petroleum technologies group L.L.C.

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BASICS OF OIL ANALYSIS

INTRODUCTION

For many years, lubricant inspection and testing has been used to help diagnose the internal condition of oil-wetted components and to provide valuable information about the lubricant serviceability. The first test methods used for this purpose included such simple procedures as smelling used oil for the sour odor of excess acid, checking visually for obvious signs of contamination or placing a small drop of sample on absorbent paper to detect contaminates and monitor additive effectiveness.

Modern day analysis is built on these early efforts. The importance of using a combination of physical and spectrochemical tests to monitor lubricant and component conditions is not universally accepted. Oil analysis test procedures are established and reviewed by such agencies as the International Standards Organization, the American Society of Testing Materials and the Society of Automotive Engineers. Today, little doubt remains that a comprehensive oil analysis program is a very valuable tool.

TREND OIL ANALYSIS

All oil analysis programs are designed to be performed as a trend analysis. This is a regularly scheduled set of samples over a span of time. A trend is a unique history of what is happening to a unit within its specific application. To establish a trend, at least three samples are needed.

All the test data on a sample is relevant to:

- Hours or mileage on the oil
- With time, the oil is accumulating more and more detectable metals
- What would be normal readings for an engine with 10,000 miles on an oil drain would be high readings on an engine with 1,000 miles on an oil drain
- Time on the engine itself
- Each system has a life span and there will be differences in results along the way

One oil sample, taken after a failure, does not show the history of how the failure developed or how long it existed. Only a trend can do this. With failure analysis it is very difficult to reconstruct what caused the problem. The test data for an oil sample will sometimes fail to support the problem or failure when the service is used as a one-sample failure analysis.

With waiting until there is an indication of a problem to use oil analysis the true value and purpose has been lost. Establishing a trend will give an early alert so that corrective action can be taken to prevent a major failure.

PETROLEUM TECHNOLOGIES OIL ANALYSIS PROGRAM

OIL ANALYSIS PROGRAM FOR ENGINES, TRANSMISSIONS AND HYDRAULIC SYSTEMS

A superior program of oil analysis is a vital part of today's good maintenance. Analysis programs detect internal engine parts that are wearing at abnormal rates, whether oil additive packages are breaking down and finally they measure the physical condition of the oil and the levels of contamination. Oil Analysis programs are vital to a strong preventative maintenance program.

WHAT DOES OIL ANALYSIS MEASURE?

Petro Tech oil analysis tests a sample of oil taken from your equipment right after shut down. Three different types of testing are done on the sample:

- Physical and chemical testing, which measures problems such as the percentage of water or fuel dilution; the presence of coolant, carbon build up or silica dirt; and a measure of viscosity
- ICP analysis, which measures the presence of even the most microscopic particles of metals, can determine whether engine component wear rates are taking place at an abnormal rate
- Infra-Red testing is performed on the sample to determine the condition of the oil additive package. This test can help to determine if the oil drain intervals are at the proper length for the equipment and conditions of usage

WHY USE OIL ANALYSIS?

Oil analysis makes it possible to literally look inside an engine, transmission or hydraulic system. By monitoring the oil, its condition and the presence of contaminates, an oil analysis user can anticipate problems, monitor system wear and repair problems before they become catastrophic.

Some of the specific uses of oil analysis include:

- Noting progressive wear in order to repair damaged parts before they become emergency break-downs
- Detection of corrosive acids, coolant, fuel dilution and other oil conditions which are caused by engine problems that could become major failures
- Planning of needed repairs based upon the noted progression of an abnormal wear pattern, which can lead to more effective equipment utilization and fewer emergency repairs
- Oil Analysis provides useful records when handling warranty problems, resale of equipment, detection of abuse and evaluation of new oils, oil filters and air filters

INFRARED ANALYSIS

Infrared analysis has been employed as an analytical technique for many years, with respect to monitoring used lubes, its application was highly limited by:

- A need for a reference sample (usually a new sample of lube being analyzed)
- Opacity of the sample
    - lack of sufficiently sophisticated instrumentation
    - corresponding costs to obtain trustworthy data

The above objections could be partially overcome. The analyzing facility limited its scope to only a few products or base materials, such as an individual lube formulator analyzing only his/her own products. The technology today, however, is now available to transcend the limitations above and is offered as a routine service.

WHAT IS INFRARED?

IR is one of numerous spectrometric techniques for analyzing the chemistry of materials. In all cases "spectrometric" analysis implies a measurement of a very specific wavelength of light energy, either in terms of amount absorbed by the sample the question or the amount emitted from the sample when suitably energized.

