
2105/23 EN

This circular replaces:
2105/22



Specification for lube oil

Valid for: TCG 2016, TCG 3016, TCG 2020, TCG 3020, TCG 2032, TCG 2032B

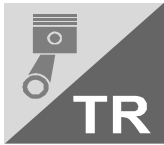
The 23rd replacement is made due to:

- Update of the approved lube oils

Imprint:
Caterpillar Energy Solutions GmbH
Servicedokumentation
M.Granson
Carl-Benz-Str. 1
68167 Mannheim
Germany
Phone: +49 621 384-8455
Fax: +49 621 384-8841
Date:
2019-06-24

Note:
There is no revision service for the parts numbers specified in this document. Only the spare parts documentation is binding for the identification of spare parts.

Copies to:
- TR
- According to SIT 7010



2105/23 EN

Contents:

- General information
- Lube oil selection
- Lube oil sampling
- Lube oil analysis
- Lube oil change
- Lube oil filter change
- Limit values
- Wear metals
- Lube oil consumption
- Interpretation of parameters of the lube oil analysis
- Interpretation of elements of the lube oil analysis
- Interpretation of the optionally analyzed elements of the lube oil analysis
- Appendix
 - Approved lube oils TCG 2016
 - Approved lube oils TCG 3016
 - Approved lube oils TCG 2020
 - Approved lube oils TCG 3020
 - Approved lube oils TCG 2032
 - Approved lube oils TCG 2032B

2105/23 EN



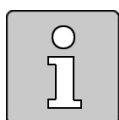
General information



Risk of destruction of components

From non-approved lube oils

- Only use approved lube oils



The owner is solely responsible for observing the lube oil specification described.

The operator must be able to demonstrate his maintenance obligation by analyzing the lube oils in accordance with this lube oil specification.

The manufacturer accepts no liability for damage caused by the use of non-approved lube oils or by improper operation.

Lube oils for combustion engines are exposed to extreme mechanical and thermal stress. The lube oil should not evaporate at the high temperatures of the cylinder liners but should form a sufficiently tenacious, pressure-stable, well adhesive lube film. It should be thin enough in the cold state to enable starting of the cold engine. The sliding surfaces of the engine components should remain wet for restarting the engine when the engine is shut down.

The lube oils must generally have the following properties:

- stable lube film at all operating temperatures
- optimal viscosity at all operating temperatures
- high thermal stability
- high resistance to aging
- wear-preventing properties
- neutralizing properties against corrosive materials
- balanced ratio of ash-forming active ingredients
- high safety reserves for long lube oil change intervals

Economic operation is achieved by as long a lube oil change interval of the lube oil filling as possible. The emphasis is always on the avoidance of damage and achievement of the expected service lives of important engine components.



2105/23 EN

Lube oil selection**Lube oils (sulfate ash content up to 0.6 wt. %)**

The lube oils listed in the section **Approved lube oils (sulfate ash content up to 0.6 wt. %)** must be used for operating gas engines.

Lube oils (sulfate ash content 0.6 - 1.0 wt. %)

Other lube oils are approved specially for operation with fuel gases with a higher pollution load (see also Technical Bulletin (TR) 3017). These are listed in the section **Approved lube oils (sulfate ash content 0.6 - 1.0 wt. %)**.

These lube oils are recognizable according to the manufacturer's data sheet by their high TBN and sulfate ash values and have a higher neutralization reserve against acids which are produced by the burning of pollutants in the fuel gas. These acids are produced, for example, from chlorine (Cl), fluoride (F) and sulfur (S). The neutralization of the acids protects the engine from corrosion.

Larger amounts of lube oil additives are necessary to ensure neutralization. However, this means the higher the neutralization potential of a lube oil, the higher the tendency for deposits to form during combustion.

If such lube oils are used in fuel gases which exhibit no continuously high pollutant loads (in accordance with the values permitted in the Technical Bulletin (TR) 3017), the additives are not consumed because no or only small amounts of acids are produced which have to be neutralized.

