


ANALYSTS, INC. 
The acknowledged leader in oil analysis since 1960

BASICS OF OIL ANALYSIS



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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 provide valuable information about 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 drop of sample on absorbent paper to detect contaminants and monitor additive effectiveness. As basic research and technology expanded, progress in lubricant testing kept pace. An increasingly large number of tests were developed to assess lubricant physical properties and detect contaminants.

In 1946 the Denver and Rio Grande Railroad research laboratory successfully detected diesel engine problems through wear metal analysis of used oils. A key factor in their success was the development of the *spectrograph*, a single instrument that replaced several wet chemical methods for detecting and measuring individual chemical elements such as iron or copper. This practice was soon accepted and used extensively throughout the railroad industry.

By 1955 oil analysis had matured to the point that the United States Naval Bureau of Weapons began a major research program to adopt wear metal analysis for use in aircraft component failure prediction. These studies formed the basis for a Joint Oil Analysis Program (JOAP) involving all branches of the U.S. Armed Forces. The JOAP results proved conclusively that increases in component wear could be confirmed by detecting corresponding increases in the wear metal content of the lubricating oil. In 1958 Pacific Intermountain Express (P.I.E.) was the first trucking company to set up an in-house used oil analysis laboratory to control vehicle maintenance costs. This extensive history makes oil analysis the oldest of the proactive maintenance technologies.

In 1960 Analysts, Inc. was founded, becoming the first independent laboratory to provide a complete oil analysis diagnostic service to all areas of business and industry.

Our modern-day oil analysis is built on the firm foundation of these early efforts. The importance of using a combination of physical and spectrochemical tests to monitor lubricant and component condition is now universally accepted. Oil analysis test procedures are established and reviewed by such agencies as the International Organization for Standardization (ISO), the American Society for Testing and Materials (ASTM) and the Society of Automotive Engineers (SAE), and a wide variety of laboratory and personnel certifications has emerged.

Analysts, Inc. is proud of our major continuing role in the original and current development of commercial oil analysis into what is now recognized as one of the most effective proactive maintenance tools available. We feel confident that the oil analysis instruments and techniques of the future will back our continuing commitment to proactive maintenance through used oil analysis.

Mark Smith
Technical Administrator

ANALYSTS, INC. 

APPLYING OIL ANALYSIS

Oil analysis is the most widely accepted and implemented form of proactive maintenance technology. It is an integral part of the maintenance plan for power plants, manufacturing plants, trucking companies, construction equipment, aircraft, refrigeration systems, processing and chemical plants, etc. Any piece of equipment that has a lubricating system is an excellent candidate for oil analysis. A successful oil analysis program requires an organized and sustained effort. Both the user and the laboratory must work closely together to achieve the desired results.

OUTLINE FOR AN EFFECTIVE OIL ANALYSIS PROGRAM

1. *Determine your primary objectives.*

Oil analysis can be applied to equipment utilization, maintenance and management:

Utilization

- Increase margins of operational safety
- Increase availability by decreasing downtime
- Increase overall component lifespan
- Control standby equipment and replacement part requirements
- Decrease fuel and oil consumption

Maintenance

- Identify and measure lube contamination and component wear
- Eliminate unnecessary overhauls or inspections
- Reduce in-service failures and field repairs
- Establish proper lubricant service intervals

Management

- Improve cost assessment and control for equipment, labor and materials
- Improve equipment record-keeping procedures
- Evaluate equipment designs / applications
- Reveal faulty operator practices

Almost any machine that has a lubrication system can be placed on an oil analysis program. Those components whose performance directly affects the continued operation of a particular unit or overall profitability of business are the most likely candidates for routine oil analysis.

2. Carefully consider your best choice for oil analysis

All oil analysis laboratories claim they are 'qualified', Although certifications and requirements that a 'qualified' used oil analysis laboratory must meet are now much more defined than in the past, one thing has not changed: *You*, the oil analysis user, must choose which laboratory best satisfies your needs.

For example, Analysts' five regional laboratories have been featured in numerous magazine articles, advertisements, and other published materials. These 'second opinions' are excellent sources of reference about our service. The best guide to choosing a laboratory, however, is *experience*. Chances are, someone in your field is already using one or more of the labs you are considering. Talk with them. They'll confirm how we define 'qualified'.

Choose a well-established laboratory – Analysts, for example, has been in operation since 1960 - long enough to have developed complete, time-tested procedures for analysis, customer contact and sales service. We offer a wide selection of sampling materials, including our patented Bellows[®], QSS[®] sampling valves, and other supplies and make sure that these materials are in stock when you need them. We provide the additional descriptive literature and training assistance needed to support your oil analysis program.

