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— 4th Edition —

BASICS OF OIL ANALYSIS



ANALYSTS, INC.

IT'S BETTER TO KNOW.

INTRODUCTION

The birth of an industry

The extensive history of oil analysis makes it the oldest of all commercial proactive-maintenance technologies. Over the past 75 years, oil analysis has helped diagnose the internal conditions of oil-wetted components and their lubricants in virtually every industry that involves heavy machinery. While today's analytical tools employ the most advanced technologies, early test methods were shockingly simple. The first diagnostic techniques merely involved smelling oil in an attempt to detect the sour odor of excess acid. Other early tests included inspecting oil with the naked eye for visual signs of contaminants or placing a sample drop on absorbent paper to detect contaminant residue.

In 1960, Edward Forgeron brought a new level of service to the industry by founding Analysts, Incorporated—the first independent commercial laboratory to offer complete oil analysis diagnostic services to all areas of business and industry. Thus taking the rudimentary methods utilized in the field and incorporating modern scientific testing to provide critical insight for maintenance departments across all industries.



A modern era for lubricant analysis

Present-day technology uses a combination of physical and chemical tests to monitor lubricant and component conditions.

These tests are established and reviewed by a number of agencies, including the International Organization for Standardization (ISO), the American Society for Testing and Materials (ASTM), and the Society of Automotive Engineers (SAE). In addition, a variety of laboratory and personnel certifications have emerged to ensure the highest levels of lab technician quality.

Today, commercial oil analysis serves a myriad of industries. Over the past seven decades it has saved countless dollars in premature equipment failure and company downtime. It has become the focus of magazines, seminars, and trade shows. And it is easily one of the most effective and proactive tools for maintaining the physical integrity of internal components. With over 50 years of leadership and experience, Analysts has played a pioneering role in this industry's development. We are proud of our legacy. Moreover, we are working to create new innovations and enhanced services in an effort to advance our industry and better serve our clients in the years ahead.

Commitment to our customers

As a sign of our continued commitment to our customers, we are pleased to release the 4th edition of our Basics of Oil Analysis book. This book is designed to help you gain a better understanding of the fundamental concepts of an oil analysis program. It is our hope that all practitioners, whether novice or experts, can gain practical information from this book to improve your oil analysis program.



APPLYING OIL ANALYSIS

Oil analysis is an integral part of the maintenance plan for power generation and manufacturing plants, over-the-road trucking fleets, off-road construction equipment, aircraft, refrigeration systems, processing and chemical plants. Any piece of equipment that has a lubricating system is a potential candidate for oil analysis.

A successful oil analysis program requires an organized and sustained effort. No TPM (Total Productive Maintenance), lean manufacturing or Six Sigma initiative will reach its goal without the processes to sustain improvement. Both the user and the laboratory must work closely together to lay the groundwork for the program and achieve the desired results.

OUTLINE FOR AN EFFECTIVE OIL ANALYSIS PROGRAM

1. Determine your primary objectives

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

Utilization

- Decrease unscheduled downtime
- Increase overall component lifespan
- Control lube consumption and oil disposal costs
- Assist product selection, comparison and verification

Maintenance

- Identify and measure lube contamination along with component wear for targeted corrective action
- Reduce in-service failures and field repairs
- Establish proper lubricant service intervals

Management

- Improve reliability, product quality and productivity
- Improve cost control for equipment, labor and materials
- Eliminate needless inspections or repairs
- Control spares and replacement costs

2. Carefully consider your best choice for an oil analysis provider

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 has been featured in numerous magazine articles, advertisements, and other published materials. These “second opinions” are excellent sources of reference about our service. However, the best guide to choosing a laboratory and sorting between the many claims these companies make, 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 has been in continuous and evolving operation since 1960 — long enough to have developed complete, time-tested procedures for purchasing, analysis, reporting, client contact and support. We offer a wide selection of sampling materials, including our SureSample® sampling container, 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 enhance your oil analysis program.

Choose a well-equipped laboratory

Each Analysts laboratory is thoroughly computerized, and most of our modern, well-maintained instruments are automated and directly interfaced with the lab’s information-management system. We adhere to published, proven testing procedures and use only the highest quality chemicals. We encourage our clients to visit our lab facilities to see this for themselves.



