service

OIL AND COOLANT DIAGNOSTICS,
YOU CAN COUNT ON.

LET'S DO THE WORK.™

ZEPPELIN Power Systems

OIL CAN
TELL MANY STORIES . . .

Z.O.D. – Zeppelin Oil Diagnostics: The word diagnostics comes from medicine. The development of this test method originated with successful blood testing practice and the resultant diagnosis.

Just like blood, oil has access to all points of the system. The functional processes at these locations influence the oil. Thus, conclusions about the condition of a technical system can be drawn by testing the oil. This idea first provided impetus for successful development in aviation.

Almost 40 years ago, Caterpillar and Zeppelin started to use oil diagnostics on machines.

Today Zeppelin has its own, comprehensively equipped oil laboratory in which our specially trained chemists conduct more than 100,000 oil diagnoses per year. Modern laboratory technology, a powerful database, and decades of experience are the basis for practice-oriented analysis with a high level of relevance.

CONTENT

BOOSTING KNOWLEDGE, GOING PLACES: ZEPPELIN OIL AND COOLANT DIAGNOSTICS.

Zeppelin oil and coolant diagnostics provide valuable information about the condition of the engine, axles, transmission, hydraulic and cooling system of any machine. This helps to prevent downtimes; it can even help to extend oil change intervals. Your machines work better, live longer and are thus more economical all told.

Like reading an open book, the experts at the Zeppelin laboratory 'read' the engine, transmission, axle and hydraulic oil, and coolants. Is the wear within the normal limits? How clean is the hydraulic fluid? When do operating fluids, units and wear parts need to be changed? Zeppelin experts often know more than everyone else, because they don't just take the unit from which the sample was taken into consideration, but also the type of machine. There is a crucial difference whether a sample comes from a stationary application (e.g., a CHP) or from a mobile application or industrial machine (e.g., a generator, farm machine)!

The database that understands your oil
Zeppelin draws on an extensive database that contains all the measured values from recent years. Each substance analysed in the engine, transmission or hydraulic oil allows a detailed statement about that unit and its wear condition. The data basis for this has been built up over decades. However, please note that detecting wear trends requires multiple measurements at regular intervals!

Oil testing instead of downtime
An example: increased silicon levels in the engine oil are all it takes to tell you that the air filter and intake system need to be checked. Dust-related engine damage can thus be largely avoided.

Analyses in the Zeppelin laboratory – state-of-the-art equipment, trained chemists and short response times

Contamination control: Stopping creeping hydraulic killers in time
Caterpillar puts a huge amount of effort into ensuring that all our machines and equipment are supplied with the purest possible hydraulic fluid and with thoroughly cleaned circuits. But things do not always stay that way in the daily grind. Even very small particles in the hydraulic fluid can cause major damage in the long term because of the high pressures and minimal production tolerances in hydraulic systems.

This is why you can also call the Zeppelin oil laboratory to determine the particle count in your hydraulic fluid. If necessary, a new oil fill, or fine filtering of the oil, is your best choice – and one of the smartest and best investments for your machine.

With more than 100,000 oil and coolant analyses per year, the Zeppelin oil laboratory has extensive experience

Coolant analysis – protects inner values
Coolant diagnosis can also be carried out in our laboratory. It helps to monitor the coolant state – that is, its boiling point and frost protection capability – and the cooling system. At the same time, regular coolant diagnosis is important to ensure that the engine parts are protected against internal perforation and corrosion.

Useful results, rapidly transmitted
The results of each Zeppelin oil and coolant diagnosis are presented in a clear-cut way and practically interpreted to make them understandable for a non-chemist. And we notify you immediately in critical cases. In addition, you can receive your current measurement results by email, or even retrieve them via the Internet (www.zeppelin-cat.de/zod).

We only let our own specially trained experts, working with our own analysis equipment, look at your oil and coolant samples

ZEPPELIN OIL DIAGNOSIS – EASY TO USE, EXTENSIVE DIAGNOSTICS, MAJOR PRACTICAL BENEFITS.

For many operators of Caterpillar machines and engines, Zeppelin oil analysis is already a regular practice. As part of our service contracts, the Zeppelin service technician takes samples from the managed machines. In addition, anyone can order sampling sets and send the oil samples for analysis to our laboratory.

The easiest way to benefit from Zeppelin oil analysis is in the scope of a service agreement. In this case, the service technician regularly takes oil samples and sends them to our oil lab. Of course, you can also request individual oil analysis from Zeppelin service. Please contact your Zeppelin location, or Zeppelin service advisor for details. We provide practical sampling sets for all customers who prefer to take oil samples themselves.

The test kits include everything you need for sampling and returning the samples to the Zeppelin oil laboratory. Newer machines are provided with defined oil sampling points, or offer an upgrade option. It is also possible to sample operating fluids with the engine running in many cases. Before taking samples, please check whether you need the special extraction pump for clean sampling and, if so, add it to your order.