Here, the advantages of these special lube oils become clear disadvantages.

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

We therefore recommend that you operate all engines with lube oils according to section **Approved lube oils (sulfate ash content up to 0.6%)** until a stable fuel gas generation has been achieved. During this time, the boundary conditions and effects of the used fuel gas on economical and reliable operation of the engine must be determined by lube oil and gas analyses.

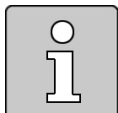
If, at the end of the system start-up process, the concentration of pollutants in the fuel gas remains continuously high and no economical lube oil change intervals are reached as a result, you can convert to lube oils in accordance with section **Approved lube oils (sulfate ash content 0.6 - 1.0 wt. %)** in agreement with the service partner responsible.

2105/23 EN



Lube oil sampling

A careful preparation and execution of the lube oil sampling is a prerequisite for useful analysis values.



Make sure that the lube oil sample is not falsified by dirt or residue lube oil in the additives.

About 100 ml of lube oil is sufficient for a routine analysis.

The lube oil sample must be taken from the lube oil circuit whilst the engine is running and warm.



For further information on the lube oil sampling, see

- Genset Operating Manual ⇒ Job cards
 - B 8-1-1 Sampling the lube oil

At least 100 ml of lube oil must be drained and properly disposed of before taking the sample. Then the necessary amount of lube oil for the lube oil sample must be taken.

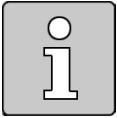
Changes in the lube oil due to sampling and transport are to be avoided.

The samples must be clearly identified and the following minimum information contained:

- Operator
- Engine type
- Engine serial number
- Manufacturer of the lube oil
- Designation of the lube oil
- Date of the sampling
- Operating hours of the engine
- Operating hours of the lube oil
- Filling amount / lube oil consumption
- Total lube oil volume



2105/23 EN

Lube oil analysis

The operator must guarantee that the analysis values necessary for choosing the lube oil change intervals are available on schedule.

The analysis lube must be presented to the operator as quickly as possible (maximum half of the lube oil analysis interval).

Perform the first lube oil analysis independently of the fuel gas type after 100 operating hours.

A detailed lube oil analysis must ensure that the engine is operated with lube oil according to the specification in this technical bulletin. Lube oil analysis reports must be kept to provide proof of this proper operation of the engine.

In case of abnormal wear values within an analysis series, the analysis must be submitted to the service partner responsible for engines still under guarantee.

The trend analysis is most suitable for monitoring the analysis values over a longer period of time. The individual analysis values are recorded here in tables or graphs. This allows an assessment of the condition of the lube oil and the engine (trend detection).

2105/23 EN



Lube oil change

Lube oil change

The entire amount of lube oil must be replaced when performing a lube oil change. The remaining lube oil volume in the engine and add-on parts should be kept as low as possible.

The lube oil change is necessary when one of the following criteria is satisfied:

- upon approximation to the permissible limit value
- after penetration of the lube oil system by coolant
- after maintenance work of the maintenance and service schedule E60 and E70
- after service work of a scope E60 or E70
- at least once a year
 - This does not include gensets with a lube oil change interval as per lube oil analysis greater than 10000 oh.

Lube oil change intervals

In addition to the lube oil quality, the lube oil change intervals are dependent on:

- the fuel gas quality
- the ambient conditions
- the operating principle of the engine

As a rule, these influences lead to a change in the lube oil parameters.

It is therefore necessary to determine the lube oil change intervals by lube oil analyses for every system.

By suitable choice of the time intervals for the lube oil analyses, the lube oil can be used until reaching the limit values.