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As you look at price, quality,
support and experience, don’t
forget to evaluate the laboratory
instrumentation and methods.
”

Choose a laboratory with a well-trained, experienced staff

Analysts’ service and technical personnel are respected members of the reliability community. More of our staff members are STLE Certified Lubrication Specialists or Oil Monitoring Analysts than all our competitors combined! We recognize the specific technical requirements for your applications and can answer your questions fully. We have an organized approach for establishing you as a client and can give you sound, practical suggestions for overcoming any obstacle you might encounter in establishing and maintaining your Analysts’ oil analysis program.

Choose a laboratory with recognized quality control

Analysts, Inc. has the strongest certified and registered ISO 17025 quality program in commercial oil analysis. By attaining the ISO 17025 certification, Analysts demonstrates on a daily basis our commitment to quality in every aspect of our business. In addition, Analysts’ quality program meets the requirements of 10 CFR 50, Appendix B — the federal specification for quality programs in nuclear power plants. All of our data analysts have one or more of the STLE CLS® and OMA certifications, and most of our technical staff members also hold these and other credentials. With our program of documentation, training, procedures and follow-up, Analysts is recognized as the leader in quality and service within the industry.

Examine example reports for reliable recommendations and easy-to-read format

Clearly stated results and recommendations are vital to the success of your oil analysis program. Analysts' reports are concise and informative. Our recommendations are specific, complete and easy to understand. The recommendations reflect a real knowledge of the operating and wear characteristics of the component sampled. Test results indicating the need for a major inspection are double-checked and verified prior to reporting to you. All of our staff of data analysts 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.

Expect rapid turnaround of analysis reports

Analysts, Inc. provides an average turnaround time of one day or less for routine samples. Over 80% of the samples received are completed the same day they are received. We notify you immediately if critical conditions are detected, and make your reports available online instantly after completion. We provide "rush" handling if you require an immediate response, and after-hours special openings can be arranged in case of emergency.



“ -----
*A sample's transit time from
sampler to lab is always the
largest part of the actual
turnaround of a sample.*
----- ”



Look for specialized summary reports

To assist our clients 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 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 website at www.analystsinc.com. This site also offers the fully web-based LOAMS® (Lube Oil Analysis Management System), developed in response to today's proactive reliability management needs. Through LOAMS, your entire oil analysis program can be managed in the cloud. From program setup to program administration, LOAMS provides the user with easy-to-use features, such as report retrieval, equipment management, label printing, graphing, user management, and much more.

3. Build the foundation for your program

Frequently there is an assumption that an oil analysis program can be hurriedly established simply by taking a few samples and sending them to the nearest, cheapest laboratory. Nothing could be further from the truth.

Sampling point survey

Before you begin sampling, a necessary first step is to identify the systems you want to sample, and collect relevant technical reference information on those systems. Next, determine any history of operating or wear problems, and the criticality of any particular system (the impact of downtime and repair upon your business process).

Selecting tests

Different combinations of physical and spectrochemical tests are used to measure the properties of the lubricant 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 characteristics of the lubricant, including contaminants and oil breakdown by-products, as well as their general effect on the lubricant properties. The **spectrochemical** analysis identifies and measures selected metallic elements present in the lubricant as



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Oil Analysis labs vary as do the tests they perform. Choosing a lab should be based on testing capabilities, service and satisfying your specific needs.
”

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” which are combinations of routinely performed tests. These packages are designed to cover the general testing needs of broad industry classifications such as power generation, manufacturing, construction, mining, and over-the-road trucking. While these packages meet most program’s needs and objectives, you can develop your own custom test slates to meet your programs goals. Analysts will assist you in selecting the proper combination of tests prior to beginning your sampling program.

Proper sampling intervals

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

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.

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

Obtaining a representative sample

This is undoubtedly 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.

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

Areas where lubricant flow is restricted or where contaminants and wear products tend to settle or collect should be avoided as sampling points.

We recommend the following sampling points in order of preference:

- A petcock or other sampling access installed **prior** to the oil filter (using Analysts' QSS® or similar valve)
- An oil-dipstick tube or other service opening (using the SureSample® or a vacuum pump)
- The sump or reservoir drain

The reservoir drain is often the easiest sampling point, but it is so prone to sampling error that we discourage it.