THE CLEAR ADVANTAGES OF Z.O.D. EVALUATION:

– Optimising oil change intervals – in normal or favourable operating conditions, the oil change intervals can be extended; in tough operating conditions, oil change intervals can be optimised
– Minimal wear on the high-quality components and optimum use of resources
– Continuous monitoring of the condition of the engine, transmission, hydraulic system, axles, etc.
– Dates for machine use or repairs can be planned more effectively
– Imminent damage can be detected at an early stage thanks to regular laboratory analyses
– Proactive repairs protect against major and unforeseen damage
– Troubleshooting support

PURPOSE OF THE OIL ANALYSES:

– **ICP emission spectroscopy**
Determination of abrasion metals, contaminants, additives and mineral oil residual content in case of switching to bio-oil
– **FT-IR spectroscopy**
Determination of oil status values
– **Particle count**
Determination of oil purity as per ISO 4406
– **PQ index**
Measurement of ferromagnetic components in the oil
– **Viscometer/viscosity**
Determination of the viscosity at 40°C and 100°C, and the viscosity index (VI)
– **Water detection/Water content**
Crackle test; Karl Fischer titration
– **Gas chromatography**
Determination of glycol and fuel content in oils
– **Flash point**
Determination of the flash point of fuels or oils
– **TBN**
Determination of the total base number
– **TAN**
Determination of the total acid number

SAMPLING SETS AND THEIR SCOPE OF ANALYSIS.

SET 1
Standard

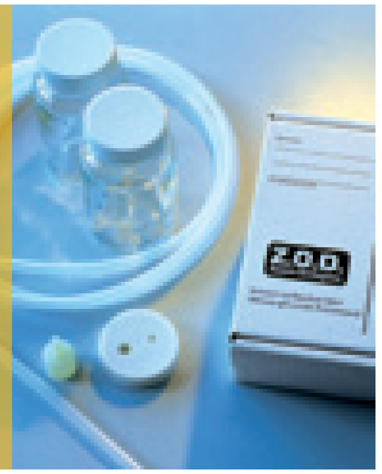
Individually, Order number	KX 2331
Pack of 10, Order number	2LZ 0513
Pack of 30, Order number	KX 2860
Pack of 50, Order number	KX 2862

Engine: ICP, FT-IR spectroscopy, water content, gas chromatography, viscosity (100°C)
Gas engines: (Recommended set 2) ICP, FT-IR spectroscopy, water content, gas chromatography, viscosity (100°C)
Hydraulics: ICP, FT-IR spectroscopy, water content, particle count, gas chromatography, viscosity (100°C)
Biohydraulics: (Recommended set 2) ICP, water content, particle count, gas chromatography, viscosity (100°C)
Transmission: ICP, water content, gas chromatography, viscosity (100°C), FT-IR spectroscopy, particle count
Axles: ICP, water content, PQ index, FT-IR spectroscopy, viscosity (100°C)

SET 2
For an extended scope of inspection

Individually, Order number	KX 2420
Pack of 10, Order number	2LZ 0609

Engine: ICP, FT-IR spectroscopy, water content, flash point, gas chromatography, TBN, viscosity (40°C, 100°C) +VI, fuel content
Gas engines: ICP, FT-IR spectroscopy, water content, gas chromatography, TBN, viscosity (40 °C, 100 °C) +VI
Hydraulics: ICP, FT-IR spectroscopy, water content, particle count, gas chromatography, TAN, viscosity (40°C, 100°C) +VI
Biohydraulics: ICP, water content, particle count, gas chromatography, TAN, viscosity (40°C, 100°C) +VI
Transmission: ICP, water content, gas chromatography, TBN, Viscosity (40°C, 100°C) +VI, FT-IR spectroscopy, particle count
Axles: ICP, water content, PQ index TBN, viscosity (40°C, 100°C) +VI, FT-IR spectroscopy, viscosity (100°C)