The lube oil change intervals must always be re-determined when:

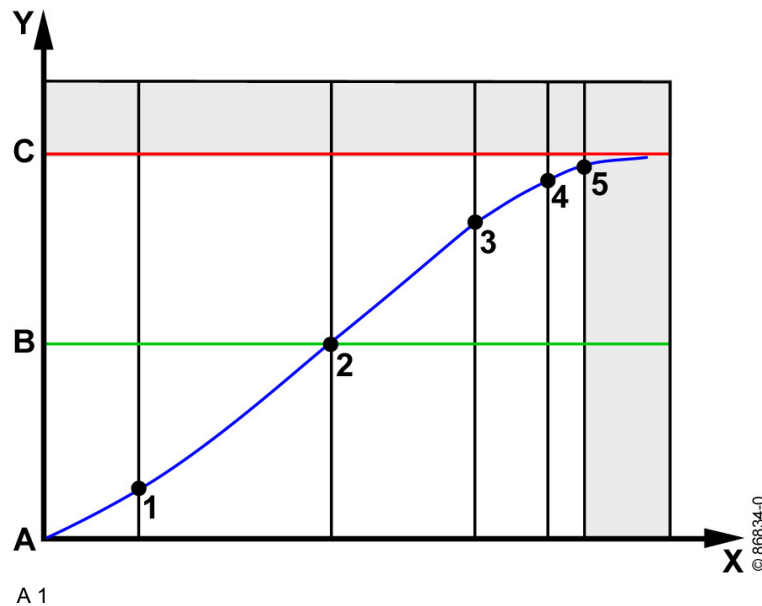
- commissioning the system
- changing the type of operation
- after maintenance work of the maintenance and service schedule E60 and E70
- after service work of a scope E60 or E70

Under unchanged operating conditions, the further lube oil analysis intervals and the necessary lube oil change must be agreed between the operator and the responsible service partner on the basis of this technical bulletin.


2105/23 EN

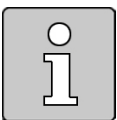
The lube oil change intervals must be determined as follows:

Example 1:



X axis:	Time period
Y axis:	Numeric value of the analysis result
A:	Initial value
B:	Half of limit value
C:	Limit value
Position 1-5:	Time of the lube oil analysis
Position 5:	Time of the next lube oil change

- First lube oil filling
 - If the analysis values (position 1) are well below half the permissible limit values B, the timer interval before the next lube oil analysis (position 2) can be doubled.
 - If individual analysis values reach half the permissible limit value B, the time interval before the next analysis (position 3) must be reduced.



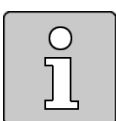
On approaching the permitted limit value C, the time intervals from analysis to analysis (position 4 and 5) must be halved respectively.

- Second and further lube oil fillings
 - After the first determination of the lube oil change interval, the first lube oil analysis can be taken after a greater interval (position 3) for the second lube oil filling.

2105/23 EN

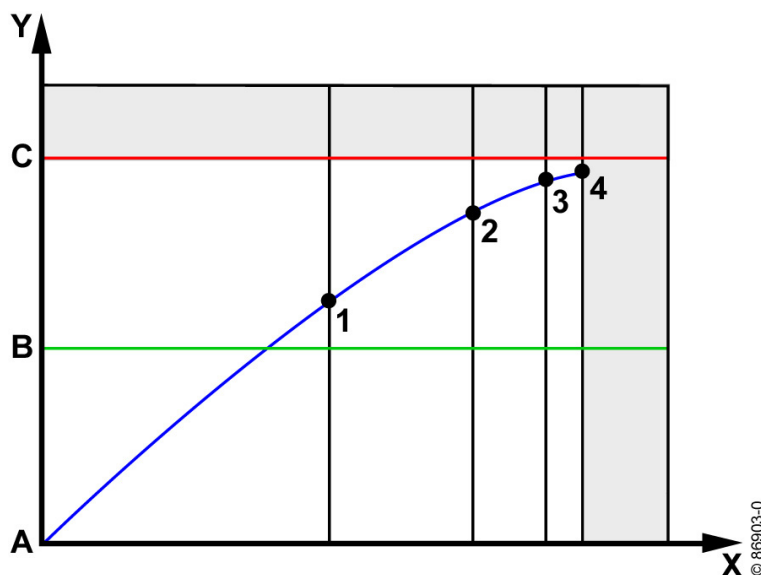


- Another lube oil analysis (position 4) is taken if comparable analysis results with the first lube oil filling are obtained.
- If, on the other hand, the same analysis values are reached, the same lube oil change interval as in the first lube oil filling can be determined.
- In case of unchanged operating conditions, the lube oil analyses for the following lube oil fillings can be taken at the same interval (position 4).



