



Oil Analysis Services
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OIL ANALYSIS TROUBLE SHOOTING GUIDE

This trouble shooting guide is designed to assist the user in not only interpreting oil analysis test reports, but implementing appropriate corrective actions as well. It is not intended to be a definitive reference, but an at a glance guide to be used with other reference materials.

SPECTROCHEMICAL ANALYSIS – WEAR METALS

IRON (Fe)

Origin: Blocks, Gears, Rings, Roller Bearings, Cylinder Walls, Cylinder Heads, Rust

Purpose: Because of its strength, iron is the base metal of steel in many parts of the engine. Since iron will rust, it is alloyed with other metals (i.e. Chromium, Aluminum, Nickel) making steel.

CHROMIUM (Cr)

Origin: Shafts, Rings, Chromate from Cooling System, chrome plating on crankshafts.

Purpose: Because of its strength and hardness, Chromium is used to plate rings and shafts that are usually mated with steel (softer). Chromium is also alloyed with iron (steel) for strength.

ALUMINUM (Al)

Origin: Bushings, Some Bearings, Pistons, Turbo Charger, Compressor Wheels

Purpose: Aluminum is a strong lightweight metal (smaller mass) which dissipates heat well and aids in thermal transfer.

COPPER (Cu)

Origin: Bearings, Bushings, Oil Coolers, Radiators, Camshaft Thrust Washers, Connecting Rod Bushings, Oil Additive for Anti-wear/anti-oxidant, valve guides.

Purpose: Copper is utilized to wear first in order to protect other components. Copper conforms well so it is used to seat bearings to the crankshaft.

LEAD (Pb)

Origin: Bearing Overlay, Oil Additive in Gear Lubes, Gasoline Contamination

Purpose: Lead is a conforming material used to plate bearings. Lead will appear in new engines while the bearings are melding and conforming. If lead appears later, misalignment may be indicated

NICKEL (Ni)

Origin: Valve Stems, Valve Guides, Ring Inserts on Pistons

Purpose: Nickel is alloyed with iron in high strength steel used to make valve stems and guides

SPECTROCHEMICAL ANALYSIS – WEAR METALS (cont')

SILVER (Ag)

Origin: Bearing Cages (low friction bearings), Silver Solder, Turbocharger bearings and wrist pin Bushings

Purpose: Silver is used to plate some components because it conforms well, dissipates heat and reduces coefficient of friction.

TIN (Sn)

Origin: Bearings, pistons

Purpose: Tin is a conforming material used to plate and protect surfaces to facilitate break-in.

MOLYBDENUM (Mo)

Origin: Piston rings, oil additives

Purpose: Molybdenum is used as an alloy in some piston rings in the place of Chromium. Molybdenum is also used as a friction-reducing additive in some oils. Soluble Molybdenum can be used as an antioxidant additive.

SPECTROCHEMICAL ANALYSIS – ADDITIVE ELEMENTS

ZINC (Zn)

Purpose: Anti-wear additive, which provides a protective film.

PHOSPHORUS (P)

Purpose: Anti-wear, Extreme Pressure additive that provides a protective film in high-pressure areas, Antioxidant Phosphorus is added to extreme pressure oils to provide a protective film. Extreme Pressure oils are characterized by high phosphorus.

BARIUM (Ba)

Purpose: Detergent: Barium is toxic and expensive but it is advantageous because it does not leave excessive ash residue.

CALCIUM (Ca) AND MAGNESIUM (Mg)

Purpose: Calcium and Magnesium are alkaline-based additives used to neutralize acids formed by products of combustion in engine oils. Calcium and Magnesium also have some detergent qualities.

BORON (B)

Purpose: Inhibitor
Boron is also found as an additive in coolant as borate. Also an additive in some gear oils.

COPPER (Cu)

Purpose: Antioxidant
Copper is added to engine oils to prevent oxidation.

SPECTROCHEMICAL ANALYSIS - CONTAMINANTS

POTASSIUM (K)

Origin: Potassium is a coolant additive and its presence in oil is indicative of coolant contamination. Also, present as an additive in some gear oils.