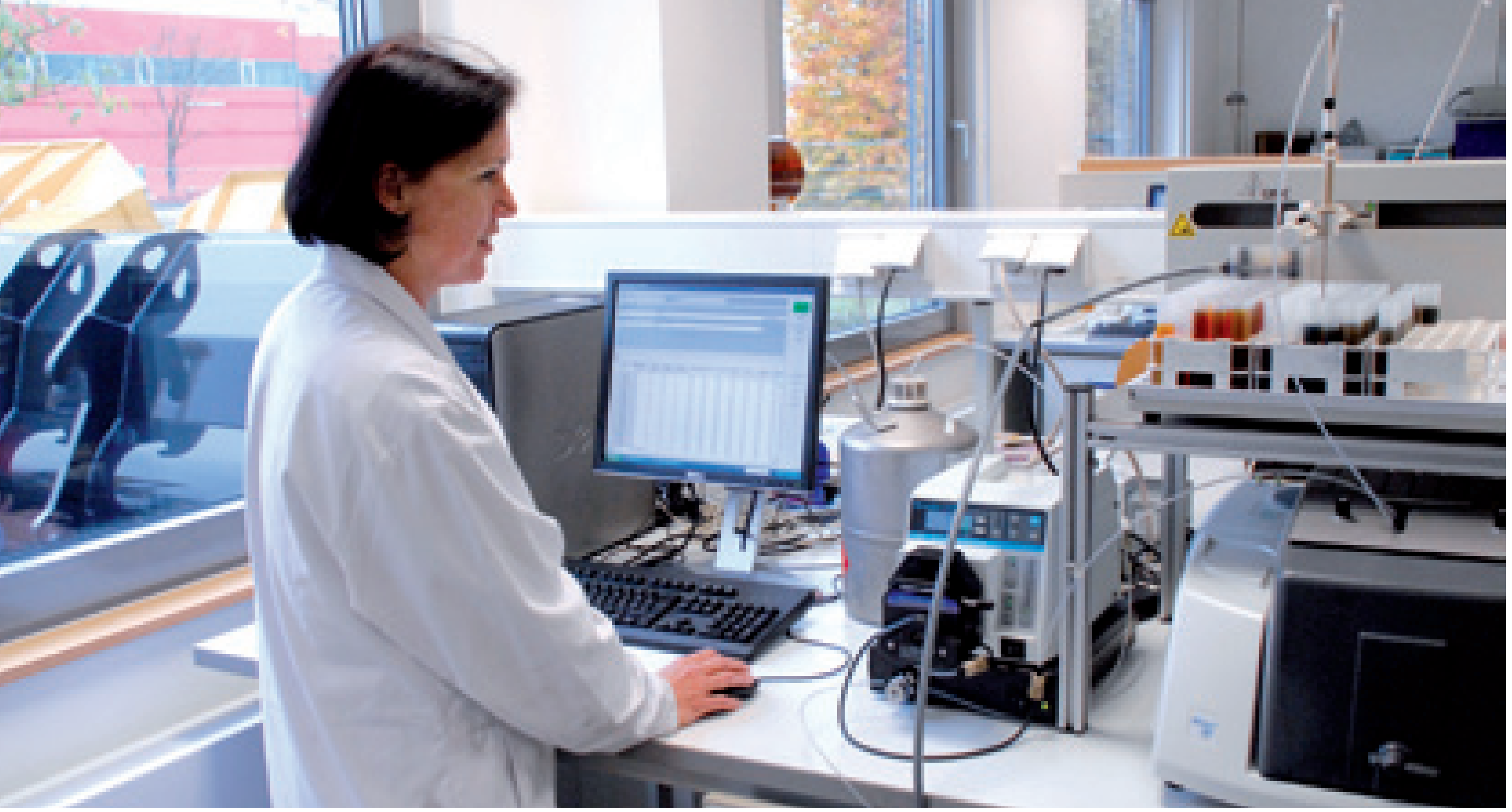
SET 3
Only for coolant analysis

Individually, Order number	KX 2764

Glycol concentration
(freeze protection temperature)
Nitrite concentration
(cavitation protection)
pH value
Conductivity
Visual inspection
Odour analysis

ZEPPELIN EXTRACTION PUMP

Order number	1u 5718



Determination of the oil state values by FT-IR spectrometry

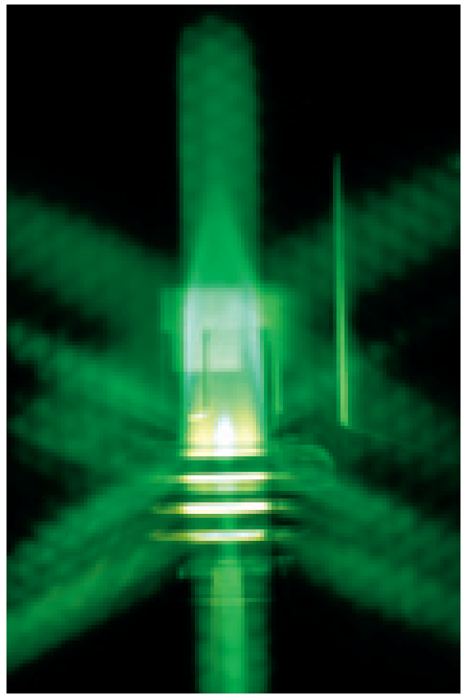
OIL STATUS VALUES – AGING CHECK FOR YOUR OIL.

Investigating oil status values
The oil status parameters are the concentrations of carbon black, oxidation, nitration and sulphation in the oil. The test oil sample is drawn into a cuvette and an infrared beam is passed through it. An infrared spectrum is recorded during the process; it registers the absorption of the infrared radiation as a function of the wave number. Quantitative evaluation is based on the comparative spectra of sample of new oil (from an existing library) and the used oil sample. This means that, for an exact evaluation, the oil brand and viscosity grade must be stated. The higher the concentration of the parameters under testing, the higher the total absorption of IR radiation, and of the individual bands for characteristic wave numbers.

Carbon black, oxidation, nitration and sulphation are determined for engine oils (see page 22 for more information); only the oxidation is measured for mineral hydraulic oils. Bio-hydraulics oils cannot be measured using IR spectrometry because of the presence of esters. They should therefore be returned as a set 2 to be able to evaluate the oil condition via the viscosity and TAN.

Based on the oil status values, we can also draw conclusions about meaningful oil change intervals for particular applications. Depending on the results, this may mean that you need to change the oil sooner, or can change it later. In the former case, this prolongs the engine service life; in the second, you save money and also protect the environment.

ABRASION ELEMENTS – MINIMISING WEAR.



ICP plasma torch

Investigation of abrasion elements, additives, and impurities; determination of residual mineral oil content for switching to bio-hydraulic oil
The abrasion elements, additives and inorganic impurities are determined by ICP emission spectrometry. Emission spectra are spectra of self-luminous substances, or substances excited to produce luminosity. Argon plasma optically excites the atoms and molecules causing them to emit the absorbed energy.