If the analysis results deviate from the previous results, the lube oil change intervals must be re-determined until repeatable results are achieved.

Example 2:



A 2

- X axis: Time period
- Y axis: Numeric value of the analysis result
- A: Initial value
- B: Half of limit value
- C: Limit value
- Position 1-4: Time of the lube oil analysis
- Position 4: Time of the next lube oil change

- If the analysis values of the first lube oil sample are already close to the permitted limit values (position 1), the operating time until the next lube oil analysis must be reduced (position 2).
- If the short distance from the limit values is confirmed, the last analysis period (position 3 to 4) must be halved.



2105/23 EN

Lube oil change intervals for TCG 2016 without increased lube oil volume

Due to the time delay between taking the lube oil sample and the availability of the analysis results (due to posting and processing times), the procedure that has already been described can only be applied to a limited extent for TCG 2016 without increased lube oil volume.

To prevent limit values from being exceeded in all cases during the analysis period, the following procedure must be applied:

- After 100 oh
 - First lube oil sample
- At 250 oh
 - Second lube oil sample, then renew lube oil

Depending on the results of the lube oil sampling, the change time can now be gradually increased by 50 operating hours, if the limit values have not yet been exceeded by the change time.

Analogous to this, the change interval must be reduced if the limit values are exceeded.

2105/23 EN

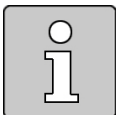


Lube oil filter change

All lube oil filters must always be replaced when performing a lube oil filter change.

The lube oil filter change is necessary:

- after 4000 operating hours at the latest - unless otherwise indicated in the maintenance plan
- with the first lube oil change after commissioning
- with the first lube oil change after maintenance work of maintenance level E60 and E70, or after repair work of a scope E60 or E70
- at least once a year
- if a SAN has been detected in the lube oil - see limit values
- after penetration of the lube oil system by coolant



After coolant has entered the lube oil system, all filter elements in the crankcase breather and the sub-stream lube oil filter (TCG 2032, TCG 2032B) must be replaced.


2105/23 EN
Limit values

Risk of destruction of components

Due to failure to comply with the limit values

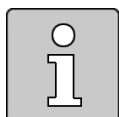
- If one of the following limit values is not complied with, the lube oil must be changed immediately.

During operation

Properties	Limit	Test method
Increase in viscosity in comparison with the new condition at 100 °C	max. 3 mm ² /s (cSt)	
Viscosity at 100 °C	min. 12 mm ² /s (cSt) max. 18 mm ² /s (cSt)	DIN 51366, ASTM D445, DIN EN ISO 3104
Water content	max. 0.2 %	DIN 51777, ASTM D1744, DIN ISO 12937
Glycol content	max. 500 ppm	DIN 51375, ASTM D4291
Total base number TBN	min. 2.0 mg KOH/g	ISO 3771, ASTM D4739
AN	not greater than the TBN	DIN EN 12634, ASTM 664
SAN ¹⁾	max. 0.2 mg KOH/g	ASTM 664
i pH value ²⁾	Min. 4.5	ASTM D7946
Oxidation ²⁾	max. 20 A/cm	DIN 51453
Nitration	max. 20 A/cm	DIN 51453
Silicon	max. 300 mg/kg	DIN 51396, ASTM D5185

¹⁾ The SAN must only be determined for Low gas quality fuel gases.

²⁾ Cannot be consulted for used oil assessment with fully synthetic ester-based lube oil.



If a wear metal exceeds its permissible limit, then the limit for silicon decreases to max. 15 mg/kg (DIN 51396, ASTM D5185)

2105/23 EN



During decommissioning

When decommissioning, the acidity of the lube oil can cause non-usage damage to parts carrying lube oil. The acidity is characterized by the alkaline reserve (TBN, Total Base Number) and the pH value.