In special cases, samples may be taken from lube filters. The lab should be advised prior to testing if this occurs.

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.

4. 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 supporting information on the machines, components and lubricants in service.

Initial equipment registration can be easily accomplished by furnishing the laboratory with a consolidated equipment list based on your sampling point survey, or by completing an individual registration form for each sampled system. In either case, the sampling point ID and current operating data is sent with each sample.

In completing our 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 a 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. Our forms provide checkboxes for common sampling positions.

NOTE: In industrial applications the “unit” and “component” often refer to the same mechanical system. In this case, the description of the sampled system will be recorded as the “unit.”

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.



“ Recording operating time on oil is absolutely essential to time-based trending — the most accurate way to pinpoint abnormal wear conditions. ”

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 to use.



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 may not be processed immediately if the client name, unit and component identification, or 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 while the needed information is established, 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. If you sample at the same time that you perform other routine maintenance and servicing activities, you should also record that information and submit it with the sample.

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

5. Use the lab interpretation of the test data properly

Our lab interpretation typically separates the overall component and fluid condition—as related to the relative severity of contamination and wear—into four main classifications.

NORMAL

Physical properties of the fluid 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 or justify diagnostic action. Caution is advised. The initial stages of an abnormality often show the same pattern of results as temporary conditions, such as extended usage or overloading.

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. Increases in operating hazard are likely. Short-term loss of performance may already be present. Large-scale repairs may be required. You may be advised to remove the unit/component from service until a confirming resample is tested and other diagnostics confirm that repairs are necessary.

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

When **trend analysis** is used (primarily in the case of wear elements), threshold values are developed to identify the boundary areas between normal and abnormal results. For wear metals, these threshold values vary for different types of component, but are usually specific and consistent 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, contamination and lubricant deterioration levels remain within the established “normal” ranges. Regardless of the threshold values, any sharp increase in wear metals or major shift in physical properties can signal the beginning of problems. Therefore, the threshold values can’t be used as “go/no-go” criteria. A great deal of caution, judgment, experience and client technical input must be used in applying threshold values properly.

Clients are contacted immediately by telephone on all samples where our interpretation detects a critical condition. Further, email 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.

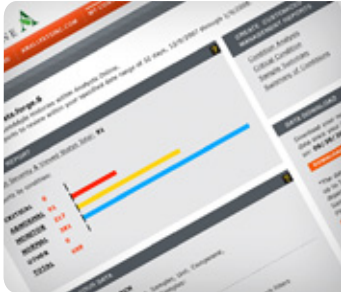
Each report should be removed as soon as possible for action items. Analysis copies should be attached to work orders or instructions. Access to electronic versions of the report(s) should be given to appropriate personnel.

6. Provide the lab with proper feedback

The interpretation guidelines' accuracy is verified by comparing the lab's maintenance recommendations with actual conditions confirmed by inspection. In this way, the test interpretations are continually refined by practical experience. Feedback from the client 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 machine conditions discovered that were not previously indicated by oil analysis
- Notification of servicing and/or maintenance performed
- Information concerning operating environment or equipment application changes

These items may be noted on the sample information form, recorded in LOAMS. If the feedback is sent separately, please provide the component reference number (on report, upper right corner, third line below the **Status Was** block).



“ One simple way of measuring program effectiveness is to trend the number and type of abnormal or critical conditions in your machines over time. ”

7. 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.



“ Oil analysis is both predictive and proactive and is probably the most cost-effective maintenance technique available. ”

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 client's overall maintenance program, management must establish a strong platform of results measurement and documentation to see oil analysis's unique contribution to profitability.



Although some benefits of oil analysis may not show clearly on the “bottom line” because they represent conditions that were prevented, many 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
- Reduction in consumable items, such as lubricants or fuels
- Increase in productivity

THE 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 client 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/client contact** promotes accurate interpretation and leads to increased client 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. Prompt report review** ensures that abnormal or critical conditions are recognized and acted on in time to prevent damage or production loss.

TESTS AND THEIR SIGNIFICANCE

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 for industrial and nonindustrial applications.

SPECTROCHEMICAL ANALYSIS

Selected metallic elements present as dissolved solids and 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 rate of the lubricated parts.

