosion damage may occur already after a short period of operation.

Three critical factors are to be considered for a proper treatment:

- **Suitable fresh water**
- **Effective corrosion inhibitor**
  - Corrosion inhibiting oil, emulsifiable
  - Chemical corrosion inhibitor (chemicals)
- **Correct dosing of the corrosion inhibitor**

7.1.1 Cooling Water Requirements

Always use clean, clear water. Suitable are:

- fresh water (deep well, spring water),
- condensate, and
- fully de-ionized water.

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

	Unit	Corrosion inhibiting	Chemicals
Alkaline earths	mmol/l	0.5 - 2.2	0 - 1.8
Hardness[1)]	°dGH	3 - 12	0 - 10[3)]
pH value[2)] (at 20 °C)	1	6.5 - 8	
Chloride ions	mg/l	max. 100	
Total chloride + sulphate ions	mg/l	max. 200	

1) Water hardness, see following explanation

2) pH value, see following explanation

3) In general, the corrosion inhibiting effect of chemicals is best when the water hardness values are low (- 0). At higher hardness values and with missing hardness stabilization, the chemicals may react with water ingredients, which may result in precipitation and a reduced protection effect.

7.1.2 Water Hardness

Water which does not meet 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.

Condensate and fully de-ionized water should be hardened with magnesium sulphate (MgSO4) by 3° dPH if corrosion protection oils are to be used.

NOTE

Ensure correct dosing!

Dosing:

For 1°dPH, 21.4 g $MgSO_4$ per ton of water are required

Definition of degree of German hardness:

Degree of German hardness (dGH) = permanent hardness (dPH) + carbonate hardness (dKH)

Comparison with other hardness specifications

1°dGH	0.18 mmol/l
1°dGH	1.79° French hardness
1°dGH	1.25° British hardness
1°dGH	17.9° US hardness

pH value

Concentration of hydrogen ions:

< 7	7	> 7
acid	neutral	alkaline

7.2 Water Treatment with Corrosion Inhibitors

Corrosion inhibitors to be used in engines must have been tested for their effectiveness according to the rules of the "Forschungsvereinigung Verbrennungskraftmaschinen e. V." (Research Association for Internal Combustion Engines).

Caterpillar Motoren GmbH & Co. KG will only issue a recommendation on the basis of the results of the test. No liability for the corrosion inhibitor used will be assumed because Caterpillar Motoren GmbH & Co. KG is not in a position to control the recipe and treatment.

Caterpillar Motoren GmbH & Co. KG has received positive test results for the anti-corrosion agents mentioned in paragraphs "Corrosion Inhibiting Oil" and "Chemical Corrosion Inhibitors" or they have proven effective over a long period of operation.

NOTE

Do not use corrosion inhibiting oil emulsions in case of systems heating living quarters with engine cooling water or in case of shell cooling! In these cases only chemicals shall be used!

7.2.1 Corrosion Inhibiting Oil (for Marine Applications only)

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

For the initial filling or after cleaning the cooling circuit a

1.5% emulsion

and for subsequent filling a

1.0% emulsion

shall be used.

The following corrosion inhibiting oils are known to be effective (alphabetic order, not exhaustive):

Producer	Brand
BP	FEDARO-M
CASTROL	SOLVEX WT3
ESSO	Kutwell 40
SHELL	Shell Oil 9156

The emulsion can generally be prepared as follows:

Add oil to the water (15 - 25 °C) while stirring thoroughly. For complete refilling take a sufficient amount of water so as to obtain a 10% emulsion with the required amount of corrosion inhibiting oil.

This 10% emulsion is added via the expansion tank to the cooling circuit which is already filled with 75% of the necessary cooling water amount. Topping up can be done while the engine is running.

7.2.2 Chemical Corrosion Inhibitors

Chemical corrosion inhibitors are offering some advantages over corrosion inhibiting oils, e. g. no risk of sludge formation due to breaking down of the emulsion, and are easier to treat and monitor.

⚠ CAUTION

Property damage due to low concentration!

Damage due to pitting corrosion in case of low concentration of the corrosion inhibitor.