To avoid damage during non-use, the following limit values must not be fallen below.

Properties	Limit value	Test method
Total base number TBN	min. 3.5 mg KOH/g	ISO 3771, ASTM D4739
i pH value	min. 5.0	ASTM D7946

If the analysis values are above the values indicated, the lube oil can remain in the genset during the shutdown phase and be used when putting into operation again.

If measured values from the lube oil analysis fall below the limit values indicated above, the lube oil must be replaced.

Then operate the genset for at least 12 hours.



2105/23 EN

Wear metals

The wear metals data provides an aid for engine assessment. In this way, changes in the engine conditions can be detected at an early stage.



For analysis, the temporal concentration progression of every individual wear metal must be monitored in several lube oil analyses (trend analyses).

The wear rate of every individual value, and not its absolute value, is the decisive factor here.

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

If the increased wear values are confirmed, the responsible service partner must be consulted.

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

Example:

Calculate wear rates

$$v_v = (c_1 - c_2) / (t_1 - t_2)$$

v_v = wear rate

c_1 = new concentration

c_2 = old concentration

t_1 = new operating hours

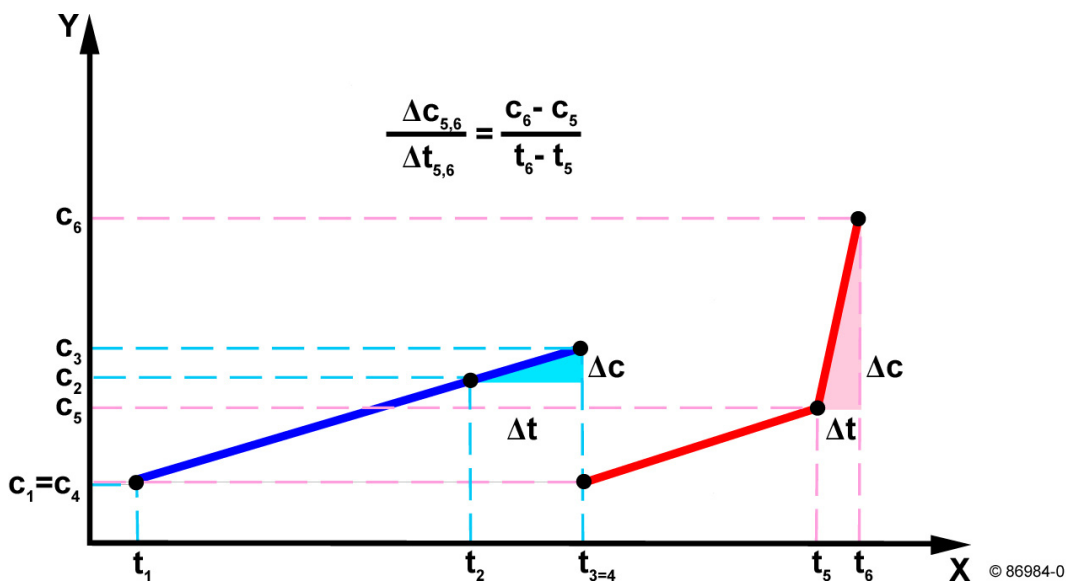
t_2 = old operating hours

2105/23 EN



Six lube oil samples were analyzed for an engine. Lube oil was changed after the 3rd lube oil analysis $t_{3=4}$. From the penultimate lube oil analysis t_5 to the last t_6 , the wear metal concentration c_6 increases considerably faster than expected from earlier lube oil analyses.

Since the last rate of increase (delta $c_{5,6}$ / delta $t_{5,6}$) is above 50 % of the limit value, the time interval up to the next lube oil analysis must be halved.