Choose a well-equipped laboratory – Each Analysts' laboratory is deeply computerized, and most of our modern, well-maintained instruments are automated and directly interfaced with the lab computer system. We follow published, proven testing procedures and use only the highest quality chemicals. We encourage our customers to visit our lab facilities.

Choose a laboratory with a well trained, experienced staff – Analysts' marketing and technical staff 'know their business'! More of our staff members are STLE Certified Lubrication Specialists or Oil Management Analysts than any other commercial oil analysis lab. We recognize the specific technical requirements for your application and answer your questions fully. We have an organized approach for establishing you as a customer and can give you sound, practical suggestions for overcoming any problems you might encounter in establishing and maintaining your Analysts' oil analysis program.

Choose a laboratory with a recognized quality control program – Analysts, Inc. has one of the strongest certified and registered ISO 17025 quality programs in commercial oil analysis. By attaining the ISO 17025 certification Analysts demonstrates on a daily basis its commitment to quality data, work and procedures. Additionally, Analysts' quality program meets the requirements of 10 CFR 50, Appendix B – the federal specification for quality programs in nuclear power plants. With our program of documentation, training, procedures and follow-up, Analysts is recognized as the leader in quality and service within the industry.

Examine the reports for reliable recommendations and easy to read format – Consistently accurate test results and interpretation are vital to the success of your oil analysis program. Analysts' report forms are the clearest and most informative in the industry. Our recommendations are specific, complete and easy to understand. The recommendations reflect a real knowledge of the operating and wear characteristics for any component sampled. Test results indicating the need for a major inspection are double-checked prior to your notification. Many of our staff of data evaluators and chemists are members of professional and technical societies, and our established position in the commercial oil analysis field ensures ready access to lubricant and component manufacturers' data.

Demand rapid turnaround of results and recommendations – Analysts meets and beats the frequently advertised "24 to 48-hour turnaround". We will notify you immediately if critical conditions are detected. You can obtain 'rush' handling if you require an immediate response, and after-hours special openings can be arranged in case of emergency.

Look for specialized summary reports – To assist our customers to manage and control their oil sampling program, we will provide any of a series of eight specially designed program management and summary reports. These reports consolidate sampling activity to compile the information such as Critical Condition Units, Condition Analysis Statistics, Summarized Sampling Activity and Summarized Sample Conditions. The reports are available on a monthly basis.

Look for a full range of information management tools and options – Analysts maintains a comprehensive Internet site at www.analystsinc.com. Analysis reports can be received via e-mail attachment directly from our laboratories. This site also offers a complete Web-based oil analysis management system. Through our Windows- based oil analysis software program LOAMS (Lube Oil Analysis Management System), your entire oil analysis program can be managed offline from a personal computer. LOAMS will download and store all sample data, print reports locally, graph sample data, print sampling schedules by component and allow the exporting of data to other software programs for further manipulation.

3. Select the proper tests for your application.

Different combinations of physical and spectrochemical tests are used to measure the properties of the lubricant itself and determine levels of contaminants and chemical elements suspended in the lubricant. The application and goals of the oil analysis program help determine the number and type of tests that should be performed.

The *physical analysis* concentrates on measuring certain physical characteristics of the lubricant. These tests also detect and measure contaminants and oil breakdown by-products, as well as their effect on the lubricant properties.

The *spectrochemical analysis* identifies and measures selected metallic elements present in the lubricant as microscopic particles. Test results are reported in parts per million (ppm) by weight. The relative concentrations of these elements are used to monitor wear rates, detect contaminants and determine additive levels.

Analysts has developed standardized 'packages' or combinations of routinely performed tests. These packages are designed to cover the general testing needs of broad service classifications such as industrial, construction, over-the-road trucking or aviation. Since each package consists of tests that the lab is already prepared to perform in volume, significant savings are realized when a package is selected rather than a random group of tests. Additional non-routine tests can be performed on request. Analysts will assist you in selecting the proper combination of tests prior to beginning your sampling program.

4. Determine the proper sampling point and method.

Obtaining a representative sample is one of the most important parts of a scheduled oil analysis program. If a sample does not represent the true condition of the lubricant and component at the time of sampling, the reliability of both the test results and their interpretation is affected.

