Reading Your Oil Analysis Report

The oil analysis test measures a lubricant's physical and chemical properties, including contaminants, additives and wear metals. All of the properties are interdependent and are evaluated individually to determine the overall quality and serviceability of the oil. Recommendations are then made regarding the condition of both the equipment and the oil. The evaluator's commentary and recommendations are included on the report. This book includes a diagram that illustrates what a typical analysis report will look like, along with definitions explaining which properties are tested and what they mean.

Physical Properties

Viscosity

Viscosity is defined as a fluid's thickness, or resistance to flow, at a specific temperature. Oil viscosity is measured using a viscometer - a "U" shaped calibrated glass tube submerged in an oil bath at a temperature of 100° celsius and 40° celsius depending on the type of fluid. The fluid is timed as it flows downward through the tube and up the other side. The oil's viscosity is measured by the number of seconds it takes to flow through the calibrated tube, known as flow time, multiplied by the tube constant. The units of measurement used to express viscosity are called centistokes, or cSt. Centistoke values are easily converted to SAE (Society of Automotive Engineers) viscosity grades by using the chart supplied on page 15. Auto gear lubes, ATF's and engine oils are tested at 100° C. All others, including industrial oils like gear and hydraulic oils, are tested the same way, but at 40° C, and are also expressed in centistokes, but are listed under the International Organization for Standardization (ISO) viscosity grade classification. ISO viscosity grades are also included in the chart.

NOTE: Oil viscosity is effected by contaminants that build up in the oil. Some contaminants will thicken oil; others will make the oil thinner.

Water/Antifreeze Contamination

Water contamination can be caused by condensation, especially in colder winter climates where wide temperature extremes cause water to form in the engine at cool down. It can also be caused by radiator or transmission oil cooler leaks, defective seals, a blown head gasket or contamination during the sampling process. Water causes rust and corrosion, impedes oil lubricity and neutralizes oil additives. When antifreeze contamination is present, glycol and coolant additives thicken the oil and turn it acidic, cause corrosion of engine components and destroy the oil's ability to lubricate. Glycol/antifreeze contamination is serious and should be corrected immediately to prevent costly engine damage. The hot plate or crackle test, Forrier Transformed Infrared Spectroscopy (FTIR), visual inspection and the Karl Fischer test can identify the presence of water. Glycol contamination is detected by colorimetric tests which react a reagent with the glycol present in the oil.

Fuel Dilution

Fuel dilution can be the result of leaking or defective injectors, excessive idling, incomplete combustion, improper timing, poor fuel quality and leaking fuel pump or lines. The effects of fuel dilution include oil thinning which may cause poor oil lubricity, poor performance and poor fuel economy. Fuel dilution is identified by sample odor, visual inspection and by laboratory FTIR scan, gas chromatography and flash point testing.

Soot and Solids

Soot is a contaminant caused by incomplete combustion and is typically a concern in diesel engines. Causes include defective injectors, a clogged air filter, excessive idling, improper air to fuel ratio and intake/exhaust valve guide problems.

NOTE: Newer model diesel engines used in over the road trucking may experience more soot generation due to delayed timing and new emissions control equipment.

Effects include increased viscosity, clogged filters, excessive emissions, abnormal wear and poor engine performance. Fuel soot is expressed as percent by volume and is detected by the FTIR scan. Other solid insoluble matter may include wear debris, dust, gasket material, manufacturing assembly debris or by-products of oxidation and nitration.

Oxidation

Oxidation occurs when lubricating oil undergoes a chemical change under the influence of high operating temperatures or while operating over extended drain service intervals. This can create acids which cause corrosion, increase viscosity and deplete additives. The process is accelerated by heat, metal catalysts and the presence of water, acids or solid contaminants. Oxidation can also cause filter plugging, lacquer build up, sludge deposits, overheating and increased wear. Oxidation is measured by an FTIR scan.

Nitration

Nitration occurs during the fuel combustion process when combustion by-products mix with the engine oil. This occurs during normal engine operation but is also a result of abnormal blow-by. The products of nitration are highly acidic. Their effects include accelerated oxidation, oil thickening, corrosion, increased wear and poor engine performance. Nitration is measured by infrared analysis or FTIR.