- X axis: Time period
- Y axis: Numeric value of the analysis result
- $t_{3=4}$ Time of changing the lube oil
- $c_1=c_4$ Concentration in the new lube oil


2105/23 EN
Limit values for wear rate
TCG 2016

Aluminum	max. 1.0 mg/kg per 100 oh
Chrome	max. 0.5 mg/kg per 100 oh
Copper	max. 2.5 mg/kg per 100 oh
Iron	max. 3.0 mg/kg per 100 oh
Lead	max. 2.0 mg/kg per 100 oh
Tin	max. 1.0 mg/kg per 100 oh

TCG 3016

Aluminum	max. 0.5 mg/kg per 100 oh
Chrome	max. 0.3 mg/kg per 100 oh
Copper	max. 1.0 mg/kg per 100 oh
Iron	max. 1.0 mg/kg per 100 oh
Lead	max. 1.0 mg/kg per 100 oh
Tin	max. 0.5 mg/kg per 100 oh

TCG 2020

Aluminum	max. 1.0 mg/kg per 100 oh
Chrome	max. 0.5 mg/kg per 100 oh
Copper	max. 1.5 mg/kg per 100 oh
Iron	max. 2.0 mg/kg per 100 oh
Lead	max. 2.0 mg/kg per 100 oh
Tin	max. 0.5 mg/kg per 100 oh

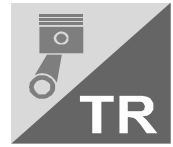
TCG 3020

Aluminum	max. 0.5 mg/kg per 100 oh
Chrome	max. 0.3 mg/kg per 100 oh
Copper	max. 1.0 mg/kg per 100 oh
Iron	max. 1.0 mg/kg per 100 oh
Lead	max. 1.0 mg/kg per 100 oh
Tin	max. 0.3 mg/kg per 100 oh

TCG 2032 / TCG 2032B

Aluminum	max. 0.5 mg/kg per 100 oh
Chrome	max. 0.5 mg/kg per 100 oh
Copper	max. 1.0 mg/kg per 100 oh
Iron	max. 2.0 mg/kg per 100 oh
Lead	max. 1.0 mg/kg per 100 oh
Tin	max. 0.5 mg/kg per 100 oh

2105/23 EN



Conversion table		
1 mg/kg	1 ppm	0.0001 %
10 mg/kg	10 ppm	0.001 %
100 mg/kg	100 ppm	0.01 %
1000 mg/kg	1000 ppm	0.1 %
10000 mg/kg	10000 ppm	1.0 %



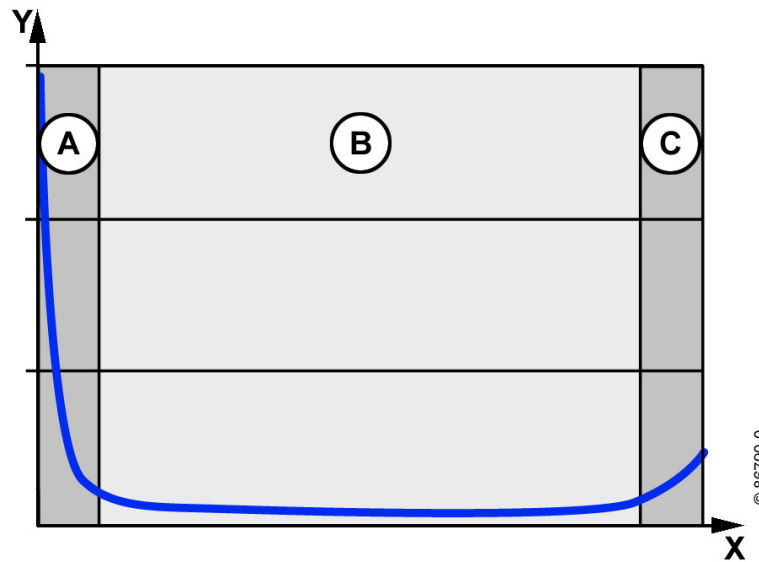
2105/23 EN

Lube oil consumption

The specific lube oil consumption is to be understood as the lube oil volume which is consumed per unit of time at a definite power.