Areas where lubricant flow is restricted or where contaminants and wear products tend to settle or collect should be avoided as sampling points. In special cases, samples may be taken from lube filters. The lab should be advised if this occurs.

We recommend that you sample a component while it is running or within 30 minutes after shutdown. This ensures that wear products and lubricant contaminants are thoroughly mixed with the lubricant and that the heavier wear particles have not settled out.

We recommend the following sampling points:

- A petcock or other sampling valve installed PRIOR to the oil filter (using Analysts' QSS[®] valve)
- An oil dipstick tube or other service opening (using the Bellows[®] or a vacuum pump)
- The sump or reservoir drain

Once a proper sampling point and method is chosen for a particular component, oil samples from that component should always be taken from the same point with the same method.

5. Determine the proper sampling interval

When beginning a routine oil analysis program, the usual practice is to sample the entire group of units/components to establish initial baseline data and quickly spot any components with serious problems. Once this process is complete, the customer and laboratory then agree on an initial routine sampling interval. This interval is based on the results of the preliminary sampling, component manufacturer guidelines, customer maintenance procedures and personnel scheduling and Analysts' experience with similar components and applications. Once the program is fully established, the routine sampling interval may be adjusted.

Once determined, routine sampling intervals should remain as constant as possible.

6. Establish consistent oil analysis baseline information.

In a busy operations and maintenance schedule, no one wants extra paperwork and record keeping. But, if an oil analysis program is to furnish anything more than test data, the user must provide information on the equipment, components and lubricants in service. One common false assumption is that an oil analysis lab can draw valid conclusions from the test results without any supporting data from the customer.

Initial equipment registration can be easily accomplished by furnishing the laboratory with a consolidated equipment list, or by completing an individual registration form for each sampled compartment. Current operating data is then forwarded with each sample.

In completing oil analysis forms and sample container labels, the following brief definitions are helpful:

UNIT I.D. NUMBER - A unique reference number for an entire functional unit. Examples include an aircraft registration number, company asset or inventory identification or a vehicle serial number.

COMPONENT - The overall type of oil-wetted system, such as engine, hydraulic, or gearbox, from which the sample is taken. Other designations such as left, number 3, rear or an actual description of the component's use, such as fan drive, winch or swing are also needed for clear identification.

TIME SINCE NEW OR SINCE LAST OVERHAUL - The operating hours or miles since the sampled compartment was first put into service, or since the last overhaul or rebuild was performed. Since normal wear rates change over the lifetime of a component and break-in may resemble abnormal wear, this information is needed as an ongoing reference for interpretation. This data may be obtained directly from an equipment or component service meter, or from general operating records.

TIME SINCE OIL CHANGE - The number of hours or miles of component use between the time the oil was last changed and the time the sample was taken. *This information is essential to time-based trending.*

OIL TYPE - The manufacturer, product name, and SAE or ISO viscosity grade *for the oil that was sampled*. Since a manufacturer may sell more than one blend of the same viscosity product, the complete name is very important in determining which testing reference oil should be used.

OIL CONSUMPTION or MAKEUP OIL - The amount of oil added to maintain a correct oil fill level in the sampled component. Complete oil changes should not be reported as makeup oil or identified as 'new oil'.

A sample usually cannot be processed immediately if the customer name, unit and component identification, and sample date are not provided. If you have sampled a particular machine before and do not ensure that the unit and component identifications match what you originally provided, testing may be delayed or the results may not be filed correctly with other samples from that machine. In addition to this "must provide" data for each sample, you should report any recent maintenance, changes in performance or unusual operating conditions.

Specific individuals should be assigned long-term responsibility for this portion of the program. If this is not possible, then a particular department should be designated for involvement. Once this responsibility is established, a system of record keeping and correct sample identification should be initiated as soon as possible.

7. Use the lab interpretation of the test data properly.

Our lab interpretation separates the overall component and lubricant condition and the relative severity of contamination and wear into four main classifications:

Normal- Physical properties of the lubricant are within acceptable limits, and no signs of excessive contamination or wear are present.

Monitor- Specific test results are outside acceptable ranges, but are not yet serious enough to confirm abnormal conditions. Caution is advised. The initial stages of an abnormality often show the same pattern of results as temporary conditions such as extended usage or over-loading.

Abnormal- Lubricant physical properties, contamination, and/or component wear is clearly unsatisfactory, but not critical. A confirming resample should be submitted. Additional diagnostic procedures may be needed to confirm each condition. Corrective actions are necessary to prevent reduction of service life or overall loss of performance.