Five of the most common types of wear are:

Adhesive / Rubbing Wear

This type of wear occurs when the oil film does not separate the roughest points of the opposing moving-part surfaces, and they begin to touch each other. Adhesive wear occurs normally during both break-in and routine 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 bond to lubricated surfaces and reduce direct part-to-part contact.

Abrasive Wear

Abrasive wear is a cutting or etching action caused when either circulating hard particles or hard-surface 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 ball/roller 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 shock 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, grease contamination in an oil system may be indicated by increases in aluminum or barium if the grease contains metallic soaps. Although the term 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 (examples include: Anti-wear, anti-oxidant, detergency, discrepancy). 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 alloying element or cast metal	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
alloying element

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.

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

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
alloying element
or cast metal

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.

Torque converter: Impellers.

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

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.

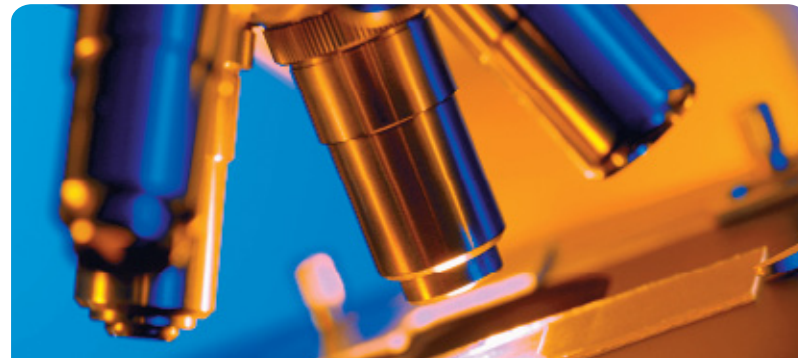
<p>CHROMIUM alloying element or plating</p>	<p>Reciprocating engines: Liners and rings; shafts; valve train.</p> <p>Turbine engine: Bearings; shafts and gears; seals.</p> <p>Geared components (general): Bearings; shafts; seals.</p> <p>Hydraulic: Rods; valves.</p> <p>Reciprocating and rotary compressors: Liners and rings; shafts; valve train.</p>
<p>LEAD & TIN alloy or flashing</p>	<p>Reciprocating engines: Bearings; some pistons, bushings and thrust washers.</p> <p>Final drive/reduction gearbox: Bearings; shafts; seals.</p> <p>Hydraulic: Pump thrust plate; bushings.</p> <p>Reciprocating and rotary compressors: Bearings; bushings.</p> <p>– Lead may still be found (rarely) in industrial paints and primers.</p> <p>– Tin may be present as an oil additive, usually in conjunction with lubricants containing molybdenum compounds.</p>
<p>NICKEL alloying element or plating</p>	<p>Reciprocating engines: Gears and shafts; valve train; bearings.</p> <p>Turbine engine: Gears and shafts; bearings.</p> <p>Geared components (general): Gears and shafts; bearings.</p> <p>Hydraulic: Gears and shafts, bearings.</p>

<p>SILVER plating; tracer</p>	<p>General: Some bearings and bushings; oil cooler solder; seals.</p> <p><i>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.</i></p>
<p>MOLYBDENUM alloy or flashing</p>	<p>General: Typically found only in certain aerospace and heavy-duty commercial or industrial steels. May also be present in fuels as heavy crude residual material.</p>
<p>MAGNESIUM alloying element</p>	<p>General: Cases and housings.</p>
<p>TITANIUM alloying element</p>	<p>General: Some shafts, bearings, and gears. Typically found only in certain aerospace and heavy-duty commercial or industrial steels.</p>
<p>ANTIMONY alloying element</p>	<p>General: Certain types of journal-bearing overlays.</p>
<p>ZINC alloying element</p>	<p>General: Brass fittings (with copper); galvanized surfaces.</p>
<p>VANADIUM alloying element</p>	<p>General: Typically found only in certain aerospace and heavy-duty commercial or industrial steels. May also be present in fuels as heavy crude residual material.</p>

