mamotec

## Technical Circular 20-02

# Lubricating oil limit values

Affected engines:

| | |
|---|---|
| ☒ MAG 24.4 X 41XA | ☐ MAH 33.3 TI 311A |
| ☒ MAG 33.3 X 31XA | ☐ MAH 49.4 TI 211A |
| ☒ MAG 49.4 X 21XA | ☐ MAH 74.6 TI 211A |
| ☒ MAG 74.6 X 21XA | ☐ MAH 84.6 TI 211A |
| ☒ MAG 84.6 X 21XA | ☒ customised special versions |
| ☒ MAG 13.6 X 11XA | |

## 1. General

This circular describes the handling, approvals and limit values of lubricating oils. Older technical circulars lose their validity with this version.
The motor may only be operated with lubricating oils approved by MAMotec.

The operator is solely responsible for compliance with the lubricating oil regulations described in this TC.

The engine manufacturer is not liable for damage caused by non-approved lubricating oils or improper operation.

In general, lubricating oils must have the following properties:

- stable lubricating film at all operating temperatures
- optimum viscosity at all operating temperatures
- high thermal stability
- high aging resistance
- wear-protective properties
- neutralising properties against corrosive substances
- balanced ratio of ash-forming agents
- high safety reserves for long lubricating oil change intervals

Economic operation is achieved by lubricating oil filling with the longest possible intervals between oil changes. In principle, the avoidance of damage and the achievement of the expected service life of important engine and plant components are the main priorities.

## 2. Lubricating oil selection

**Lubricating oils (sulphated ash content up to 0.5 weight %)**

For the operation of MAMotec gas engines, the lubricating oils listed in the section „Released lubricating oils (sulphated ash content up to 0.5 % by weight)" must be used. These are designed for the operation with natural gas with low pollutant content.

**Lubricating oils (sulphated ash content 0.5 - 1.0 weight %)**

Further lubricating oils are approved especially for operation with fuel gases with an increased pollutant load. These are listed in the section Released lubricating oils (sulphated ash content 0.5 - 1.0 weight %).

To ensure neutralisation, larger quantities of lubricating oil additives (e.g. sulphated ash) are required. However, this means that the higher the neutralisation potential of a lubricating oil, the higher the tendency to form deposits during combustion.

If such lubricating oils are used with fuel gases which do not have permanently high pollutant loads, the additives are not consumed as no or only small quantities of acids are produced which have to be neutralised.

Here the advantages of these special lubricating oils partly turn into clear disadvantages.

- The unused additives form deposits in the combustion chamber and in the downstream system parts such as exhaust gas heat exchanger, silencer, etc.
- In the combustion chamber, these deposits can combine with elements present in the fuel gas, such as silicon (Si). These compounds are very hard and lead to abrasive wear on pistons, piston rings, cylinder liners, valves and valve seat rings.

We therefore recommend to run all engines with lubricating oils according to the section "Released lubricating oils (sulphated ash content up to 0.5%)" until a stable fuel gas production has been achieved. During this time, the boundary conditions and effects of the fuel gas used on an economical and reliable operation of the engine must be determined by lubricating oil and gas analyses.

If the pollutant concentration in the fuel gas remains permanently high after completion of the start-up process of the system and thus no economical lubricating oil change intervals can be achieved, it is possible to change over to lubricating oils according to section "Released lubricating oils (sulphated ash content 0.5 - 1.0 wt.%)" in consultation.

## 3. Taking oil samples

Care must be taken that the lubricating oil sample is not contaminated by dirt or lubricating oil residues in the auxiliaries.

A small amount of lubricating oil is sufficient for a routine analysis.

The lubricating oil sample must be taken from the lubricating oil circuit while the engine is running and at operating temperature.

Before sampling, at least 20 ml of lubricating oil must be drained and disposed of properly. Then the required amount of lubricating oil for the lubricating oil sample must be taken.

A change of the lubricating oil by sampling and transport has to be avoided.