Other indicators that may suggest abnormal nitration levels are a rapid reduction in the oil's reserve alkalinity (Total Base Number).

Total Base Number (TBN)

Depending upon the application, different oils have different blends of additives designed to maintain the oil's lubricating properties and protect equipment. Base (alkaline) additives are present in automotive engine oils to neutralize acidic by-products of combustion. New oils start out with the strongest TBN they can possess, depending upon the base oil and the additive chemistry used to make them. Over its service life, a motor oil will lose its ability to neutralize acids. Measuring the TBN strength of the oil is very important when extending oil drain intervals, as the TBN value indicates the capability of the additives to protect the engine from acidic corrosion. The standard test for measuring an engine oil's acid neutralizing strength, or Total Base Number, is the ASTM-D 4739 Reserve Alkalinity Test. TBN is expressed using a value number, which decreases as nitration and oxidation values rise over the service life of the oil. Because an oil's characteristics are interdependent, TBN depletion reflects other characteristics of the engine oil that are out of acceptable range. This may indicate that the oil's service life has ended and the oil should be changed.

Diesel and Gasoline Engine Guidelines

Physical Properties, Contaminants and Degradation

	NORMAL	ABNORMAL	EXCESSIVE
Glycol	0	Trace	Trace
Water	< 0.05%	0.05%	> 1.0%
Fuel Dilution	< 1.0%	2.0%	3.0%
Viscosity	In grade	± One SAE/ISO Viscosity Grade Change	± Two SAE/ISO Viscosity Grade Change
Solids	< 1.5%	2.0%	> 4.0%
Soot (diesel only)	< 2.0%	3.0%	> 4.0%
Oxidation*	Expressed as absorption units per cm^{-1}		50.0 Synthetic 30.0 Petroleum
Nitration*	Expressed as absorption units per cm^{-1}		50.0 Synthetic 30.0 Petroleum
TBN	Change oil when TBN strength diminishes to < 2		
TAN (industrial)	1 - 3	3 - 4	> 4

* - Under normal conditions, the level of oxidation will be similar to the level of Nitration.

Wear Metals Analysis

(Spectrochemical)

Wear metals identified by spectrochemical analysis are expressed in parts per million (PPM) of the environment they inhabit. The sizes of wear metal particles that can be identified by spectrochemical analysis are between 3 and 10 microns. To put the linear measurement of a one micron particle into perspective, 1 micron = 0.000039/inch. When equipment is in operation, it generates wear metal particles which are carried by the lubricant as it flows through the components of the machine. Under normal conditions, the generation of wear metals is very gradual and increases slowly as the equipment is used. It is important to remember these points concerning wear metals:

- No two pieces of equipment wear at the same rate.
- Even identical pieces of equipment will exhibit variation in their rate of internal wear.
- How equipment is used will affect wear rates. Vehicles, for example, which are subjected to continuous stop and go driving or heavy towing will experience a greater rate of internal wear than those operated continually at highway speeds with no tow load.
- When equipment is new, initial break in wear rates will be higher. When equipment is reaching the end of its service life internal rates of wear will also increase.
- The amount of time or miles on the oil reflects the level of wear metals present in the sample. For example, when using extended drain capable motor oils and extending oil drains beyond conventional recommended intervals, wear metals will exhibit an accumulative effect which indicates higher PPM levels.
- Repairs made to the equipment can affect the wear metal rate by skewing the PPM of metals present in the fluid. Opening an engine or replacing a component can expose the engine's lubricating oil to outside contaminants, manufacturing residual particulate and seal material residue.
- Chips or metal particles visible to the eye are not detected by spectrometric analysis. Equipment failure can sometimes occur without significant production of detectable wear metals, as in cases where rapid failure or fatigue failure takes place.

An elemental interpretation guide has been provided in this book. Please remember that these range limits are to be used as a GUIDELINE only. Many factors will influence the wear metals results your sample receives based upon your particular application. The range limits stated in the interpretation guide are based upon recommended petroleum oil drain intervals. Wear metal source charts, which are also included in this book, can help identify the source of wear metals that may have been tested as abnormal.