SPECTROCHEMICAL ANALYSIS – CONTAMINANTS (cont')

SODIUM (Na)

Origin: External contamination, additive or coolant. Sodium is not a wear metal. Its source is from coolant or the environment (salt) and or salt water.

SILICON (Si)

Origin: External (dirt), Additive, Sealant's. Silicon can be an anti foam additive in the form of silicone.

FUEL DILUTION

Fuel dilution of crankcase oil by unburned fuel reduces lubricant effectiveness. The thinning of lubricant can lead to decreased lube film strength adding to the risk of abnormal wear. Depending on certain variables, when fuel dilution exceeds 2.5% to 5%, corrective action should be taken. Both gas chromatography and fuel dilution meters measure fuel dilution.

SOURCE

Incorrect air to fuel ratio
Extended idling
Stop and go driving
Defective injectors
Leaking fuel pumps or lines
Incomplete combustion
Incorrect timing

RESULT

Metal to metal contact
Poor lubrication
Cylinder ring wear
Depleted additives
Decreased oil pressure
Reduced MPG
Reduced engine performance
Shortened engine life

SOLUTION

Check fuel lines, worn rings, leaking injectors, seals, and pumps
Examine driving or operating conditions
Check timing
Avoid prolonged idling
Change oil and filters
Check quality of fuel
Repair or replace worn parts

VISCOSITY

Viscosity is one of the most important properties of lubricating oil. Viscosity is a measurement of resistance to flow at a specific temperature in relation to time. The two most common temperatures for lubricating oil viscosity are 40°C and 100°C. Viscosity is normally evaluated by a kinematic method and reported in centistokes (cSt). In used oil analysis the used oil's viscosity is compared to that of the new oil to determine whether excessive thinning or thickening has occurred.

VISCOSITY (con't)

SOURCE

High viscosity

Contamination soot/solids
Incomplete combustion- A/F ratio
Oxidation degradation
Leaking head gaskets
Extended oil drain
High operating temperature
Improper oil grade
Mixing of oils

Low Viscosity

Additive shear
Fuel dilution
improper oil grade
Mixing of Oils

RESULT

High Viscosity

Increased operating costs
Engine overheating
Restricted oil flow
Oil filter by-pass
Harmful deposits or sludge

Low Viscosity

Engine overheating
Poor lubrication
Metal to metal contact
Increased operating costs

SOLUTION

Check air to fuel ratio
Check for incorrect oil grade
Inspect internal seals
Check operating temperature
Check for leaking injectors
Change oil and filter
Check for loose fuel crossover lines

WATER/COOLANT CONTAMINATION

Water presence in engines indicates contamination from outside sources. These sources may be condensation of moisture from the atmosphere, or from internal water leaks. Engines at normal working temperatures normally evaporate water. However, water may remain in the oil when engine temperatures are too low for evaporation to occur. Other types of equipment, when operated at satisfactory temperatures also have a tendency to evaporate water contamination.

Oil analysis can identify water/coolant contamination before a problem occurs. ASTM D-6304, the Karl Fischer method is used to measure water in systems, which are sensitive to low moisture content.

SOURCE

Low operating temperature
Defective seals
New oil contamination
Coolant leak
Improper storage
Cracked head
Weather/moisture
Product of combustion

RESULT

Engine failure
High viscosity
Poor lubrication
Corrosion
Increased engine heat
Acid formation
Weld spots
Reduced additive effectiveness

WATER/COOLANT CONTAMINATION Con't

SOLUTION

- Tighten head bolts
- Check head gaskets
- Inspect heat exchanger and oil coolers
- Evaluate operating conditions
- Check for external sources
- Change oil filters
- Pressure check cooling system

SOLIDS

Solids represent a measurement of all solid and solid-like material in a lubricant. The makeup of solids depends on the system. In diesel engines fuel soot is usually the major component measured. In non-diesel components wear debris and oil oxidation products are measured.