The samples must be clearly marked and contain the following minimum information:

- Operator
- Engine type
- Engine serial number
- Lubricating oil manufacturer
- Designation of the lubricating oil
- Date of sampling
- Engine operating hours
- Operating hours of the lubricating oil
- Refill quantity / lubricating oil consumption
- Total lubricating oil volume

## 4. Lubricating oil analysis

A complete lubricating oil analysis must ensure that the engine is operated with lubricating oil according to the specifications of this technical circular. Lubricating oil analyses must be kept so that proof of this proper operation of the engine can be provided.

In case of abnormal wear values within an analysis series, the analysis must be made available to the responsible service partner within the warranty period for engines.

The trend analysis is best suited to observe the analysis values over a longer period of time. Here, the individual analysis values are summarised in tables or graphics. In this way an assessment of the condition of the lubricating oil or the engine can be made (trend recognition).

## 5. Lubricating oil change

**Lubricating oil change**

When changing the lubricating oil, always renew the entire lubricating oil quantity. The residual lubricating oil quantity in the engine and attachments must be kept as low as possible.

The lubricating oil change is necessary if one of the following criteria is fulfilled:

- before exceeding the limit values of this circular
- after coolant penetration into the lubricating oil
- after maintenance work of repair level I1 I2 I3
- after maintenance work on the engine
- before decommissioning for more than three months
- at least once a year

**Lubricating oil change intervals**

The lubricating oil change intervals are, apart from the lubricating oil quality, dependent on

- the gas quality
- the ambient conditions
- the operating mode of the motor

Generally, these influences lead to a change in the lubricating oil characteristics.

It is therefore necessary to determine the lubricating oil change intervals for each plant by means of lubricating oil analyses.

The first lubricating oil analysis must be carried out after 100 operating hours, irrespective of the type of gas.
The lubricating oil can be used until the limit values are reached by selecting suitable intervals for the lubricating oil analyses.

The lubricating oil change intervals must always be redetermined at

- the commissioning of the plant

- Change of operating mode

- after repair work of a scope I1 I2 or I3

If the operating conditions remain unchanged, further lubrication analysis intervals and the required lubricating oil change must be agreed between the operator and the engine manufacturer on the basis of this Technical Circular.

# 6. Lubricating oil limit values

If one of the following limit values is exceeded, an immediate lubricating oil change must be carried out.

| Properties | Limit value | Test method |
|---|---|---|
| Viscosity at 100 °C | min. 12 $mm^2/s$ (cSt)<br>max. 15 $mm^2/s$ (cSt) | DIN EN ISO3104<br>DIN 51366, ASTM D 445 |
| Viscosity increase compared to the new condition at 100 °C | max. 10% of fresh oil value | |
| Water content | max. 0,1 % | DIN 51777, ASTM D 1744<br>DIN ISO 12937 |
| Glycol content | max. 500 ppm | DIN 51375, ASTM D 4291 |
| Total base number TBN | min. 2,0 mg KOH/g | ISO 3771, ASTM D 4739 |
| AN | not greater than TBN | DIN EN 12634, ASTM 664 |
| SAN | 0 mg KOH/g | ASTM 664 |
| i pH (not required for natural gas) | more than 4,5 | |
| Oxidation | 20 A/cm | DIN 51453 |
| Nitration | 20 A/cm | DIN 51453 |
| Silicon | max. 150 mg/kg | DIN 51396, ASTM D 5185 |
| **If a wear metal exceeds its permissible limit value, the limit value for silicon is reduced to:** | max. 10 mg/kg | DIN 51396, ASTM D 5185 |

# 7. Wear metals

The information on the wear metals is an aid for engine evaluation. This allows early detection of changes in the engine condition.

For evaluation, the temporal concentration course of each individual wear metal has to be observed over several lubricating oil analyses (trend analysis).

The decisive factor here is the rate of each individual value and not its absolute value.

Rate = (concentration new - concentration old) / (operating hours new - operating hours old)

If a wear metal exceeds 50% of the analysis value listed below, the time intervals for sampling must be halved.

If the increased wear values are confirmed, contact the engine manufacturer.

All measurements must be carried out according to DIN 51396 (ICP OES / RFA).

| | |
|---|---|
| Aluminium | max. 10 mg/kg per 1000 hours |
| Chromium | max. 10 mg/kg per 1000 h |
| Copper | max.10 mg/kg per 1000 hours |
| Iron | max.15 mg/kg per 1000 hours |
| Lead | max. 10 mg/kg per 1000 hours |
| Tin | max. 5 mg/kg per 1000 hours |

# 8. Lubricating oil consumption

The specific lubricating oil consumption is the amount of lubricating oil consumed per unit of time and at a certain power.