- Check the concentration regularly

The following substances, amongst others, are currently being used in our engine:

Producer	Additive	Limit values of nitrite content as NO_2 in mg/l
Coracon	Coracon Liquid BL1	1200 - 1500
	Coracon Liquid BL 6	—
Rohm + Haas	Dia-Prosim RD 11	1400 - 2100
	Dia-Prosim RD 25	—
Ashland (Drew Ameroid)	DEWT-NC (Ship)	1500 - 2250
	CWT-110 (Stationary)	
	Maxigard	800 - 1100
	Liqui dewt	500 - 700
Maritech	Marisol CW	1000 - 2000
Nalfleet	9-108	750 - 1000
	9-111	
Unitor	Dieselguard NB	1500 - 2500
	Rocor NB Liquid	
Vecom	CWT Diesel/QC2 (D99) Caretreat 2 Die-	1500 - 2500
Arteco	Havoline XLI	—
Marichem Marigases	DCWT Non Chromate	1500 - 2500
Marine care	Caretreat2 Diesel	1500 - 2500
Caterpillar	SCA™	1400 - 2400
Caterpillar	ELI™	500 - 700

⚠ WARNING

Hazard due to toxic chromates!
Some corrosion inhibitors contain toxic chromates! The handling of such corrosion inhibitors may cause intoxication.

- Observe the safety notes of the manufacturer!
- In spite of their otherwise good properties, chromates should not be used!
- Methods of application and control procedures must be obtained from the producers, ensuring particularly that no toxic substances are used when fresh water generators are connected to the circuit;

NOTE

Notes are designed to improve working procedures and quality assurance.

7.3 Monitoring and Maintenance of the Treated Cooling Water

7.3.1 Corrosion Inhibiting Oil

A daily check of the coolant level at the sight glass of the expansion tank is just as important as checking the corrosion inhibiting oil content every 750 operating hours. In case of a longer engine stop (for more than a week), a check of the corrosion inhibiting oil content is compulsory.

Take the emulsion sample from the supply line from expansion tank upstream of the pump and let it stand for 1 h. Pour off any oil which has risen to the surface.

Carry out an emulsion test, e.g. by means of a hand refractometer (available at specialist shops for laboratory equipment).

0%	Cooling water change and cleaning necessary.
< 0.5%	Low concentration. Emulsion freshening required
0.5-1.0%	Emulsion okay.
> 1.0%	Excessive concentration. Emulsion needs to be adjusted.
> 1.5%	Carry out a measurement with new sample water. If the result is confirmed, the emulsion needs to be adjusted.

Emulsion freshening in case of low concentration:

Mix the required amount of oil according to **Diagram II** with treatment water to obtain a highly concentrated emulsion.

Always add oil to water

Fill in the mixed emulsion via the expansion tank, this is possible also with engine running.

Emulsion Correction for Excessive Concentration:

Drain the cooling water emulsion according to **Diagram III** and refill the circuit with treatment water.

⚠ CAUTION

Observe the notes on safety, application and disposal issued by the producer!

7.3.2 Chemical Corrosion Inhibitors

	NOTE
	In case of recirculating cooling water with chemical corrosion inhibitors, the cooling water does not have to be changed. For a safe corrosion protection it is critical to comply with the specified concentration.

A concentration check of the chemical corrosion inhibitors considering the limit values is to be carried out with the relevant testing equipment every 150 h in accordance with the instructions of the producer.
After a freshening up of the concentration ensure good mixing with the engine running!

7.4 Changing the Treated Cooling Water

7.4.1 Corrosion Inhibition Oil Emulsion

Change the corrosion inhibition emulsion every 7,500 operating hours or, at the latest, once a year if, due to longer lay times, the 7,500 operating hours are distributed over a one-year period. In case of recirculating cooling water with chemical corrosion inhibitors, the cooling water does not have to be changed.

7.4.2 Cleaning the Cooling Water Chambers before Changing the Emulsion

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

Remove cooling water inlets at the engine block and flush out any sludge deposits that may have formed.