Critical- Lubricant physical properties, contamination and/or component wear is clearly serious enough to require immediate diagnostic and corrective action to prevent major long-term loss of performance or component failure in service. Increases in operating hazard are likely. Short-term loss of performance may already be present. Large-scale repairs may be required. It may be necessary to remove the unit/component from service until a confirming resample is tested and diagnostics confirm that repairs are required.

These assessments are relative and are assigned using both trend analysis and condemning limits.

When trend analysis is used (as in the case of wear metals and certain contaminants), threshold values are developed to identify the boundary area between normal and abnormal results. For wear metals, these threshold values vary for different types of component, but are specific and stable for each individual model of a given application. The values do not provide sharp lines of 'normal/abnormal' interpretations; instead, they indicate ranges of increased likelihood that a problem has developed to a particular point. Generally, the lubricant and component condition can be considered 'normal' as long as the wear metal, contamination and lubricant deterioration levels remain within the established 'normal' ranges. Regardless of the threshold values, however, any sharp increase in wear metals or major shift in physical properties can signal beginning problems. Therefore, the threshold values cannot be used as 'go/no-go' criteria. A great deal of caution, judgment, experience and customer input must be used in applying threshold values properly.

Customers are contacted immediately by telephone on all samples where our interpretation detects a critical condition. Further, computer generated fax and/or e-mail copies of all critical or abnormal samples are dispatched upon completion of our evaluation. On these reports the lab will recommend specific maintenance actions designed to correct not only the indicated problems but also the causes of these problems.

When many components are involved in your analysis program, a spreadsheet ledger system is helpful in summarizing each component's oil analysis status. The columns should record date of sampling for each compartment, and separate incoming reports by the overall sample status. If you sample at the same time that you perform other routine maintenance and servicing activities, you should record this information and submit it with the sample. Many oil analysis management applications, such as Analysts' Online and LOAMS systems, automatically format oil analysis data in this layout.

Each report should be read as soon as possible. Copies of the analysis should be attached to any work orders or instructions.

8. Provide proper feedback.

The interpretation guidelines' accuracy is verified by comparing the lab test result-based predictions with actual conditions confirmed by inspection. In this way, the test interpretations are continually refined by practical experience. "Feedback" from the customer includes:

- Abnormal lubricant or component conditions that you suspect are present
- The findings of any inspection performed as a result of oil analysis program recommendations
- Abnormal lubricant or component conditions discovered that were not previously indicated by oil analysis
- Notification of servicing and maintenance performed
- Information concerning operating environment or equipment application changes

These items may be noted on the sample information form, recorded on a copy of the previous analysis report, or detailed on a separate report sheet.

9. Measure cost effectiveness.

The economic goals of reducing operating expenses and increasing profit margins have not changed since Analysts was founded. Routine oil analysis *will* help you achieve substantial savings in maintenance and repair costs. The program operates much like a medical checkup; if problems are detected, they can be corrected before they develop into serious and hazardous conditions that are costly to repair. When samples are reported normal, then the immediate value of oil analysis is a personal 'peace of mind' rather than an economic return. As the number of sampled pieces of equipment increases, the financial benefit of oil analysis also increases. Greater equipment availability and reliability means more production, less downtime and increased profits.

The importance of tracking the savings generated by your oil analysis program cannot be over-emphasized. Manpower, parts and tool expenses will all be affected. However, because a well-run oil analysis program is deeply integrated into a customer's overall maintenance program, management must establish a strong platform of results measurement and documentation to see oil analysis's unique contribution.

Although some benefits of oil analysis may not show clearly on the 'bottom line' because they represent abnormalities that were prevented, most of the economic savings from oil analysis can be calculated by comparing-

- Parts and labor expenses for component repair, overhaul, or replacement
- Loss of revenue during downtime

...before oil analysis with the same cost factors (plus the analysis expenses) after the program has been established and by estimating the-

- Extension of the average component operating lifespan before overhaul or replacement
- Reduction in consumable items such as lubricants or fuels
- Increase in productivity

...for the overall group of units/components that you have placed on a routine oil analysis program.