The lubricating oil consumption is determined over a longer period of time with the same operating mode in continuous operation.

After the first hours of operation (running-in period) the lubricating oil consumption decreases. Subsequently, it should remain constantly low over a longer period of time. With a very long running time, the wear in the engine increases and with it the lubricating oil consumption again.

# 9. Evaluation of the lubricating oil analysis

**Viscosity**

Unity: mm2/s

The viscosity characterises the fluidity of the lubricating oil (resistance against displacement of two adjacent layers, internal friction). The viscosity depends on temperature.

An increase in viscosity is caused by:

- Ageing/oxidation
- Soot/solid foreign matter
- Evaporation of low boiling components

**Water**

Unity: weight %

Water in the lubricating oil generally leads to an emulsion, which in total increases the risk of wear and corrosion.

Water increases the viscosity of the lubricating oil. Possible causes:

- Leaks in the coolant system
- Condensation processes in the lubricating oil system due to frequent starts or emergency stops
- Improper storage of the lubricating oil
- Insufficient ventilation of the crankcase or lubricating oil tank
- Penetration of rainwater through the exhaust system

**Glykol**

Unity: ppm

Glycol leads to sludge formation through reaction with lubricating oil agents and filter clogging.

Glycol is incompatible with mineral oil. Possible causes:

- Leaks in the coolant system
- Contamination with a polyglycol-based lubricating oil

**Total Base Number (TBN)**

Unity: mgKOH/g

The TBN indicates the alkaline reserve of the lubricating oil and characterises the chemical neutralisation capacity.

This is a necessary property of the lubricating oil to control corrosive wear.

When the lubricating oil is used, the alkaline reserve is reduced by reaction with acids. The acids are ultimately reaction products of the combustion process as well as ageing/oil oxidation and nitration.

When operating with acid-forming fuel gases (especially landfill, sewage and biogases), a rapid decomposition of the TBN can be expected.

**Acid Number (AN, formerly TAN) or neutralisation number (Nz)**

Unity: mgKOH/g

The method detects the strong and weak acids. The strong acids are recorded separately as Strong Acid Number (SAN). Lubricating oil agents influence the size of the AN, which can be between 0.5 and 2 mgKOH/g for new lubricating oils.

Oxidation and nitration processes can produce weak organic acids. These are only partially neutralised by the alkaline properties of the lubricating oil. If the lubricating oil still has a sufficient alkaline reserve, the AN only covers the weak organic acids.

There is a rough correlation between AN increase, lubricating oil ageing and lubricating oil nitration.

**Strong Acid Number (SAN)**

Unity: mgKOH/g

The method only detects strong acids (e.g. sulphuric acid). If a SAN is reweighted, there is a risk of corrosion.

**Ageing/Oxidation**

Unity: A/cm

Ageing/oxidation is caused by the reaction of the base oil and active ingredient molecules with oxygen, which leads to an increase in viscosity and acid number. Component lacquering and sludge deposition can occur. The oxidation products can form organic acids, which lead to corrosion even if the lubricating oil still has an alkaline reserve.

The extinction is measured at the wave number 1710 cm-1 in the infrared light spectrum, where the carbonyl compounds formed during oxidation are recorded.

**Nitration**

Unity: A/cm

Nitration results from reactions of the base oil and active ingredient molecules with nitrogen oxides. The effects are comparable to those of ageing / oxidation. They lead to changes in the characteristics of the lubricating oil. In comparison, however, the risk of the formation of corrosive reaction products is higher. In case of strong nitration, a strong reduction of the alkaline reserve usually occurs.

The absorbance is measured at the wave number 1630 cm-1 in the infrared light spectrum.

**i pH**

Unity: none

The method is used to determine the pH value of the lubricating oil. The measurement result is given in dimensionless pH-value units. An overacidification of the lubricating oil leads to corrosive wear.