The concentration or increase in abrasion metals in lube oil can result in the following instructions or statements:

- We can identify imminent damage at an early stage in many cases. To do so, we use wear-element tables that enable us to detect, and sometimes can even locate, excessive wear or damage.
- Foreign bodies in the oil can reveal, e.g., mixing of incompatible oils or ingress of other impurities. The wear-element table is consulted to interpret the results. For example, if the silicon content is too high, the air intake system and air filters need to be checked.
- Increase of copper, sodium and lead indicates heat exchanger leakage. In this case, a coolant additive test is performed.
- Along with other tests, a decrease in additive elements can provide information about the used oil condition. The following additives are examined: molybdenum, sodium, zinc, phosphorous, barium, calcium and magnesium.

Determination of the residual mineral oil content for switching to bio-hydraulic oil
Mineral oil determination is based on the comparison of the concentration of additives of new bio-oil, mineral oil and mixed oil. Three oil samples are necessary for precise determination of the mineral content:

1. The mineral oil is the oil that is in the machine and designated for replacement by bio-oil.
2. New bio-oil is the oil which will replace the mineral oil.
3. Mixed oil, is the oil remaining in the machine after flushing.

ICP emission spectrometer

Particle counts to determine oil purity

OIL PURITY AND
FUEL DETECTION.

DETERMINING THE OIL PURITY

Solid contaminants in hydraulic oils, such as dust, rust particles, fine abrasion, cause unexpected malfunctions and premature wear of components.

Very fine-grained dirt particles that are not visible to the naked eye can be responsible for initial damage, as they act like grinding paste.

Engineering developments have led to continuous decreases in gap tolerances. The soiling responsible for abrasive wear and surface fatigue is thus also smaller than 5 microns. When measuring the oil purity, each particle in the sample passed through the sensor is counted and assigned to the respective size range. Oil purity classes are specified at particle sizes of > 4 microns, > 6 microns and > 14 microns. Furthermore, the particles are assigned to certain shapes.

OPTICAL EXAMINATION BY MICROSCOPE

The microscope is used to observe visible wear and contamination in the oil. The images can be recorded using a camera and archived.

PQ INDEX MEASUREMENT

The PQ index states the ferromagnetic component, i.e., the concentration of ferrous metals in the oil. The sample is passed into a magnetic field and the change in susceptibility is measured.

FUEL DETECTION IN THE OIL

Leaks in the fuel system or unfavourable operating conditions can cause oil dilution by fuel.

Using gas chromatography, it is possible to determine the fuel content in the oil as well as the fuel type (diesel, biodiesel, petrol). See page 14 for a brief description of the analysis method.

Gas chromatography

Viscometer

VISCOSITY, TBN AND TAN –
OPTIMISING OIL CHANGE INTERVALS.

Determining the viscosity
Viscosity is the ability of a substance to prevent its own deformation by the action of a shearing force.

Its absolute value, and changes in it depending on temperature and pressure, are determined by the molecular structure. This in turn determines how well an engine starts, how smoothly it runs, and how smoothly the transmission switches gear. It is critical to forming an effective lubricating film, both in terms of strength and of lubricating film thickness. The fluid friction in lubricating gaps affects the mechanical loss and thus the energy loss of moving parts. Thus, the right choice and constant monitoring of the viscosity are importing to achieving satisfactory lubrication results.

The flow time through a glass capillary under controlled conditions is an accurate measure of the resistance to shape change in the flow of a fluid. At the Z.O.D. lab, we thus determine the viscosity by measuring the flow times at constant temperatures. The values are measured at 40°C and 100°C to provide the kinematic viscosity in mm^2/sec. The viscosity index (VI) is determined from the viscosities at 40°C and 100°C. It is a measure of the change in viscosity as a function of temperature.

Determining the TAN/TBN by titration (top),
TAN measurement (bottom)

Determining the TBN (Total Base Number)
The combustion of sulphurous fuels generates acids which need to be neutralised by alkaline additives in the lubricating oil. Determining the TBN reveals whether an oil has a sufficiently high neutralisation potential.

The TBN is defined as the amount of perchloric acid, expressed as the equivalent amount of potassium hydroxide in mg, required to neutralise all of the alkaline components contained in 1 g of oil.

In sewage and landfill gas operations, the reaction products of the sulphur, chlorine and fluorine compounds contained in the fuel gas can lead to the formation of strong acids, combined with a drop in TBN and an increase in the acid number. If the neutralisation capacity of the used oil is exhausted, there is a danger of highly corrosive wear.

Determining the TAN (Total Acid Number)
The TAN expresses the content of acidic components in the lubricating oil. It is defined as the amount of potassium hydroxide in mg required to neutralise the acids contained in 1 g of oil.

Based on the values for viscosity, TBN and TAN, we can also draw conclusions about meaningful oil change intervals for particular applications. Depending on the results, this may mean that you need to change the oil sooner, or can change it later. In the former case, this prolongs the engine service life; in the second, you save money and also protect the environment.

WATER AND COOLANT DETECTION –
PREVENTION IS BETTER THAN REPAIR.

WATER DETECTION IN LUBE OIL
Water is undesirable in the lubricating oil. In combustion engines, water is a by-product of fuel combustion, but typically in the form of steam which escapes through the exhaust pipe. Water can condense in the crankcase if temperatures are too low. Small amounts of water can be dissolved in the oil, without this leading to oil turbidity. As the oil temperature increases, the ability of water to dissolve in oil increases.