SPECTROCHEMICAL ANALYSIS (ppm)																				PHYSICAL PROPERTIES					
IRON	CHROMIUM	LEAD	COPPER	TIN	ALUMINUM	NICKEL	SILVER	SILICON	BORON	SODIUM	MAGNESIUM	CALCIUM	BARIUM	PHOSPHORUS	ZINC	MOLYBDENUM	TITANIUM	VANADIUM	POTASSIUM	FUEL (% VOL.)	VIS @ 40 C cSt	VIS @ 100 C cSt	WATER (%)	SOOT/SOLIDS (% VOL.)	GLYCOL
15	0	0	20	0	4	0	0	6	2	6	28	3854	0	1187	1306	0	0	0	0	< 1	N/A	16.26	0	0.4	NEG

Gasoline and Diesel Engine Wear Metals

Oil Additives

As is illustrated above, iron, chromium, lead, copper, tin and aluminum are wear metals specific to gasoline and diesel engines. These are listed to the left on the spectrochemical analysis report. Nickel and silver are rarely seen in an analysis report.

Oil additives and some contaminants are listed to the right on the spectrochemcial analysis. These cover a range of items from silicon to potassium.

ELEMENTAL INTERPRETATION GUIDE

This chart is to be used as a *guide only*. Levels *will* vary. Levels listed in parts per million. Levels are based on manufacturer recommended fluid drain interval. Shortened or extended intervals may present varied wear metal levels.

Spectrochemical

Element	Diesel*			Gasoline			Transmission			Final Drive			Automatic Transmission		
	N	A	E	N	A	E	N	A	E	N	A	E	N	A	E
Iron	10/40	100	300	5/25	350	500	50/200	300	400	150/300	400	500	50	100	250
Chromium	1/8	12	15	5/20	25	40	10	20	30	10	20	30	5	10	20
Lead	15	30	75	30	70	150	20	50	150	20	50	150	30	70	150
Copper	3/15	50	150	5/30	100	300	5/250	325	400	50/150	250	300	50	100	250
Tin	15	20	30	20	30	40	10	20	30	10	20	30	5	20	50
Aluminum	10	15	25	5/20	30	40	10	30	50	-	-	-	10	30	50
Nickel	5	10	15	5	10	15	10	15	25	10	15	25	10	15	25
Silver	3	10	30	3	10	30	-	-	-	-	-	-	-	-	-
Silicon†	15	25	30	20	30	40	30	40	50	30	40	50	30	40	50
Sodium	25	100	150	20	100	150	30	40	50	50	150	200	30	100	150

N = Normal **A** = Abnormal **E** = Excessive

Manganese, Boron, Magnesium, Calcium, Barium, Phosphorus, Zinc and Molybdenum - Fluid additive system and/or in certain cases contaminate. No standard levels.

† = Over oil baseline

Titanium, Vanadium and Cadmium wear elements - no standard levels established.

* = Automotive Diesel

Normal levels will vary due to operating conditions, component age and manufacturing differences.

WEAR METAL REFERENCE GUIDE - Engine

When trace metals are detected, the following components could be the source:	Iron Fe	Copper Cu	Lead Pb	Aluminum Al	Silicon Si	Chromium Cr	Tin Sn	Sodium Na	Potassium K
Journal Bearings		X	X	X			X		
Bushings		X	X	X			X		
Cam Shaft	X								
Coolant Additives					X	X		X	X
Crankshaft	X								
Cylinder Walls	X					X			
Exhaust Valve	X					X			
Anti-Friction Bearing	X								
Gasket Materials		X			X				
Gasoline Additive			X					X	
Housing/Castings	X			X	X				
Ingested Dirt					X			X	
Oil Additive		X			X			X	
Oil Cooler		X							
Oil Pump Bushing		X	X	X			X		
Oil Pumps	X			X					
Pistons	X			X			X		
Rings	X					X			
Thrust Washers		X	X	X			X		
Timing Gears	X								
Turbo-Charger/Super-Charger	X			X					
Valve Guides	X	X							
Valve Train	X								
Wrist Pin-Bushings		X	X	X			X		
Wrist Pins	X								

