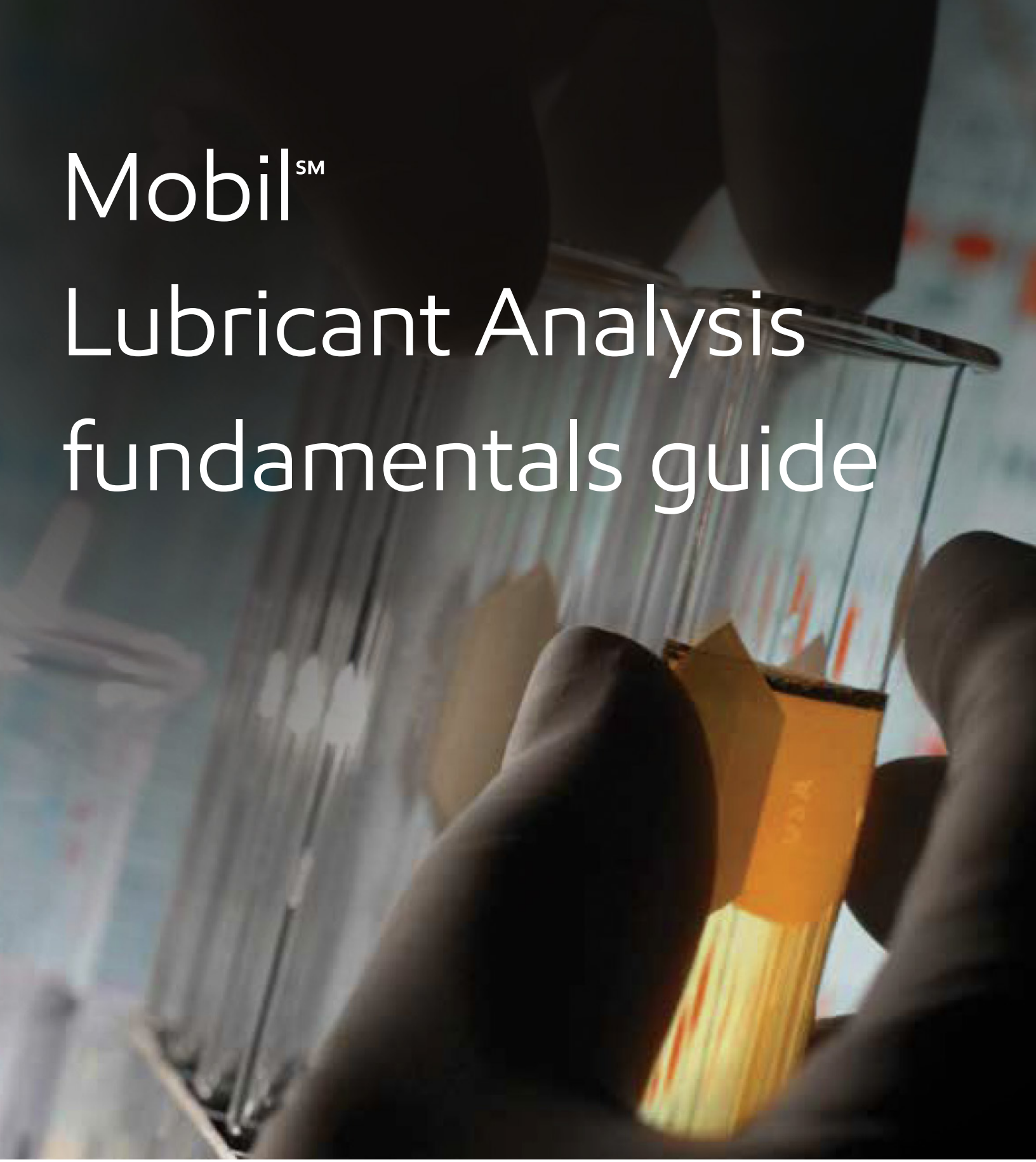

Mobil℠ Lubricant Analysis fundamentals guide

Mobil™

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How to:
Get help

Mobil Lubricant Analysis[SM] offers an innovative oil analysis program backed by industry-leading application expertise.

If you have questions or need assistance contact your local ExxonMobil sales representative or our Technical Help Desk.