FIVE KEYS TO SUCCESSFUL OIL ANALYSIS

As with any diagnostic method, the user must share in the responsibility for success when using this well-established and widely accepted proactive maintenance tool. To achieve overall success for your oil analysis program, use these proven keys:

1. **Clearly defined customer goals and program requirements** ensure that the tests performed fit the application and that the service is being fully utilized on an ongoing basis.
2. **Representative samples** ensure that the true condition of the lubricant and component can be determined by reliable, accurate testing.
3. **Frequent lab-customer contact** promotes accurate interpretation and leads to increased customer confidence and interest in maintaining an active oil analysis program.
4. **Complete sample information** speeds processing and increases the Data Analysts' ability to fully interpret the test results.
5. **Rapid report review** ensures that abnormal or critical conditions are recognized and acted on in time to prevent damage or loss of performance.

Without a working knowledge of oil analysis tests and their significance, the user may be uncertain about the value of the service and how each test interrelates with the others to provide a useful, accurate picture of internal component and lubricant conditions. The following information is provided as a general orientation to what Analysts considers are the most important oil analysis tests.

SPECTROCHEMICAL ANALYSIS

Selected metallic elements present as microscopic particles suspended in the fluid to be analyzed are identified and measured in parts per million by weight. The analyzed elements are grouped into three main categories:

1. *Wear metals*

Relative motion between lubricated parts is always accompanied by friction between the opposing part surfaces. Despite the fact that these surfaces are usually coated with an oil film, friction wears them away. Some of the particles produced as the parts wear are small enough to remain suspended in the circulating oil. Since these wear products are composed of the same materials as the surfaces from which they originated, the level of each wear metal remaining in the used oil indicates the relative wear condition of the lubricated parts. Scientists working in the field of *tribology*, the study of wear, still disagree on how many separate kinds of wear exist. As few as four and as many as twenty-five classes of wear have been proposed. Five of the most commonly accepted types of wear are:

Adhesive wear- This type of wear occurs when the oil film becomes so thin that the roughest points of the opposing moving part surfaces begin to touch each other. Adhesive wear occurs normally during both break-in and routing service as the parts wear slightly to maintain alignment. If severe adhesion occurs due to load, speed or temperature conditions, scuffing and scoring will result. Metal may be torn off the part surfaces or transferred from one part to another and eventual seizure of the affected parts is likely. In normal service, adhesive wear is controlled with antiwear additives, which coat the lubricated surfaces and reduce direct part-to-part contact.

Abrasive wear- Abrasive wear is a cutting or scratching action caused when either hard particles or hard projections wear away softer surfaces. Sources of abrasive particles identified by oil analysis include contaminants such as dirt entering a component oil system and metal particles formed during wear.

Fatigue wear- Fatigue wear occurs when cyclic or repeated load stresses cause cracking, spalling, and pitting of the component part surfaces. This type of wear is more commonly associated with rolling element bearings and gears where the part surfaces roll past each other.

Corrosive (chemical) wear- Corrosive or chemical wear results when chemical reactions cause corrosion or oxidation of part surfaces and part movement or fluid pressure dislodges material from this surface layer. This type of wear is associated with rust-promoting conditions, corrosive contaminants and excessively high levels of chemically active additives.

Cavitation wear- Cavitation wear occurs when metal is removed from parts by the impact of collapsing cavitation bubbles on the part surfaces. Cavitation itself is associated with partial vacuums formed in a liquid by sudden changes in pressure and may be caused by vibration, reduced or uneven liquid flow and other factors involving particular component part shapes and movements.

2. *Contaminants*

Depending upon the circumstances, many different substances may be classified as contaminants. Silicon, in the form of silicon dioxide (sand), is one of the most common contaminants monitored with spectrochemical analysis. Similarly, the presence of grease contaminating an oil system may be indicated by increases in aluminum or barium if the grease contains metallic soaps. Although contamination is commonly associated with substances entering a component's oil system from an outside source, wear metals themselves are also a form of contaminant.

3. *Additives*

Additives are chemical compounds added to oils, fuels, and coolants to impart specific beneficial properties to the finished products. Additives create new fluid properties, enhance properties already present and reduce the rate at which undesirable changes take place in a fluid during service.

WEAR METALS AND CONTAMINANTS

SILICON

Silicon is typically associated with dirt contamination. This contamination can result from any condition that allows dirt to enter a component oil system. Other sources of silicon include seals, oil and coolant additives and greases.

IRON and alloys

Reciprocating engine: Gears and shafts; block; cylinder liners; valve train; connecting rods, rings and oil pump; some bearings; some pistons; some accessory systems.

Turbine engine: Gears and shafts; bearings; pumps; housings.

Transmission: Gears and shafts; bearings; brakes and disks; pumps and shift spools; PTO; housing.

Torque converter: Shafts; bearings; some housings.

Differential: Shafts and gears; bearings; housing.