IR is an absorption form of spectrometric analysis. Unlike atomic absorption, IR is not concerned with specific elements (lead, copper, etc.) but rather with the grouping of atoms in specific combinations to form what are called "functional groups". These various functional groups help to determine a materials properties or expected behavior.

By knowing which wavelengths are absorbed by each functional group of interest, one can cause the appropriate wavelength to be directed at the sample being analyzed and measure the amount of energy absorbed by the sample. The more energy absorbed, the more of that particular functional exists in the sample. Results can therefore be numerically quantified. The units of measurement are usually expressed as "Absorbance Units".

HOW DOES IR APPLY TO LUBE ANALYSIS?

It is useful for the layman to treat infrared analysis as the chemistry of Carbon, Hydrogen, Oxygen, Nitrogen and Sulfur and the various combinations in which these elements configure or attach themselves.

By identifying and quantifying certain functional groups one can derive highly dependable information about the lube, whether new or used. This includes, but is not limited to:

BASIC PHYSICAL COMPOSITION

Most lubes consist of two major components, base stock and additive. It is possible to distinguish between differing base stocks with IR for the purpose of quality control. The feature is particularly useful for assurance that a synthetic lube is not being inadvertently contaminated with mineral oil, thereby impairing the synthetic's beneficial properties.

ADDITIVE CHEMISTRY

This is part of the routine infrared inspection. It can determine if the lubes contain additives and if the additives are effective. This is not a difficult process provided the lab is familiar with the product being tested. In most instances the question of specific additive depletion can be answered.

CONTAMINATION

IR is particularly useful for detecting oxidation products. Such products are detrimental to good lubrication if present in significant quantity. It is also sensitive to coolant contamination (water or glycol). Manufacturing plants that produce certain types of chemicals that may be introduced into the lube system would be able to detect the presence of these contaminates as they accumulated in the lube.

LUBE DEGRADATION

Oxidation is developed from varying combinations of heat, air and lube agitation, this is usually characterized by lube thickening. The IR test determines the amount of oxidation present in the sample tested. Nitration and Sulfation determinations are used to detect the build up of potentially corrosive Nitric and Sulfuric acids.

IR APPLICATION SUMMARY

Many laboratories try to determine the amount of additive or additive depletion by measuring the amount of additive metals present in the oil. While the tests used to determine these metals are easily performed, they can be misleading. Additive metals can easily fluctuate +20% to –20% as a normal circumstance. Also, many of the same metals that are present in the additives are also present in components within a unit (Magnesium is also present in small amounts in aluminum alloys). Therefore, it is possible to have a loss of an additive metal and a secondary gain from an internal component and not see the actual additive metal loss. It is also possible for a wide variety and quantity of additives to be used to meet the same specification for an oil. Therefore, the level of a metal detected to determine an additive does not necessarily reflect the usefulness of that additive in the oil.

Infrared analysis is the most accepted test method in the industry today to determine the condition of lubes. The method looks at both the additives in the oil and the actual condition of the oil itself. This method gives a true and complete analysis of the lubricant in a way that no other test can duplicate.

WEAR ELEMENTS

These metals indicate wear on a particular component of an individual unit. The particles of these metals indicate a wear problem on the microscope level before the problem can be detected by conventional means. The existence of a wear problem is determined not only by absolute values of metals, but more importantly a relative increase or trend in one or more of these metals.

WEAR METAL SOURCES

Iron	Cylinders, gears, rings, crankshafts, liners, bearings, housing, rust
Chromium	Rings, roller/taper bearing, rods, platings
Lead	Bearing overlays, additives in gear oil and gasoline
Copper	Brushings, bearings, thrust -washers, friction plates, oil cooler, additive in oil
Tin	Bearings, bushings, pistons
Aluminum	Pistons, bearings, pumps, blowers, rotors, thrust -washers
Nickel	valves
Silver	Bearings, bushings
Manganese	Trace elements in liners and rings, additive in gasoline
Titanium	Trace element
Vanadium	Trace element

CONTAMINENTS

These elements can be an indication of contamination from outside the system. The source and amount of contamination can be determined by comparison to a previous, non-contaminated sample of the same unit. Specific test for some contaminants can supplement the analysis.

CONTAMINENT SOURCES

Silicon	Element used to determine the level of airborne dirt and abrasives in the oil
Boron	Present in most permanent anti-freeze systems
Sodium	Present in most permanent anti-freeze systems
Potassium	Present in most permanent anti-freeze systems

ENGINE — CONDEMNING LIMITS

WEAR METALS
Limits are established by trend over a number of samples. There are guidelines we use initially (See attached guidelines).

SOLIDS
The limit for solids is 5.0% by volume. This is an accumulation of all products in the sample such as metals, dirt, soot and etc.