ADDITIVES

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

MOLYBDENUM	General: Extreme pressure additive or solid lubricant in specialty oils and greases; corrosion inhibitor in some conventional coolants or supplemental additives.
MAGNESIUM	General: Detergent, dispersant, alkalinity increaser.
SODIUM	General: Corrosion inhibitor in oils and coolants.
BORON	General: Detergent, dispersant; anti-oxidant in oils and coolants.
BARIUM	General: Corrosion and rust inhibitors; detergent; anti-smoke additive in fuels.
PHOSPHORUS	General: Anti-wear; combustion chamber deposit reducer; corrosion inhibitor in coolants.
POTASSIUM	General: Corrosion inhibitor; trace element in fuels; also found as a mineral salt in sea water (marine cooling systems).
CALCIUM	General: Detergent, dispersant, alkalinity increaser.
ZINC	General: Anti-wear, anti-oxidant, corrosion inhibitor.



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 most commonly 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. Water contamination can be assessed with the "crackle" test. 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 promotes oil gelling and 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, widely specified by OEM's as the preferred measurement method.

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 engine-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. In this way, certain contaminants and physical changes in the lubricant can be directly measured as a molecular spectrum. Glycol (coolant) contamination, sulfates, acid and base changes, and certain additives may also be detected, along with an extremely wide range of organic compounds. Infrared analysis 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 conditions such 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.



Neutralization Number

Both the acid content and the alkaline content of a lubricant may be measured and expressed as a neutralization number obtained from a wet chemical titration:

Acid Number (AN, “TAN”)

Measures the total amount of acidic material present in the lubricant; multiple methods have been developed to perform this test. Generally, an increase in AN above that of the new product indicates oil oxidation, or mixing with a more acidic product or contaminant. The results are expressed as a numeric value corresponding to the amount of the alkaline chemical potassium hydroxide required to neutralize the acid per one gram of sample.

Base Number (BN, “TBN”)

Measures the total alkaline content present in the lubricant; multiple methods have been developed to perform this test. Many of the additives used in engine oils contain alkaline (basic) materials intended to neutralize the acid-forming processes of aging and fuel combustion. A relatively high BN is associated with increased protection against ring and cylinder liner corrosion, and damage to “yellow” metals, such as copper and bronze. Abnormal decreases in BN indicate a reduced acid-neutralizing capacity and/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 alkaline potassium hydroxide per gram of sample.

Particle Counting

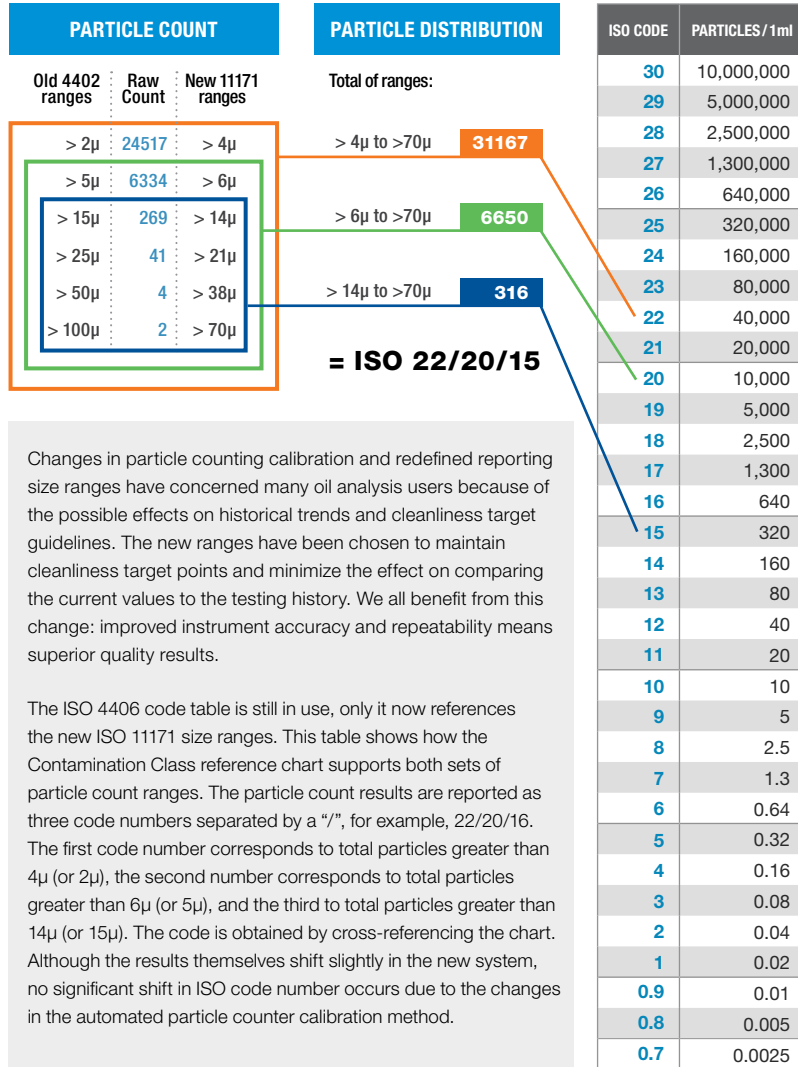
This test uses instruments with special detectors which count and size particles present in the fluid. Results are reported as numbers of particles in a specific size range per a given volume of sample.