Transaxle/final drive/reduction gearbox: Gears and shafts; bearings; housing.

Hydraulic: Rotors, vanes, pistons, and rods; housing and bores; gears and shafts; valves.

Reciprocating and rotary compressors: Gears and shafts; case; valves; cylinder liners; crossheads; rings and screws or turbines; bearings; some oil cooler tubing.

COPPER and alloys

Reciprocating engine: Bearings; wrist pin and valve train bushings; other bushings and thrust washers; oil cooler tubing. Also may be present as an oil additive or a crossover contaminant from a leaking transmission seal.

Turbine engine: Some main and accessory bearing retainers; bushings and nuts; some oil control valves.

Transmission: Discs; bearings; bushings and thrust washers; oil cooler tubing.

Torque converter: Retainers and separators.

Differential: Bearings; bushings, retainers, and thrust washers.

Final drive/reduction gearbox: Bearings; bushings, retainers, and thrust washers; oil cooler tubing.

Hydraulic: Bearings and bushings; swash plate cups; valves; some pistons; some pump cylinders; oil cooler tubing.

Reciprocating and rotary compressors: Bearings; bushings, thrust washers and retainers; oil cooler tubing.

ALUMINUM and alloys

All components: Aluminum oxides present in the environment, typically associated with silicon (dirt) contamination.

Reciprocating engine: Pistons; bearings; bushings; blocks, main and accessory cases and housings; some oil cooler tubing.

Turbine engine: Main and accessory case, housings; some retainers; seals; baffles.

Transmission: Some cases; bushings and retainers.

ALUMINUM and alloys (cont'd)

Torque converter: Impellers.

Differential: Bushings and thrust washers.

Final drive/reduction gearbox: Bushings and thrust washers.

Hydraulic: Some pump housings.

Reciprocating and rotary compressors: Case; impellers, some pistons and crossheads; retainers.

CHROMIUM alloy and plating

Reciprocating engines: Liners and rings; shafts; valve train.

Turbine engine: Bearings; shafts and gears; seals.

Geared components (general): Bearings; shafts; seals.

Hydraulic: Rods; valves.

Reciprocating and rotary compressors: Liners and rings; shafts; valve train.

LEAD and TIN overlay or flashing

Reciprocating engine: Bearings; some pistons; bushings and thrust washers.

Final drive/reduction gearbox: Bearings; bushings.

Hydraulic: Pump thrust plate; bushings.

Reciprocating and rotary compressors: Bearings; bushings.

--The use of lead as an extreme pressure (EP) oil additive has been banned.

--Tin may be present as an oil additive, usually in conjunction with lubricants containing molybdenum compounds.

NICKEL alloy (with iron); plating

Reciprocating engine: Gears and shafts; valve train; bearings.

Turbine engine: Gears and shafts; bearings.

Geared components (general): Gears and shafts; bearings.

Hydraulic: Gears and shafts, bearings.

SILVER plating; tracer

General: Some bearings and bushings; oil cooler solder; seals.

Silver is also occasionally used as a physical 'tracer' to indicate that wear has progressed to a certain point. In this application, silver is either plated directly onto a part surface or incorporated into a layer under the surface. The wear condition of the part can then be related to the amount of the tracer deposited in the oil. This usage is most often found in aerospace applications.

MOLYBDENUM alloy (with iron); plating

General: Some bearings; some piston rings.

MAGNESIUM alloy

General: Cases and housings.

TITANIUM alloy (with iron)

General: Some shafts, bearings, and gears. Typically found only in certain aerospace and heavy commercial or industrial applications.

ANTIMONY alloy (with lead and/or tin)

General: Certain types of journal bearing overlays.

ZINC alloy

General: Brass fittings (with copper); galvanized surfaces.

ADDITIVES

Most modern lubricants and coolants contain organometallic oil additives. Some of these additives are formed from compounds of one or more of the same chemical elements used in component parts.

MOLYBDENUM

Extreme pressure additive in specialty oils and greases; corrosion inhibitor in some coolant supplemental additives.

MAGNESIUM

Detergent, dispersant, alkalinity increaser.

SODIUM

Corrosion inhibitor in oils and coolants.

BORON

Detergent, dispersant; anti-oxidant in oils and coolants.

BARIUM

Corrosion and rust inhibitors; detergent; anti-smoke additive in fuels.

PHOSPHORUS

Anti-wear; combustion chamber deposit reducer; corrosion inhibitor in coolants.