An oil-water emulsion accelerates oil aging and impairs the lubricity; this significantly aggravates foaming and component corrosion. For hydraulic oils, foaming leads to cavitation in the hydraulic system, which can lead to serious damage.

CRACKLE TEST
This typical method involves apply an oil sample of about 0.5 ml oil to a hot plate at 140°C. If the sample contains water, it evaporates on the plate; in case of low water concentrations, a crackling noise is heard; in case of higher water concentrations, small droplets of oil are projected up. Based on the crackle intensity, a water content as low as 0.1% can be detected.

KARL FISCHER TITRATION
A precisely defined quantity of oil is placed in a heating chamber at a temperature of 120°C, and the evaporated water is fed through a gas circuit into the Karl Fischer solution. The concentration of water is determined by coulometric titration. This titration method can detect water content as low as 0.01%.

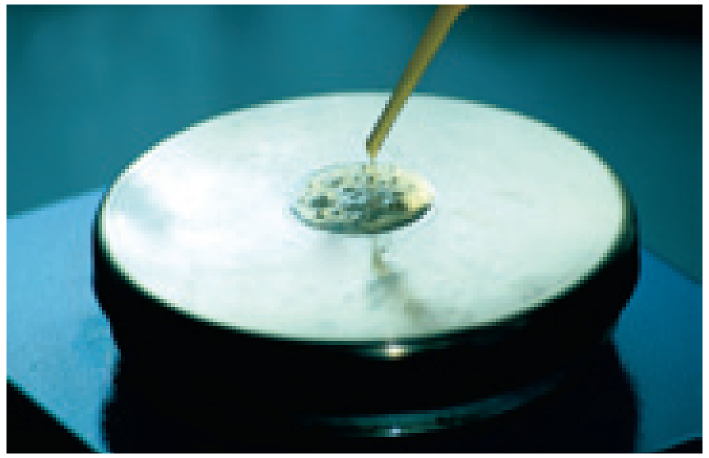
COOLANT DETECTION IN THE OIL
Leakages such as leaking cylinder head gaskets, heat exchangers, or sleeve liners, can cause coolant contamination in lubricating oils. If the oil is contaminated with coolant, this rapidly impairs the oil quality.

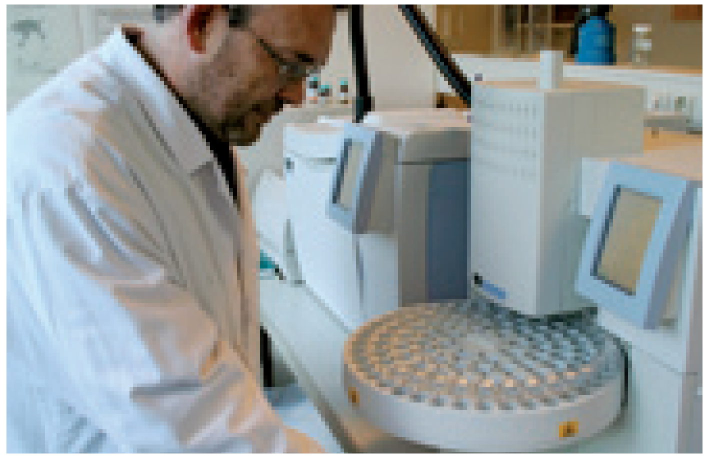
More specifically, the following quality degradations occur:
- Increase in viscosity due to oil thickening
- Formation of sludge and deposits
- Increase in nitration values due to increasing oil acidity

Since every coolant contains glycol as an antifreeze agent, it is possible to detect coolant in the oil by means of gas chromatography. Gas chromatography is used to break down complex mixes of materials into their components.

In this case, the mixture to be analysed is evaporated in an oven, and injected through an injector into a thin capillary column. The separation column is installed in a thermally controllable oven and is permanently traversed by hydrogen as a carrier gas. When the vapour phase of the used motor oil enters the separation column, the gaseous components are flushed through the column by the carrier gas.

Depending on their structure and the prevailing temperature in the oven chamber the individual components then have dwell for different times on the surface of the column. They are thus separated to reflect their boiling points. On exiting the column, a detector registers the individual components and draws them as peaks in a chromatogram.


Crackle test


Gas chromatography

Water determination according to Karl Fischer

Determining the nitrate concentration

COOLANT ANALYSIS –
PROTECTS THE COOLING SYSTEM.

COOLANT ANALYSIS
Coolant analysis enables coolant diagnostics. Regular coolant analysis makes the diagnosis most meaningful and monitors the condition of the coolant and the cooling system (pitting and corrosion) in the best possible way.

RECOMMENDED SAMPLING INTERVALS
Perform stage 1 coolant analysis depending on the application every 500 hours of operation. Perform stage 2 coolant analysis once a year.

REGULAR COOLANT ANALYSIS: STAGE 1
Stage 1 coolant analysis examines the properties of the coolant in terms of:

- Glycol concentration (frost protection temperature)
- Nitrite concentration (cavitation protection)
- pH value
- Conductivity
- Appearance
- Smell

REGULAR COOLANT ANALYSIS: STAGE 2
Stage 2 coolant analysis is a comprehensive chemical investigation of the coolant; besides revealing the condition of the coolant it also indicates the condition of the components in the cooling circuit. Stage 2 coolant analysis includes:

- All analyses from stage 1
- Identifying the cause of metal corrosion and contamination
- Identifying accumulated contaminants that cause corrosion
- Identifying accumulated impurities that cause scale
- Identifying potential electrolysis in the engine cooling system
- Quantitative determination of all metals that can appear due to corrosion
- Quantitative determination of all corrosion protection additives

Regular sampling is also important for coolant analysis

Determination of the glycol content in the coolant

Conductivity and pH measuring instrument

Karl Fischer hydrometer (determining water)

WEAR ELEMENTS – ORIGINS AND CAUSES.