SOURCE

- Extended oil drain intervals
- Environmental debris
- Wear debris
- Oxidation by-products
- Leaking or dirty filters
- Fuel soot

RESULT

- Shorter engine life
- Filter plugging
- Poor lubrication
- Engine deposits
- Formation of sludge
- Accelerated wear Decreased oil flow

SOLUTION

- Drain oil
- Flush system
- Change operating environment
- Reduce oil drain intervals
- Change filters

TOTAL BASE NUMBER

Total Base Number (**TBN**) represents the amount of alkaline additives in the lubricant which neutralizes the acidic products of combustion.

SOURCE OF LOW TBN

- High sulfur fuel
- Overheating
- Extended oil drain
- Improper oil type

RESULT

- Decrease of total base number
- oil degradation
- Increased wear rate
- Acid build up in oil

SOLUTION

- Use low sulfur diesel fuel
- Re-evaluate oil drain intervals
- Verify total base number of oil being used
- Change oil
- Test fuel quality

TOTAL ACID NUMBER

Total Acid Number (**TAN**) is the quantity of acid or acid-like derivatives in the lubricant. An increase in **TAN** from that of the new lubricant should be monitored. The **TAN** of a new oil is not necessarily nil since oil additives can be acidic in nature. Increases in **TAN** usually indicate lubrication oxidation or contamination with an acidic product. **TAN** is an indicator of oil serviceability.

SOURCE

High sulfur fuel
Overheating
Excessive blow-by
Extended oil drain intervals
Improper oil type

RESULT

Corrosion of metallic components (especially soft metals such as bearings)
Promotes oxidation
Oil degradation
Oil thickening
Additive depletion

SOLUTION

Drain oil
Reduce oil drain intervals
Confirm oil type being used
Check for overheating
Check Fuel Quality

FUEL SOOT

Fuel Soot is formed of carbon and is always found in diesel engine oil. Laboratory testing is used to determine the quantity of fuel soot in used oil samples. Recent EPA emission regulations have placed greater importance on fuel soot levels. The fuel soot level is a good indicator of engine combustion efficiency and should be monitored on a regular basis.

SOURCE

Improper air/fuel ratio
Improper injector adjustment
Poor fuel quality
Incomplete combustion
Low compression
Worn engine parts/rings

RESULT

Poor engine performance
Poor fuel economy
harmful deposits or sludge
increase wear
Carbon deposits
Clogged filters

SOLUTION

Ensure injectors are working properly
Check air induction/filters
Change oil
Assess oil drain intervals
Check compression
Avoid excessive idling
Inspect driving and operating conditions
Check fuel Quality

OXIDATION

Lubricating oil in engines and other components will combine with available oxygen under certain conditions to form a wide variety of harmful by-products. Heat, pressure and catalyst materials accelerate the oxidation process. By-products of oxidation form lacquer deposits corrode metal parts and thicken oil beyond its ability

OXIDATION (con't)

to lubricate. Most lubricants contain additives, which inhibit or retard the oxidation process. Differential infrared analysis is the method used to measure the level of oxidation in used oil.

SOURCE

Overheating
Extended oil drain intervals
Improper oil type/inhibitor additives
Combustion by-products/blow-by

RESULT

Shortened equipment life
Oil filter plugging
Increased viscosity
Corrosion of metal parts
Increased operation expenses
Increased wear rate
Decreased engine performance

SOLUTION

Use oil with oxidation inhibitor additives
Shorten oil drain intervals
Check operating temperatures
Check quality of fuel

NITRATION

Nitration products are formed during the fuel combustion process when combustion by-products enter the engine oil during normal operation or as a result of abnormal blow-by past the compression rings. These products are highly acidic, create deposits and accelerate oil oxidation. Infrared analysis represents the only method of accurately measuring nitration products in used oil.

SOURCE

Improper scavenge
Low operating Temperatures
Defective seals
Improper air/fuel ratio
Abnormal blow-by

RESULT

Accelerated oxidation
Nitrous oxides introduced into the system
Acidic by-products
Increased cylinder wear
Oil thickening
Combustion deposits
Increased total acid number

SOLUTION

Increase operating temperature
Check Crankcase venting hoses and valves
Ensure proper air/fuel mixture
Perform compression check

PARTICLE COUNT

Particle Count testing basically measures the relative cleanliness of a given fluid. It is primarily used for hydraulic and turbine systems to evaluate the effectiveness of the filters. It has been proven that reducing the particulate debris in the fluid can greatly increase the life of these systems.