POTASSIUM Compounds

Corrosion inhibitor; trace element in fuels; also found as a mineral salt in sea water.

CALCIUM

Detergent, dispersant, alkalinity increaser.

ZINC

Anti-wear, anti-oxidant, corrosion inhibitor.

ANTIMONY

Anti-wear, anti-oxidant.

PHYSICAL ANALYSIS

VISCOSITY

Viscosity is a lubricant's internal resistance to flow at a given temperature in relation to time, and is considered to be the single most important physical property of a lubricant. Changes in viscosity indicate improper servicing, dilution, contamination or lubricant breakdown in service. Viscosity is usually determined with a kinematic method and the results are reported in centistokes (cSt)*. In addition to the viscosity result, the crankcase oil viscosity class of an engine lubricant may also be expressed as an SAE Grade.

*1 Centistoke (cSt)= 1 square millimeter per second

WATER

The presence of water in a non-water-base fluid indicates contamination from an outside source or from condensation. Excessive levels of water promote lubricant breakdown and component part corrosion. Results are reported in percent (%) volume.

In certain components and applications where water contamination must be kept extremely low, the Karl Fischer titration method is used to measure and report water content in parts per million (ppm).

FUEL SOOT by LEM®

LEM® is the acronym for Light Extinction Measurement, an Analysts, Inc. patented process to determine fuel soot. LEM measures the fuel soot dispersed in the oil of diesel engines. This is an indication of the combustion efficiency of the engine.

An excessive concentration of soot allows the oil to gel, forming sludge in the engine, leading to poor oil circulation. It is affected by fuel injector efficiency, injector timing, integrity of the ring-piston seal, oil consumption and the load on the engine. Results are reported in weight percent (%). LEM is the most efficient and accurate method to measure fuel soot.

FUEL DILUTION

Fuel dilution indicates the relative amount of unburned diesel fuel or gasoline present in an engine lubricant. This dilution is associated with improperly adjusted or malfunctioning fuel system assemblies. Excessive fuel dilution lowers lubricant load-carrying capacities, promotes lubricant breakdown and increases the risk of fire or explosion. Fuel dilution is determined by gas chromatography and is reported in percent (%) volume.

GLYCOL

Positive test results indicate the presence of ethylene glycol, most commonly associated with cooling system leaks. Glycol contamination promotes wear, corrosion, sludging, and lubricant breakdown. If the analysis indicates that coolant additives or water contamination is present in the oil sample, additional chemical tests are used to confirm ethylene glycol contamination.

INFRARED ANALYSIS

When an organic compound, such as lubricating oil, is exposed to infrared light, the substances present in the compound will absorb the light at specific wavelengths. The amount of absorbance at a particular wavelength is related to both the type and quantity of absorbing material. When the infrared absorbance spectrum of an unused oil provided by the customer is compared to the spectrum of the same type of used lubricant, certain contaminants and physical changes in the lubricant can be directly measured. Although infrared analysis can detect and measure an extremely wide range of organic compounds, it is most frequently used in oil analysis to monitor:

Fuel Soot

The amount of fuel soot carbon suspended in the engine lubricant. Higher values indicate reduced combustion efficiency due to such conditions as air intake or exhaust restrictions, injector malfunctions or excessive idling. Test results are reported on an absorbance scale.

Oxidation

The chemical incorporation of oxygen into and subsequent loss of lubricant performance due to aging, adverse or abnormal operating conditions or internal overheating. Test results are reported on an absorbance scale.

Nitration

The organic nitrates formed when combustion by-products enter the engine oil during normal service or as a result of abnormal 'blow-by' past the compression rings. Test results are reported on an absorbance scale.

Water

Water contamination produces a characteristic peak in most oils, which can be easily measured. Test results are reported in % volume.

Glycol (coolant) contamination, sulfates, and certain additives may also be monitored using infrared analysis.

NOTE: The determination of oxidation requires a sample of new oil for an instrument and interpretation reference.

NEUTRALIZATION NUMBER

Both the acid content and the alkaline content of a lubricant may be measured and expressed as a neutralization number:

Total Acid Number (TAN)

Measures the total amount of acidic material present in the lubricant. Generally, an increase in TAN above that of the new product indicates oil oxidation or contamination with an acidic product. The results are expressed as a

numeric value corresponding to the amount of the alkaline chemical potassium hydroxide required to neutralize the acid in one gram of sample.