Fill the engine with an alkaline cleaning solution (e.g. P3T 308 of Henkel; 0.5% solution) and run it for approximately 12 hours. Stop the engine and let it cool down to 30 °C.

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

Then add 90% of the required amount of treatment water. Prepare a highly concentrated emulsion with the remaining 10% and the required amount of corrosion inhibiting oil (according to Diagram II).

	NOTE
	Always add oil to water!

Add the emulsion to the cooling circuit via the expansion tank.

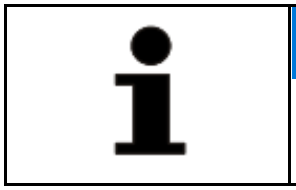
7.5 Cooling Water with Antifreeze

At temperatures around or below the freezing point of the cooling water, the coolant must be treated with antifreeze.

Only an anti-freezing agent with a corrosion protective effect may be used; contact Caterpillar Motoren GmbH & Co. KG for currently customary agents), for example

- BASF Glysantin G48
- GlycoShell AF 405
- BP Antifrost X 2270
- Havoline XLC
- CAT® ELC™.

To achieve adequate corrosion protection, a 30% concentration is necessary. The maximum concentration is 50%.



NOTE

The anti-freezing agent must be changed annually!

When an anti-freezing agent is used, a reduction in cooling efficiency is to be expected. In case of doubt, consult Caterpillar Motoren GmbH & Co. KG.

For summer operation, it is advisable to drain off the cooling water containing anti-freezing agent and replace it by cooling water with chemical corrosion inhibitor to ensure adequate cooler performance at high ambient temperatures.

7.5.1 Cleaning of the Cooling Water Chambers

Before severely scaled cooling water chambers can be cleaned, they must be precleaned as described under "Cleaning the cooling water chambers before changing the emulsion" and flushed well with water under pressure. This will remove any loose impurities such as sand and sludge which may have deposited at places where the water flow rate is low.

The suppliers of the corrosion inhibitors are usually offering also good cleaning agents for scale, such as:

Producer	Cleaning agent
Drew Chemical	SAF - ACID
Rohm + Haas	RD 13 M

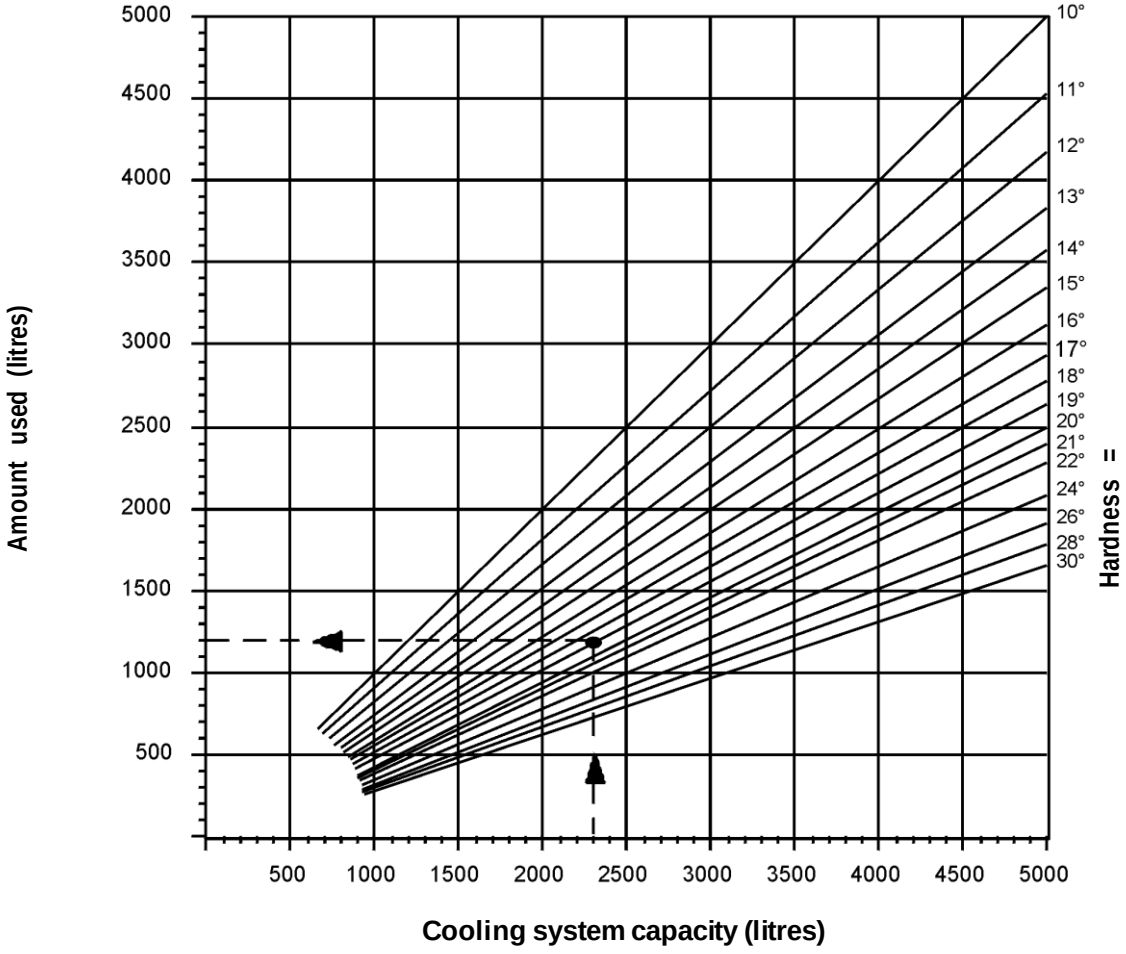
⚠ CAUTION

Hazard due to cleaning agents!
When carrying out cleaning work on the machine, improper handling of the cleaning agents will lead to hazards!

- Observe the safety notes of the producers.
- After draining off the cleaning agent, flush the cooling water chambers/cooling system with a 1% sodium carbonate solution and after that flush through with fresh water.