SOOT
The limit for soot is 5.0% by volume. These are combustion products in the sample. (Please note that this limit may be increased in the future due to the higher amounts of soot being put out by the newer engines.)

VISCOSITY
The limit for viscosity is an increase or decrease of one grade.

FUEL DILUTION
The limit for excessive fuel in the oil is 3.0%. Inter-city truck or equipment that idles a lot may reach 3%. Please note that Cummins Engine Company allows 5% fuel dilution before it is considered a problem.

ANTIFREEZE
The limit for antifreeze is any trace amount. There should never be any amount of antifreeze present in the oil.

WATER
The limit for water is .30%.

OXIDATION
The condemning limit for oxidation, as expressed on our report, is at 75% of allowable. This is a converted reading directly from the Infrared scan. Maximum 35 a/cm.

NITRATION
This reading indicates nitrate acids building up in the system. The condemning limit for nitration, as expressed on our report, is at 75% of allowable. This is a converted reading directly from the infrared scan. Maximum 35 a/cm.

SULFATION
This reading indicates sulfur acids building up in the system. The condemning limit for sulfation, as expressed on our report, is at 75% of allowable. This is a converted reading directly from the infrared scan. Maximum 35 a/cm.

ENGINE — TYPICAL WEAR RATES

	Copper	Iron	Chromium	Aluminum	Lead	Silicon	Tin
Cummins	0-25	0-45	0-4	0-8	0-35	0-15	0-5
Cummins 13M/ISM	0-45	0-100	0-15	0-15	0-35	0-15	0-5
Caterpillar	0-20	0-35	0-4	0-8	0-30	0-15	0-5
Caterpillar (3406E)	0-20	0-50	0-4	0-8	0-30	0-15	0-5
Caterpillar(C-12)	0-100*	0-75	0-8	0-8	0-30	0-15	0-5
Caterpillar(C-15)	0-100*	0-85	0-8	0-8	0-30	0-15	0-5
Detroit DD 15	0-25	0-85	0-4	0-10	0-35	0-15	0-5
Detroit 60 Series (new)	0-40	0-150	0-10	0-15	0-35	0-20	0-5
Detroit 2 Cycle	0-25	0-150	0-4	0-10	0-35	0-15	0-5
International DT	0-45	0-100	0-4	0-12	0-35	0-15	0-10
Navistar Maxxforce	0-15	0-150	0-10	0-15	0-35	0-15	0-10
Gasoline	0-120	0-150	0-10	0-20	0-25	0-25	0-10

CUMMINS	Copper	Iron	Chromium	Aluminum	Lead	Silicon	Tin
4BT & 6CT	0-25	0-45	0-4	0-8	0-35	0-15	0-5
Mercedes Engines Volvo Engines	0-10	0-55	0-4	0-8	0-10	0-15	0-5
MBE 4000	0-40	0-100	0-10	0-25	0-35	0-20	0-5
Mack 300/350	0-25	0-125	0-8	0-10	0-30	0-15	0-10
Paccar MX-13	0-20	0-35	0-10	0-15	0-10	0-15	0-5

These values are typical for the engines described above. These are only guidelines and the wear rates for a particular engine should be determined by a trend established from a number of samples on that engine. (Please note: Copper and Aluminum levels have been running higher on the newer engines. These metals appear to be coming from oil cooler and inter cooler leaching.

***NOTE:** Copper is high in these Caterpillar engines but will lower between 75,000 and 100,000 miles.

Industrial Oil Analysis Program

INDUSTRIAL — CONDEMNING LIMITS

Wear Metals
Limits are established by trend over a number of samples. There are guidelines we use initially (See attached guidelines).

Solids
The limit for solids is .1% by volume. This is an accumulation of all products in the sample such as metals, dirt and etc.

Antifreeze
The limit for antifreeze is any trace amount. There should never be any amount of antifreeze present in the oil. Exception: Water Glycol Oils.

Water
The limit for water is .30%. Exceptions: Turbines .1%

Oxidation
The condemning limit for oxidation, as expressed on our report, is at 75% of allowable or 20 Abs/cm. This is a converted reading directly from the Infrared scan.

Nitration
(Same as above). This reading indicates nitrate acids building up in the system.

Sulfation
(Same as above). This reading indicates sulfur acids building up in the system.

Particle Count
The limit is determined by the manufacturer of the system and usually will be determined by the type of pump, valves and pressures in the system.

Additive Metals
These metals are usually Zinc, Calcium, Phosphorus etc. The limits are determined by knowing the new oils starting point and using a 25% drop in the levels as a condemning level.