Total Base Number (TBN)

Measures the total alkaline content present in the lubricant. Many of the additives now used in engine oils contain alkaline (basic) materials intended to neutralize the acidic products of combustion. A relatively high TBN is associated with increased protection against ring and cylinder liner corrosion. Abnormal decreases in TBN may indicate reduced acid neutralizing capacity or a depleted additive package. The test first determines the amount of acid required to neutralize the alkaline content of the sample. The final result is then expressed as an equivalent amount of potassium hydroxide in one gram of sample.

SOLIDS, WEIGHT by membrane filtration

Solids content in an oil sample may also be measured by weight. The test determines the amount of filterable solid material in the sample with particle sizes greater than the filter pore size specified for the test. The test is performed by vacuum filtration and the result is reported as a numeric value. The result may be expressed either as a weight percentage which compares the weight of the liquid sample to the weight of the solid material in it, or as the actual weight of the solid material in a specified volume of sample.

AUTOMATED PARTICLE COUNT

This instrument uses a special detector which counts and sizes particles present in the fluid. Results are reported as numbers of particles in a specific size range per a given volume of sample.

The size ranges and reporting methods are in world-wide transition due to calibration and procedure changes, and a well-known aerospace standard (NAS 1638) is being retired in favor of a related and more modern SAE standard. The new standards and ranges have been carefully researched and selected for maximum accuracy and minimum impact on previously established particle count guidelines.

Three size ranges represent the ISO 4406 standard: >4 *microns* (changed from >2 microns), >6 *microns* (changed from >5 microns) and >14 *microns* (changed from >15 microns). Six size ranges represent the SAE AS4059 standard: the three ISO ranges previously noted, plus three additional ranges-- >21 *microns*, >38 *microns*, and >70 *microns* (changed from >25 microns, >50 microns, and >100 microns).

Results from the particle count are then used to determine fluid cleanliness via ISO or SAE classification codes. The ISO Class code is expressed as three separate numbers (for example, 20/15/12). The first number represents the relative contamination level from the first size range, and the second and third ranges are similarly calculated. The SAE Class code has separate size range limits for each of the six particle sizes, but the code is generally expressed as the single highest limit reached within any of the six classes (for example, SAE Class 5).

Abnormal particle contamination levels are associated with increased wear, operational problems, with close tolerance components, fluid contamination or degradation and loss of filter efficiency.

DIELECTRIC STRENGTH

This test measures an oil's ability to withstand an electric current without failing. Oil is placed in the gap between two electrodes and an increasingly higher voltage is applied to the oil until an arc forms across the gap. In large transformers, the circulating oil is formulated to act as an insulator. The relative insulating capacity of the transformer oil is indicated by the dielectric strength. Generally, small amounts of water, dirt, or metal will affect the test result. For this reason, the dielectric principle forms the working basis for many different models of field-test type oil analyzers. Results are reported in kV (kilovolts).

FERROGRAPHY

Ferrography is an analytical technique in which wear metals and contaminant particles are magnetically separated from a lubricant and arranged according to size and composition for further examination. It is widely used in oil analysis to determine component condition through direct examination of wear metal particles.

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There are three stages in a complete ferrographic analysis: (1) direct reading (DR) ferrography, (2) analytical ferrography and (3) the ferrogram interpretation and report.

DR (direct reading) ferrography precipitates the wear particles from a sample and electronically determines the quantity of 'large' (over 5 microns) and 'small' (1 to 2 microns) particles present in the sample. Wear calculations from these results indicate the rate, intensity and severity of wear occurring in the sampled machine. In cases where the DR ferrography wear trends indicate an abnormal or critical wear condition, analytical ferrography can reveal the specific wear type and probable source of the wear condition.

Analytical ferrography uses the Ferrograph Fluid Analyzer to concentrate on direct microscopic evaluation of the wear particles. A ferrogram slide is prepared by drawing the oil sample across a transparent glass or plastic plate in the presence of a strong magnetic field. Wear particles are pulled to and sorted on the plate in a manner similar to that used in the direct-reading ferrograph. After deposition, the oil is washed away, leaving the particles clean, aligned with the magnetic field, and fixed to the plate. An experienced evaluator then examines the ferrogram to determine the composition and sources of the particles and the type of wear present.

The DR ferrography report includes spectrochemical analysis, large and small particle quantity indexes, and the results from wear rate, intensity and severity calculations. An analytical ferrography report includes specific type and quantity classifications of the metallic and non-metallic debris present on the slide, a color photomicrograph of the ferrogram, an assessment of the sampled machine's overall wear status and a detailed interpretation of the ferrography results.