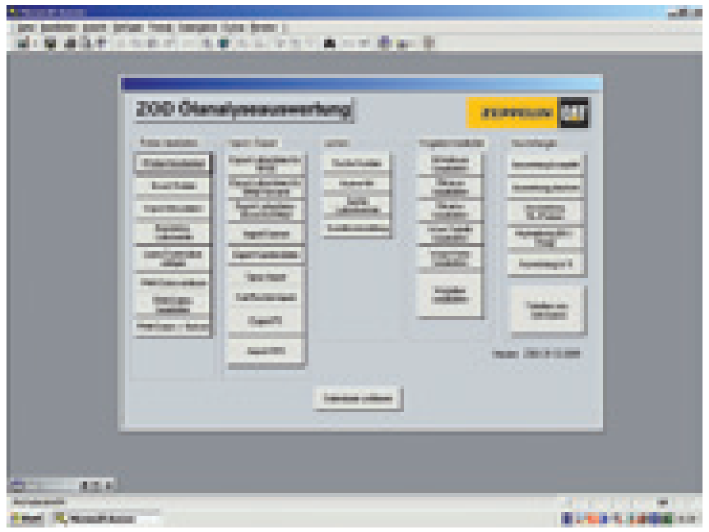
Overview

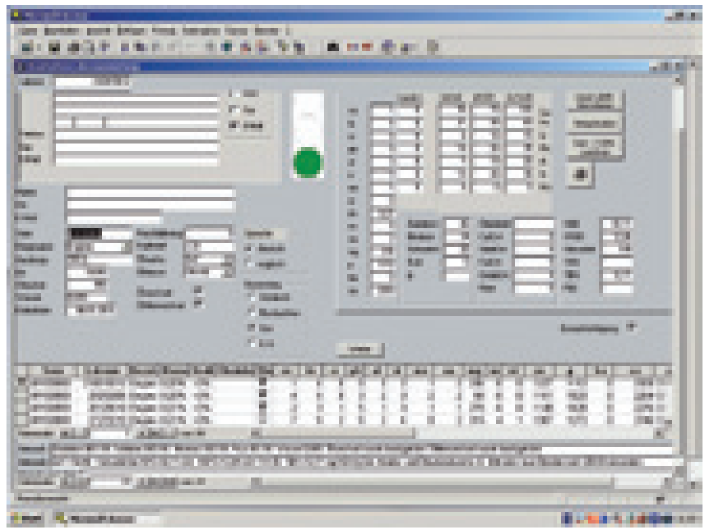
Element	Engine	Transmission	Hydraulics	Drives, axle planetary gear	Differentials
Copper (Cu)	Oil additives (no damage cause), leaching of heat exchangers, plain bearings: – Turbocharger – Governor – Oil pump – Piston pin – Rocker – Roller tappet – Compressor – Injection pump – KW thrust washer – Steering wheels – Water pump – Oil pump drive	Oil additives (no damage cause) Leaching of heat exchangers Plain bearings in the torque converter Friction plates of the gear and directional clutches Friction plate on the converter bridging clutch (only sintered bronze) Friction plates on the steering couplings and brakes (sintered bronze/shared oil sump)	Oil additives (no damage cause) Leaching of heat exchangers Plain bearings on pump Pressure plates (gear pumps) Sliding pieces and contact surfaces (axial piston pumps) Bronze thrust washers (vane pumps)	Oil additives (no damage cause) Thrust washers (wheeled units) Bronze plain bearings (some wheeled units)	Oil additives (no damage cause) Thrust washers bronze plain bearings (some wheeled units)
Iron (Fe)	Cylinder liners Gear wheels: Crankshaft Camshaft Piston pin Oil pump Valvetrain Compressor Cam followers	Gear wheels Steel clutch plates Antifriction bearings Oil pump housing Splines Shafts Transmission housing Steering/brakes (shared oil sump)	Cylinders Pumps	Gear wheels Bearings Splines Shafts Planet carrier Housing Thrust pieces	Gear wheels Bearings Splines Shafts Housing
Chromium (Cr)	Antifriction bearings Compressor Piston rings Exhaust valves Crankshafts (reground)	Antifriction bearings (some)	Antifriction bearings (some) Bent piston rods Pump race	Antifriction bearings (some)	Antifriction bearings (some)
Aluminium (Al)	Main bearings Connecting rod bearings Camshaft bearings Balancer shaft bearings Crankshaft thrust bearings Rocker carriers Oil pump bearings Steering wheel bushes Compressor Pistons Injection pump roller tappets Ingress of dirt (clay/loamy soil)	Torque converter/pump impeller Oil pump bearings Ingress of dirt (clay/loamy soil)	Piston rod bushing Pump housing Ingress of dirt (clay/loamy soil)	End face mechanical seals Bushes made of bronze/aluminium alloy (some wheeled units) Ingress of dirt (clay/loamy soil)	Thrust washers Bushes made of bronze-aluminium alloy (some wheeled units) Ingress of dirt (clay/loamy soil)
Lead (Pb)	Main bearings Connecting rod bearings Camshaft bearings Turbocharger bearings	Clutch disc linings (binders)	–	–	–
Molybdenum (Mo)	Upper piston rings (some engines) Molybdenum greases	Molybdenum greases	Molybdenum greases	Molybdenum greases	Molybdenum greases
Silicon (Si)	Ingress of dirt Silicon lubricating greases Anti-foam oil additives	Ingress of dirt Silicon lubricating greases Anti-foam oil additives	Ingress of dirt Silicon lubricating greases Anti-foam oil additives	Ingress of dirt Silicon lubricating greases Anti-foam oil additives	Ingress of dirt Silicon lubricating greases Anti-foam oil additives
Sodium (Na)	Cooling system leakage Water ingress Condensation Oil additives (no damage cause)	Cooling system leakage Water ingress Condensation Oil additives (no damage cause)	Cooling system leakage Water ingress Condensation Oil additives (no damage cause)	Cooling system leakage Water ingress Condensation Oil additives (no damage cause)	Cooling system leakage Water ingress Condensation Oil additives (no damage cause)