The instrument that is normally used is a Parker Hannifin Particle Counter that measures the total population of particles in different size ranges. High levels of water can produce erroneously high readings. After the analysis is completed, and ISO Cleanliness Rating is determined from the results. The ISO Cleanliness Rating consists of three numbers and is a convenient method to communicate the sometimes-unwieldy particle results.

The first number represents 4-micron (silt) particles. The second number represents 6-micron (silt) and the (abrasive) particles, and the third number represents the 14 micron (abrasive) Particles.

SOURCE

Water contamination
 Oil oxidation
 Worn seals
 Ineffective filtration
 Dirty make up oil

RESULT

Increased wear
 System Failure
 Equipment Failure
 Plugging and/or leakage
 Pressure pulsing
 Sluggish valves or actuators

SOLUTION

Change filter
 Change Oil
 Use higher quality filters
 Insure integrity of seals

Typical fluid cleanliness levels for hydraulic components:

Component types	Normal	Abnormal	Excessive
Servo Valves	XX/14/11	XX/16/13	XX/18/15
Vane and Piston Pumps	XX/16/13	XX/18/15	XX/20/17
Directional and pressure Control Valves	XX/16/13	XX/18/15	XX/20/17
Flow control valves and Cylinders	XX/18/15	XX/20/17	XX/22/19

ISO CLEANLINESS RATING REFERENCE CHART

Data Acquisition: In order to assign an ISO Cleanliness Rating to represent the contamination level of a fluid, the number of particles greater than 6 micron and 14 micron unit volume must be available. Furthermore, the particle population must be obtained from a particle counting system, which has been calibrated per ISO/DIS 4406:1999, or an ISO approved equivalent method in order to assign a valid cleanliness rating. The actual counting system is immaterial as long as the acceptable calibration certification is available.

ISO CLEANLINESS RATING REFERENCE CHART

Particle Concentration

<u>(Particles per millileter)</u>	<u>Range Number</u>
10 000 000	30
5 000 000	29
2 000 000	28
1 300 000	27
640 000	26
320 000	25
160 000	24
80 000	23
40 000	22
20 000	21
10 000	20
5000	19
2500	18
1300	17
640	16
320	15
160	14
80	13
40	12
20	11
10	10
5	9
2.5	8
1.3	7
0.64	6
0.32	5
0.16	4
0.08	3
0.04	2
0.02	1
0.01	0.9
0.05	0.08
0.25	0.07

INTERPRETING THE RESULTS TEST REPORTS AND TAKING CORRECTIVE ACTION

Once all of the tests are complete, a highly trained Data Evaluator evaluates the results. The evaluation will result in (1) a statement that the unit is normal, or (2) specific maintenance recommendations will be made. The report recommendations are only one tool that can assist you in making your maintenance decisions.

RECOMMENDATION CATEGORIES

Normal

No explanation is needed for this category. Keep in mind that it is important to know that a unit is normal. This can save you unnecessary tear-down.

Abnormal

This category is followed by specific maintenance recommendations, or a notation that component wear is abnormal: there might, for example, be a recommendation to change oil and filters, and a comment noting that abnormal bearing wear is present. We are not telling you that it is time to tear down the unit. We are suggesting that you perform the maintenance suggested, and advising you that bearing wear is present. A second sample in a shorter time span might be requested. We do not recommend that you go into a unit on an abnormal recommendation unless you have discussed the report with the appropriate Laboratory Data Evaluator or you have indications that the unit has a more serious problem than is apparent in the report. Again, your judgement must be based on all of the tools at your disposal, including our report, your knowledge of the unit and your experience.

Critical

This is the category we use to indicate potential failure and a serious condition exists. We will indicate the suspected nature of the problem and make a recommendation for maintenance action. Critical units require immediate attention.