The lube oil consumption is determined over a longer period in the same type of operation in continuous operation.

The lube oil consumption drops after the first few operating hours (run-in time). Then it should remain constantly low for a longer period. The wear in the engine increases with a very long running time and with it the lube oil consumption.



A 4

X axis:	Period
Y axis:	Lube oil consumption
Range A:	Run-in time
Range B:	Operating period
Range C:	Period of rising lube oil consumption due to increasing material wear

2105/23 EN



Interpretation of parameters of the lube oil analysis

Viscosity

Unit: mm²/s

The viscosity indicates the flow capacity of the lube oil (resistance to shift of two adjacent layers, inner friction). The viscosity is temperature-dependent.

The viscosity is increased by:

- Ageing/oxidation
- Soot/solid foreign bodies
- Evaporation of lightly boiling components

Total Base Number (TBN)

Unit: mgKOH/g

The TBN indicates the alkaline reserve of the lube oil and characterizes the chemical neutralization capacity.

This is a necessary property of the lube oil to check the corrosive wear.

With the use of the lube oil, 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.

In operation with acid forming fuel gases (especially landfill, sewage and biogases), a fast decomposition of the TBN is to be expected.

Acid Number (AN, formerly TAN) or Neutralization Number (Nz)

Unit: mgKOH/g

The method covers the strong and weak acids. The strong acids are recorded separately as Strong Acid Number (SAN). Lube oil ingredients influence the value of the AN which may be between 0.5 and 2 mgKOH/g in new lube oils.

Oxidation and nitration processes can produce weak organic acids. These are only partially neutralized by the alkaline properties of the lube oil. If the lube oil has a sufficient alkaline reserve, the AN only records the weak organic acids.

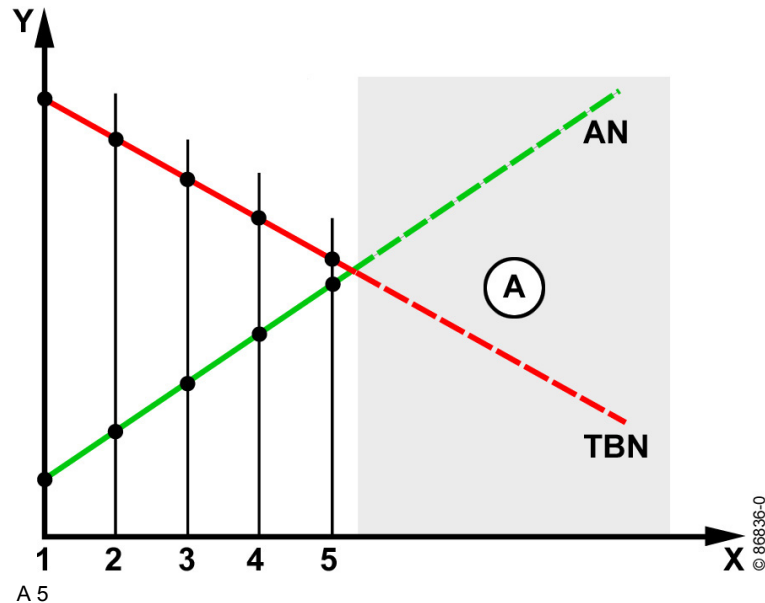
There is a rough correlation between AN rise, lube oil ageing and lube oil nitration.



2105/23 EN

Explanation of the relation between TBN and AN

The TBN falls whilst the AN rises. Since, according to the limit value list, the AN must always be smaller than the TBN, no engine operation is permitted in range A.



X axis:	Period
Y axis:	Numeric value of the analysis result
Range A:	Non-permitted operating period
Position 1-5:	Time of the lube oil analysis
Position 5:	Time of the next lube oil change

Strong Acid Number (SAN)

Unit: mgKOH/g

The method only covers strong acids (e.g. sulfuric acid). If a SAN is proven, there is a risk of corrosion. The determination of the SAN is only necessary for fuel gases of the Low gas quality.