COMBINATIONS OF
WEAR ELEMENTS.

Overview

Main element	Secondary element	Potential wear	Problem area, causes of damage, secondary damage
Engine – upper area			
Silicon (dirt)	Iron, chromium, aluminium	Cylinder liners, piston rings, pistons	Air intake system, air filter, soiling
Iron	Chromium, aluminium	Cylinder liners, piston rings, pistons	Abnormal operating temperatures, oil decomposition, soiling, seized/broken piston rings
Chromium	Molybdenum, aluminium	Piston rings, pistons	Compression loss, oil consumption, oil decomposition
Iron		Cylinder liners, gear wheels, valve trains	Abnormal operation crankshaft, lack of lube oil, soiling, deposits
Motor – lower section			
Silicon (dirt)	Lead, chromium	Bearing shells	Soiling
Lead	Aluminium	Bearing shells	Lack of lube oil, soiling in the cooling and/or fuel system
Hydraulics			
Silicon (dirt)	Iron, chromium Iron, copper	Cylinders, piston rods Hydraulic pump	Soiling Oil decomposition, soiling
Transmission			
Aluminium	Iron, copper	Torque converter	Oil decomposition, soiling
Copper	Iron	Clutch friction plates with sintered bronze linings	Oil decomposition, soiling
Drives, axle planetary gear			
Silicon (dirt)	Iron, aluminium, sodium	Gear wheels	Soiling, aluminium (clay/loamy soil), sodium (water)
Iron	Chromium	Gear wheels, bearings	Incorrect preload





The software tool, specially developed by Zeppelin, helps our technicians to interpret the oil samples in an unambiguous way

Engine

Fe, Cr, Al	Pistons, piston rings, cylinder liners
Pb, Al	Bearing shells
Pb, Al, Fe	Bearings, crankshaft
Na, Cu	Coolant or glycol in the oil
Si, Fe, Cr	Soiling in the upper engine area
Si, Fe, Al, Pb	Soiling in the lower engine area
Cu, Pb, carbon black	Turbocharger bearings
Cr, Sn	Antifriction bearings Cam followers, water pump, compressor
Sn	Testing for lead – bearing shell wear
Cu, Al, Fe	Connecting rod eye and piston pins
Fe, Cr	Broken or seized piston rings, ether start-up, operating temperatures too high or too low, oil spray nozzles damaged

Carbon black

Cr, Fe	Piston rings, cylinder liners
Mo, Cr, Fe	Top piston ring with moly plasma coating, compression rings, oil scraper rings and liner wear

Oxidation

Cu	High peak values due to heat exchanger leaks
Fe	Liners, gear wheels, or valve train
Pb, Al	Bearings
Al	Self-oxidation possible, piston skirt wear

Sulphur

Pb	Historic values: increase by a few ppm for each 20 % increase in the sulphur content

Sulphur and carbon black

Targeted value for satisfactory engine life:
20 – 30% of the other element in each case (generally carbon black reaches the higher percentage)

Transmission

Fe, Cu	Clutch disc lining wear (only friction discs with sintered bronze); Check the filter screens – looks similar to filter material
Al	Torque converter
Al, Cu, Fe	Torque converter
Cu	Leaching of the heat exchanger
Cu, Na (possibly Si)	Probably cooling system leak – check for glycol content
Fe, Cr	Antifriction bearings

Oxidation increase, extended oil change intervals, coolant ingress into system – watch out for any oil overflow

Pb = EP transmission oil

Side drives/ axle planetary gear

Si, Fe	Na in case of water ingress, Al in some clay/loamy soils – soiling ingress; mainly in deployment on landfills and boggy ground; soiling can also enter through mechanical seals during pressure cleaning Oil additives: Cu and/or Pb can increase
Fe, Cr	Gear wheels and antifriction bearings (typically incorrectly preloaded)
Fe	Consistently high values indicate gear wheel damage, check ling magnetic plug for metal accumulation

Also check

- Number of operating hours. Have repairs been performed and/or non-original spare parts been used recently?
- Take local topography and geography into account
- Check wear on the opposite side
- Match with wear tables
- Has there been a driver change?