7.6 Appendix

7.6.1 Determining the Cooling Water Mixture for 10°dGH

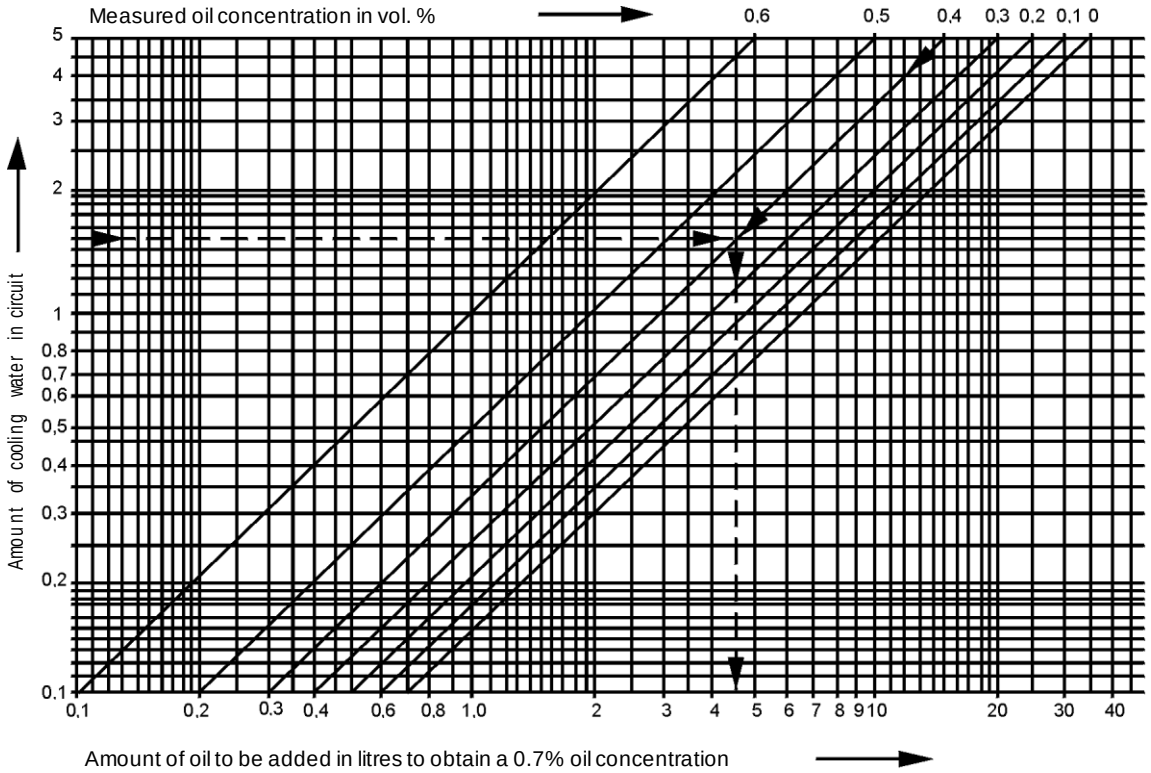


Example:

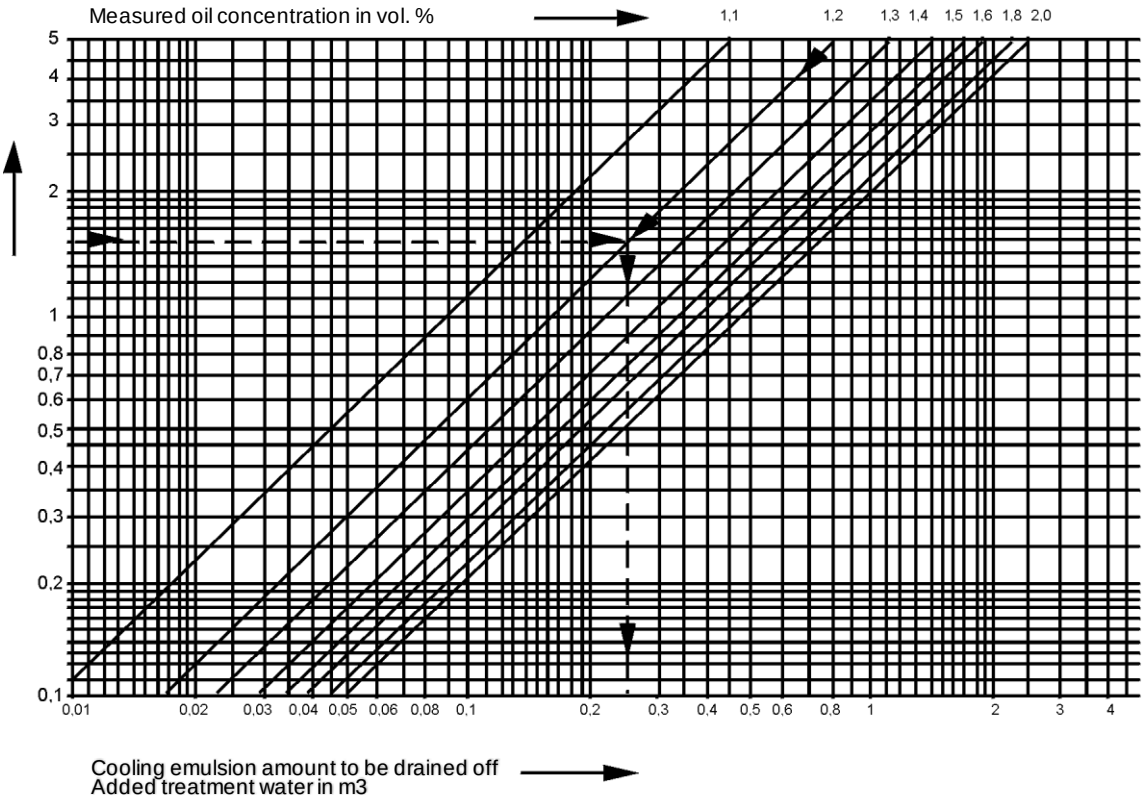
- Cooling system capacity: 2300 l
- Hardness of available fresh water: 19°dGH

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 (1200 l) 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.

7.6.2 Emulsion Freshening in Case of Low Concentration



7.6.3 Emulsion Correction for Excessive Concentration



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