HYDRAULIC and GEAR BOXES — Typical Wear Rates

	Copper	Iron	Chromium	Aluminum	Lead	Silicon
Hydraulic	0-25	0-25	0	0	0	0-10
Gear Boxes	0-50	0-350	0	0	0	0-40

ISO—INTERNATIONAL STANDARDS ORGANIZATION

Typical Hydraulic Components Requirements

ISO 15/14/11	Servo Control Valves
ISO 17/16/13	Vane and Piston Pumps
ISO 17/16/13	Directional and Pressure Control Valves
ISO 18/17/14	Gear Pumps
ISO 19/18/15	Flow Control Valves and Cylinders

Suggested Contamination Levels for Various Hydraulic Systems

Target Class	Sensitivity	System
14/13/9	Super Critical	Silt sensitive control system. Laboratory or Aerospace.
16/15/11	Critical	High performance servo and high pressure systems.
17/16/13	Very Important	High quality systems. General machine requirements.
19/18/14	Important	General machinery and mobile systems. Medium pressure & medium capacity.
20/19/15	Average	Low pressure industrial systems
22/21/17	Main Protection	Low pressure with large clearances.

INDUSTRIAL—RECOMMENDED CLEANLINESS CODE CHART

Actuators

Pressure	<2000	2000-3000	3000+
Cylinders	19/18/15	19/18/15	19/18/15
Vane Motors	19/18/15	18/17/14	17/16/13
Axial Piston	18/17/14	17/16/13	16/15/12
Gear Motors	20/19/17	19/18/15	18/17/14
Radial Piston	19/18/14	18/17/13	17/16/13
Cam Wave Motor	17/16/14	16/15/13	15/14/12

Bearings

Pressure	<2000	2000-3000	3000+
Ball Bearing System	14/13/11	-	-
Roller Bearing System	15/14/12	-	-
Journal Bearings (High Speed)	16/15/13	-	-
Journal Bearings (Low Speed)	17/16/14	-	-
General Industrial Gear Boxes	16/15/13	-	-

Pumps

Pressure	<2000	2000-3000	3000+
Fixed Gear	19/18/15	18/17/15	-
Fixed Vane	19/18/15	18/17/14	17/16/13
Fixed Piston	18/17/15	17/16/14	16/15/13
Variable Vane	17/16/14	16/15/13	-
Variable Piston	17/16/14	16/15/13	15/14/12

INDUSTRIAL—RECOMMENDED CLEANLINESS CODE CHART

Valves

Pressure	2000	3000+
Directional (Solenoid)	19/18/15	18/17/14
Press Control	18/17/14	18/17/14
Flow Control	18/17/14	18/17/14
Check Valves	19/18/15	19/18/15
Cartridge Valves	17/16/13	16/15/12
Proportional Directional/ Flow/Pressure	16/15/12	15/14/11
Servo Valves	15/14/11	14/13/10

PETROLEUM TECHNOLOGIES OIL ANALYSIS PROGRAM

WHY PETROLEUM TECHNOLOGIES ANALYSIS?

There are many oil analysis products on the market, from free oil company analysis to elaborate and expensive testing. Petro Tech analysis programs are designed to meet both the normal and special analysis requirements of engines, transmissions and hydraulic systems. With our help, a full service oil analysis program can round out and make your preventive maintenance program complete. We can custom tailor our services to meet your particular needs. Our customized approach produces better results than what a mail order business can offer in the industry today.

The services we provide are competitively priced. We do not lower our standards in order to meet costs. Our goal has always been to provide the best service at a fair price. We have accomplished both.

PETROLEUM TECHNOLOGIES OFFERS:

- State of the art, fully computerized analytical equipment
- 48 hour turnaround time from receipt of the sample
- Immediate faxing of the report if the results indicate abnormal conditions
- Computerized reports giving the previous four analysis
- All of the results are reviewed by qualified technicians who have years of mechanical background
- In addition to engine testing, we test transmissions, rear ends and hydraulic systems
- We offer competitive pricing packages

INTERPRETATION OF RESULTS

How do we interpret the data? This is a question frequently asked by customers. Normally a customer should not have to interpret test data as the function of the laboratory is to provide this. The data is presented primarily to let the customer know which of the values triggered the maintenance recommendations. Customers can and will eventually become competent at evaluating reports for their own operation.

Analyzing trends is a complicated process and involves the interplay of all the test data, not just wear metals or contaminates separately. This is why it is best to leave the primary interpretation to the laboratory staff. Our experience has allowed us to become familiar with trends and related factors. The customer's help is needed in providing us with a current evaluation of a troubled unit because they may have the information which can help us pinpoint the problem.

Petroleum Technologies Group, LLC

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