Al, Cu, Fe	Bronze bushes in driving axles (differential gears, planetary gear axles)
H_2O, Fe, Na	Water ingress
Cu	Increasing trend: Thrust washers worn

Hydraulics

Cu	Radiator/heat exchanger leak
Fe, Cr	Cylinder (plus Si = soiling; check for scoring on piston rods and soiling deposits on scraper rings) Possible pump or engine wear (Cr from pump bearings)
Fe, Cr (no Si)	Dirt ingress into pump or motor (possibly also Cr increase)
Cu, Fe, Si	Vane pump = Cu, Cr, Fe Axial piston pump = Cu, Fe (Al in case of Swash plate bearing wear) Gear pump = Cu, Fe, or Al (housing)
Cu, Si, Na Al	Possibly cooling system leak – check for glycol Possibly wear on the swash plate bearing in case of axial piston pumps

OIL LUBRICITY
IN THE COMBUSTION ENGINE.

All oil components that come into contact with the combustion process are altered chemically to a lesser or greater extent. This impacts the lubricity and corrosion protection properties of the oil. The most important changes are detected by the oil status values. For and overall evaluation of the oil's suitability for use, the oil status values, the results of wear analysis, and other investigations all need to be taken into consideration. Other important factors in the assessment include oil service life, and the top-up volume.

CARBON BLACK
Incomplete combustion of fuel results in the formation of carbon black, which then partially enters the oil. Carbon black affects the oil properties negatively and can result clogging of filters and lines if larger amounts occur. Therefore, each engine oil contains dispersants which keep the carbon black in suspension. The amount of carbon black must not exceed the capacity of the dispersants.

Causes of increased carbon black formation in Caterpillar engines
- Incorrect injection volume adjustment
- Poor injector function
- Defective turbocharger
- Clogged air filters
- Increased blowby values
- Incorrect valve timing
- Unfavourable engine operation (for example, permanent full acceleration, extreme overload)

Consequences of carbon black formation
- Reduces the lubricating effect of the oil
- Increases abrasion when the capacity of the dispersant is exhausted and an agglomeration of carbon black particles is possible
- Clogged filters for the same reason
- Deposits on pistons
- Increased wear on cylinder liners
- Increased oil consumption

Benefits of determining the carbon black content
- Correct determination of the oil change interval; oil change intervals can be optimised in combination with wear particle analysis
- Can be used for performance diagnosis
- Can be used as an indicator of machine load for cost control

OXIDATION
Oxidation of lubricating oil occurs when it is exposed to combustion conditions (heat, water, acid, solid impurities) and metallic catalysts. Oil damaged by oxidation more or less loses its lubricating properties; it becomes more viscous and forms resins. Oxidation is the main characteristic of oil aging. It occurs in diesel engines, gas engines, and hydraulic systems.

Causes of oxidation
- Operating at high ambient temperatures
- Excessive operating temperatures due to defective or incorrect coolant thermostats or engine overload
- Delaying oil change intervals
- High abrasion values
- Contamination by water and glycol

Consequences of oxidation
- Reduced lubricity of the oil
- Increase in oil viscosity
- Clogging of the oil filters
- Formation of deposits on pistons
- Seizing of piston rings

Benefits of determining the oxidation
- Correct determination of the oil change intervals in combination with wear analysis
- Possible indication of excessive operating temperatures, air ingress and/or delayed oil change intervals

NITRATION
The nitrogen oxide produced during the combustion of atmospheric nitrogen causes organic oxygen-containing nitrogen compounds in the oil that are displayed in the IR spectrum. They have a similar effect on the oil as the oxidation products and also contribute to oil aging. Nitration occurs in diesel, petrol and gas engines.

Causes of the nitration
1. Whenever NOx is produced during operation:
   - Particularly in petrol and gas engines
   - Incorrect ignition timing
   - Fuel-lean combustion mixtures
2. Increased blow-by values

Consequences of nitration
- Reduces the lubricity of the oil
- Increase in oil viscosity
- Oil filter clogging
- Scale formation
- Aggravates corrosion

Benefits of determining the nitration
- Indicator of the remaining nitration protection in the oil
- Indicator of excessively low- or high-temperature operation of the engine
- In combination with other analytical values from the IR analysis and wear analysis, the oil change intervals can be accurately determined

SULPHATION
Sulphation means the formation of sulphur oxides from sulphur compounds during the combustion process in the engine. In combination with the water that also occurs there, sulphur trioxide forms strong sulphuric acid.

Causes of sulphation
- The main source of sulphur is the sulphur content in the fuel
- Low operating temperatures aggravate the nascent sulphur trioxide content
- High levels of humidity and water condensation in the crankcase aggravate sulphuric acid formation
- Increased blowby values
- Base additive content (TBN) in the oil too low in comparison with the resulting sulphur oxides

Consequences of sulphation
- Sulphuric acid attacks metal surfaces of valves, piston rings and cylinder liners
- Sulphuric acid reacts with various additives and destroys them, sludge is then formed in the oil

Benefits of determining sulphation
- Determining sulphation is a direct indicator of the previous use of protective additives
- It indirectly says something about the sulphur content of the fuel
- It indirectly indicates that the engine is operated at excessively low temperatures

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