Analysts use two different methods to perform the particle count: the pore blockage/flow decay method, and the APC (automated particle count), a laser-based method. Each has particular strengths and appropriate applications.

For these methods, three size ranges represent the current ISO 4406 standard: >4 microns, >6 microns and >14 microns. Three additional ranges (>21 microns, >38 microns, and >70 microns) complete the count where detailed sizing is required by a particular standard or customer requirement.

Results from the particle count are then used to indicate fluid cleanliness via ISO 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. Abnormal particle contamination levels are associated with increased wear, operational problems with close tolerance components, fluid contamination or degradation and loss of filter efficiency.

Particle Counting Chart:



Changes in particle counting calibration and redefined reporting size ranges have concerned many oil analysis users because of the possible effects on historical trends and cleanliness target guidelines. The new ranges have been chosen to maintain cleanliness target points and minimize the effect on comparing the current values to the testing history. We all benefit from this change: improved instrument accuracy and repeatability means superior quality results.

The ISO 4406 code table is still in use, only it now references the new ISO 11171 size ranges. This table shows how the Contamination Class reference chart supports both sets of particle count ranges. The particle count results are reported as three code numbers separated by a “/”, for example, 22/20/16. The first code number corresponds to total particles greater than 4μ (or 2μ), the second number corresponds to total particles greater than 6μ (or 5μ), and the third to total particles greater than 14μ (or 15μ). The code is obtained by cross-referencing the chart. Although the results themselves shift slightly in the new system, no significant shift in ISO code number occurs due to the changes in the automated particle counter calibration method.

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.

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 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. An experienced evaluator then examines the ferrogram to determine the composition and sources of the particles and the type of wear present.

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.

QSA®

Analysts has developed an innovative test— Quantitative Spectrophotometric Analysis (QSA)— to accurately determine a used lubricant's likelihood to promote harmful sludge and varnish build-up. Based on the lubricant type and the application, the basic QSA® rating allows a trained diagnostician to determine the presence or likelihood of internal sludge and varnish build-up.

There are numerous types of insoluble contaminants found in lubricating systems. Insoluble contaminants are those materials that will not dissolve in the oil. The two most general classifications of insoluble contaminants are hard contaminants, such as dirt, debris and wear particles, and soft contaminants, composed of the various oil degradation by-products.

Varnish originates from these soft contaminants. It is a thin, insoluble film that over time deposits throughout the internal surfaces of a lubrication system. The degradation process accelerates as the lubricant undergoes continued exposure to air, water, and high temperatures. The presence of varnish in hydraulic and lubrication systems causes many serious problems, including but not limited to the sticking of varnish-coated control valves. Also, once the varnish has formed, it takes a major investment in time and money to clean up an affected system.

Specialty Testing

Test slates for certain industrial systems, greases, fuels, coolants or other special investigations, often include non-routine or ASTM specification tests. A comprehensive overview of these tests can be viewed on Analysts, Inc's website at: www.analystsinc.com. Our fully equipped laboratories give us the widest possible testing capabilities, and we have specially designed analysis programs for certain applications and fluids. Please contact us for detailed information related to your specific needs. A list of our facilities and contact information can be found on the back cover.

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