Underlined Figures That Need Close Attention: A serious problem could be developing and the unit should be closely monitored.

Re-samples: We will request a second sample to establish a trend whenever we have a potential “critical” unit with no previous history. If the wear increases, you will be advised of the suspected nature of the problem.

In some cases, the data will identify an obvious problem. For example, a high level of water contamination along with high levels of boron and sodium is a good indication of antifreeze contamination. A high particle count and high levels of silicone usually indicate dirt or dust contamination, and the need to check air filters or breathers, reservoir access covers or oil storage and handling procedures.

Sometimes however, the analytical data from an individual sample does not provide enough information to make more subtle judgments about oil or equipment condition. In these situations it is necessary to monitor the trends in analytical data over a series of samples to establish a wear trend pattern. By monitoring wear metals such as iron, lead, copper, and tin it is possible to detect the early stages of possible bearing failure. In most cases it can detect problem far enough in advance that it will allow for scheduling a bearing inspection at a convenient time, reducing or eliminating expensive equipment downtime and repairs.

One measure of the degradation of an engine is an increase in viscosity. Normally, a viscosity increase from one grade to the next is a warning that the oil has reached the end of its useful life.

Most engine oils are formulated with a variety of additives, which enhance lubricity, inhibit oxidation and corrosion and reduce the tendency for sludge and deposit formations. The levels of these additives can be determined by monitoring the Total Base Number (TBN), the reduction of a TBN below 3.0 is a warning that the additives have been depleted and an oil change should be scheduled. Some additive levels can be measured with spectrographic metals analysis. This test will detect the levels of zinc, phosphorus, calcium, and magnesium, which are common elements in most additive packages.

The most common engine oil contaminants are silicon (dirt), fuel dilution, and antifreeze coolant. Silicon (dirt) contamination is the most common form of contamination and causes serious engine wear due to its abrasive action against all moving parts within the engine. Silicon levels above 20ppm greater than the new oil should be considered cause for inspection of the air intake system to locate the source of entry for the dirt and other airborne debris.

Fuel dilution is serious since it can significantly reduce oil viscosity and lubricities thus causing engine wear. Fuel dilution can initially be detected by a lowering of the flash point of the oil, accompanied by a noticeable viscosity reduction, and a heavy fuel odor.

Coolant is another very common oil contaminant and probably the most serious. Water from the coolant reduces the lubricity, which causes severe bearing problems, while the glycol degrades at high temperatures and forms sludge. Monitoring water contamination levels is not reliable, since normal engine temperatures are high enough to evaporate the water over time and keep detectable levels as low as 0.05%. Coolant levels can be detected by chemical analysis and by monitoring the levels of boron, phosphorus, sodium and potassium in the oil.

Wear metal analysis can indicate which engine components are wearing and if the wear is becoming significant. This information can make the difference between minor component inspections and repairs and major overhauls. Wear metal levels are provided by spectrographic analysis of the oil sample, indicate the element level in parts per million (ppm), of each of the common metals found in the engine: iron, aluminum, chromium, lead copper tin, nickel and silver.

Wear metal analysis requires more than simply plotting data on a graph. Wear metals can be generated from as many as a dozen different engine parts and locations making it difficult to identify the specific part that is wearing excessively. It is the knowledge acquired through years of experience and analytical training, that the analyst can draw upon, to provide the most accurate analysis possible for customers.

SAMPLING TECHNIQUES

Samples should ALWAYS be taken hot or just after shutdown to assure that all the particles are in suspension in the oil. Always clean around drain plug to avoid contamination. Taking samples from the same location each time will give uniform reports. When using sample pumps and tubing, make sure that a NEW piece of tubing is used for each sample. Oil Analysis spectrometers can only see particles under 10 microns. It is prudent for the oiler to visually check the oil flow for visible particles. Cutting open (with a filter cutter, not a hacksaw) filters and inspecting them can give evidence of immediate parts failure that oil analysis will not see because of the size of the particles. Keep the lids on the oil sample bottles until you are ready to fill them and cap them as soon as they are filled. Just dirty air can bring up the silicon count and give erroneous results.