WEAR METAL REFERENCE GUIDE - Manual Transmission

When trace metals are detected, the following components could be the source:	Iron Fe	Copper Cu	Lead Pb	Aluminum Al	Silicon Si	Chromium Cr	Tin Sn	Sodium Na	Potassium K
Bushings		X	X	X			X		
Clutch Faces	X	X							
Coolant Additives					X	X		X	X
Anti-Friction Bearings	X								
Gears	X								
Ingested Dirt					X				
Oil Additives					X				
Oil Cooler		X		X					
Pumps	X			X					
Thrust Washers		X	X				X		
Gasket Materials or Silicon Sealant		X			X				
Housing/ Castings	X			X	X				

WEAR METAL REFERENCE GUIDE - Automatic Transmission

When trace metals are detected, the following components could be the source:	Iron Fe	Copper Cu	Lead Pb	Aluminum Al	Silicon Si	Chromium Cr	Tin Sn	Sodium Na	Potassium K
Journal Bearings	X	X	X	X			X		
Bushings		X	X				X		
Coolant Additives					X			X	X
Anti-Friction Bearings	X								
Gasket Materials and Silicone Sealant					X	X			
Gears	X	X							
Ingested Dirt					X				
Shafts	X								
Thrust Washers		X	X				X		
Valves	X								
Housing/Castings	X			X	X				

WEAR METAL REFERENCE GUIDE - Differential Drive

When trace metals are detected, the following components could be the source:	Iron Fe	Copper Cu	Lead Pb	Aluminum Al	Silicon Si	Chromium Cr	Tin Sn	Sodium Na	Potassium K
Journal Bearings		X	X	X			X		
Bushings		X	X				X		
Anti-Friction Bearings	X								
Gears	X								
Ingested Dirt					X				
Oil Additives					X				
Oil Pump		X		X					
Road Salt								X	
Shafts	X								
Thrust Washers		X		X			X		
Gasket Materials and Silicon Sealant		X			X				
Housing/Castings	X			X	X				

WEAR METAL REFERENCE GUIDE - Industrial Gears

When trace metals are detected, the following components could be source:	Iron Fe	Copper Cu	Lead Pb	Aluminum Al	Silicon Si	Chromium Cr	Tin Sn	Sodium Na	Potassium K
Journal Bearings		X	X				X		
Bushings		X	X				X		
Anti-Friction Bearings	X								
Gasket Materials or Silicone Sealants		X					X		
Gears	X	X							
Ingested Dirt					X				
Oil Additives					X				
Pumps	X	X		X					
Shafts	X								
Thrust Washers		X		X					
Housing/Castings	X		X	X					

WEAR METAL REFERENCE GUIDE - Hydraulics

When trace metals are detected, the following components could be the source:	Iron Fe	Copper Cu	Lead Pb	Aluminum Al	Silicon Si	Chromium Cr	Tin Sn	Sodium Na	Potassium K
Journal Bearings		X	X	X			X		
Bore & Rods	X					X			
Bushings		X	X	X			X		
Cylinders	X			X					
Anti-Friction Bearings	X								
Gasket Materials or Silicone Sealant		X			X				
Gears	X								
Guides		X							
Ingested Dirt					X			X	
Motors	X			X					
Oil Additives		X			X				
Oil Cooler		X		X					
Pistons	X	X							
Pumps	X			X					
Rods	X					X			
Spools	X	X				X			
Thrust Plates		X							
Valves	X								
Vanes	X								
Housing/Castings	X			X	X				

WEAR METAL REFERENCE GUIDE - Air Compressor

When trace metals are detected, the following components could be source:	Iron Fe	Copper Cu	Lead Pb	Aluminum Al	Silicon Si	Chromium Cr	Tin Sn	Sodium Na	Potassium K
Journal Bearings		X	X	X			X		
Bushings		X	X				X		
Coolant Additives					X	X		X	X
Crankshaft	X								
Cylinder	X								
Anti-Friction Bearings	X								
Ingested Dirt					X				
Oil Additives		X			X			X	
Oil Cooler		X		X					
Oil Pump	X			X					
Pistons				X					
Rings	X					X			
Rotors	X								
Screws	X			X					
Shaft	X								
Thrust Washers		X	X				X		
Wear Plates	X	X	X				X		
Housing/Castings	X			X	X				
Gasket/Sealants		X			X				