Ageing/oxidation

Unit: A/cm

Ageing/oxidation is caused by reaction of the basic oil and ingredient molecules with oxygen which leads to an increase in the viscosity and the Acid Number. Component smearing and sludge deposits can occur. The oxidation products can form organic acids which lead to corrosion even when the lube oil still has alkaline reserves.

The extinction at the wave number 1710 cm^{-1} in the infrared light spectrum is measured whereby the carbonyl compounds formed in the oxidation are measured.

2105/23 EN



Nitration

Unit: A/cm

Nitration is caused by reactions of the basic oil and ingredient molecules with nitrogen oxides. The influences are comparable with those of the ageing/oxidation. They lead to changes in the lube oil parameters. However, the risk of corrosive reaction products is higher in comparison. In the case of strong nitration, a strong decomposition of the alkaline reserve usually also occurs.

The extinction at the wave factor cm^{-1} in the infrared light spectrum is measured.

i pH

Unit: none

The method serves to determine the pH value of the lube oil. The measurement result is specified in dimensionless pH value units. Over-acidification of the lube oil leads to corrosive wear.

Water

Unit: wt.%

Water in the lube oil generally leads to an emulsion which leads on the whole to increased wear and corrosion risk.

Water increases the viscosity of the lube oil.

Possible causes:

- Leaks in the coolant system
- Condensation processes in the lube oil system by frequent starts and emergency stops
- Improper storage of the lube oil
- Insufficient ventilation of the crankcase or lube oil tank
- Penetration of rain water into the exhaust system

Glycol

Unit: ppm

Glycol leads to formation of sludge and filter blockage due to reaction with the lube oil ingredients.

Glycol is incompatible with mineral oil.

Possible causes:

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



2105/23 EN

Interpretation of elements of the lube oil analysis

Silicon

Unit: mg/kg

Possible origin:

- Component in antifoaming ingredients
- Dust from the sucked-in air
 - leads to abrasive wear even in the smallest of amounts.
- Compounds of fuel gases (e.g. landfill, sewage and biogases)
 - The silicon load in the lube oil also gives an indirect indication of the silicon load of the fuel gas.

Sodium

Unit: mg/kg

Typical element of ingredients for corrosion protection in the coolant. Strong increase in the sodium content is a sign of contaminated coolant. The engine must be checked continuously for possible coolant leaks in the course of further operation.

In many cases no water can be found in the lube oil despite high sodium values and the associated contamination because this evaporates due to the lube oil temperature in engine operation.

Aluminum

Unit: mg/kg

Typical wear element of pistons and slide bearings for example.

Aluminum may also be a part of contaminated suction intake air under certain circumstances.

Iron

Unit: mg/kg

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

2105/23 EN



Chrome

Unit: mg/kg

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

Copper

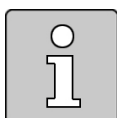
Unit: mg/kg

Typical wear element of bearings and corrosion product of lube oil coolers and lube oil lines. Copper is also part of different mounting compounds.

Lead

Unit: mg/kg

Typical wear element of slide bearings and solder from lube oil coolers and lube oil lines.



The cause of a rapid change in the wear rate for lead and copper is frequently chemically corrosive wear (note limit value for i pH value).

Tin

Unit: mg/kg

Typical wear element of slide bearings.

Molybdenum

Unit: mg/kg

May be part of lube oil ingredients as well as different mounting compounds.

Also used as a running surface coating for sliding bearings.

Interpretation of optionally analyzed elements of the lube oil analysis

Potassium and boron

Unit: mg/kg

Typical elements of ingredients for corrosion protection in the coolant. An increase in the lube oil is a sign of a contamination by coolant.

However, boron is a typical element of frequently used ingredients in the lube oil.

Calcium, zinc, phosphorus, sulfur

Unit: mg/kg

Typical elements of ingredients in the lube oil.

Sulfur is also a part of the lube oil and fuel gases.



2105/23 EN

Service Information

This document was created digitally and is valid without a signature.

This is a translation of the German original. All translations are based on the German original.