**Silicon**

Unity: mg/kg

Possible origin:

- Component in antifoam agents
- Dust from the intake air leads to abrasive (sanding) wear even in the smallest quantities.
- Compounds from fuel gases (e.g. landfill, sewage and biogases)
- The silicon load in the lubricating oil also indirectly gives an indication of the silicon load of the fuel gas.

**Natrium**

Unity: mg/kg

Typical element of active substances for corrosion protection in the coolant. A strong increase of the sodium content in the lubricating oil is a sign of contamination of the coolant. The engine must be constantly checked for possible coolant leaks during further operation.

In many cases, no water is detectable in the lubricating oil despite high sodium values and the associated contamination, as this evaporates due to the lubricating oil temperature during engine operation.

**Aluminium**

Unity: mg/kg

Typical wear element of, for example, pistons and slide bearings.

Under certain circumstances, aluminium can also be a component of contaminated intake air.

**Iron**

Unity: mg/kg

Typical wear element of cylinder liners, cams/tappets, shaft journals, Piston rings and gear wheels.

**Chrome**

Unity: mg/kg

Typical wear element of piston rings, valve stems, cams/tappets and other high-alloy engine components.

**Copper**

Unity: mg/kg

Typical wear element of bearings as well as corrosion product of lubricating oil coolers and lubricating oil lines.

Copper is also a component of various assembly pastes.

**Lead**

Unity: mg/kg

Typical wear element of plain bearings as well as solder from lubricating oil coolers and lubricating oil lines.

**Tin**

Unity: mg/kg

Typical wear element of plain bearings.

**Molybdenum**

Unity: mg/kg

Can be a component of lubricating oil agents as well as of various assembly pastes. Rarely used as tread coating of piston rings.

## Optional analysis values

### Potassium and boron

Unity: mg/kg

Typical elements of active substances for corrosion protection in the coolant. A Increase in lubricating oil is a sign of contamination by coolant.

However, boron is also a typical element of frequently used active substances in lubricating oil.

### Calcium, zinc, phosphorus, sulphur

Unity: mg/kg

Typical elements of active ingredients in lubricating oil.

Sulphur is also a component of lubricating oil and of fuel gases.

## 10. Release list lubricating oils

**sulphated ash content up to 0,5 % by weight**

| Manufacturer / Product | Base oils | Sulph-ated Ash cont. | TBN | class | Viscosity at 40 °C |
|---|---|---|---|---|---|
| Product | | Weight % | mgK OH/g | SAE | $mm^2/s$ |
| **ADDINOL** | | | | | |
| MG 40 Extra LA | Mineral | 0,5 | 6,5 | 40 | 136 |
| **BayWa** | | | | | |
| MethaFlexx NG | Mineral | 0,45 | 5,5 | 40 | 156 |
| MethaFlexx NG plus | Mineral | 0,45 | 5,9 | 40 | 141,5 |
| **FUCHS PETROLUB AG** | | | | | |
| TITAN GANYMET LA | Mineral | 0,45 | 5,5 | 40 | 156 |
| TITAN GANYMET PLUS LA | Mineral | 0,45 | 5,9 | 40 | 141,5 |
| **Shell** | | | | | |
| Mysella LA | Mineral | 0,45 | 5 | 40 | 138 |
| Mysella XL | Mineral | 0,5 | 4,5 | 40 | 131 |
| **Mobil** | | | | | |

**sulphated ash content from 0,5 to 1,0 % by weight**

| Manufacturer / Product | Base oils | Sulph-ated Ash cont. Weight % | TBN mgKOH/g | class SAE | Viscosity at 40 °C $mm^2/s$ |
|---|---|---|---|---|---|
| **ADDINOL** | | | | | |
| MG 40 Extra Plus | Mineral | 0,85 | 9,8 | 40 | 133 |
| **Petro Canada** | | | | | |
| Sentron LD 5000 | HC | 0,57 | 4,9 | 40 | 124 |
| Sentro CG 40* | HC | 0,92 | 8,5 | 40 | 128 |
| **FUCHS PETROLUB AG** | | | | | |
| TITAN GANYMET PLUS | Mineral | 0,8 | 9,2 | 40 | 132 |
| TITAN GANYMET ULTRA | HC[3] | 0,7 | 8,2 | 40 | 105 |

* only suitable for biogas

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