Find the appropriate Technical Help Desk contact number here:

Technical Help Desk »

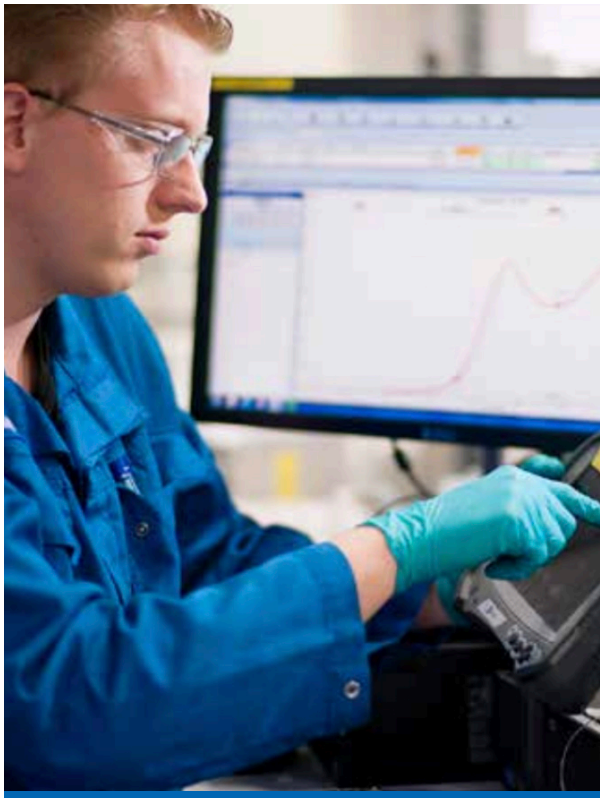
Mobil℠ Lubricant Analysis condition-monitoring fundamentals

In today's industry, condition-based maintenance practices have gained widespread acceptance. Key industry leaders increasingly realize that oil analysis is a critical component in any equipment monitoring program. A successful oil analysis program can help:

Mobil℠ Lubricant Analysis simplifies the lubrication monitoring process while producing reliable results that help guide maintenance professionals to the best decisions for their operations.

Mobil Lubricant Analysis provides informative reports on the condition of your equipment and lubricant, backed by the unmatched flexibility, expertise, and quality assurance of ExxonMobil.

- **Flexibility —** Perform many tasks more efficiently with Mobil Lubricant Analysis online capabilities.
- **Expertise —** Through global Original Equipment Manufacturer (OEM) relationships and hands-on lubrication experience, ExxonMobil supports your maintenance activities.
- **Quality —** Make decisions with confidence by leveraging the quality assurance offered by ExxonMobil.



Points to consider
Oil analysis

Oil analysis is an effective condition-monitoring tool. Additional equipment monitoring practices (inspections, vibration, operator logs, etc.) can be implemented to further enhance the value of your overall equipment reliability program.

How to:
Establish and maintain a successful oil analysis program

1. Establish goals and metrics
2. Obtain management commitment
3. Train and educate personnel
4. Identify equipment and sample frequencies
5. Implement the program
6. Respond to analysis results
7. Measure program results versus goals and metrics
8. Review and modify program
9. Document savings

What and when to sample

Oil analysis is most effective as a diagnostic tool when samples are taken from the appropriate equipment at scheduled intervals.

1. Determine what to sample — Consider the five general factors listed below when selecting equipment for the program, and refer to your OEM manual for guidance on recommended sample frequency.

Operating environment	Fluid age factor	Equipment age factor	Target sample results	Economic impact of failure
▪ High dirt/dust environment ▪ High loads/pressures/ speeds ▪ High temperatures ▪ Low temperatures ▪ Chemical contamination ▪ Wet environment	▪ Hours/miles/kilometers since last change ▪ Oxidation, contamination ▪ Synthetic, premium, mineral	▪ Hours/miles/kilometers ▪ Rated life expectancy ▪ Make and model number	▪ Above control limits ▪ Within control limits	▪ Safety risk ▪ Operational criticality ▪ Repair costs ▪ Downtime cost ▪ Lost production ▪ Spared unit

2. Determine when to sample — A regular pattern of sampling will establish a credible historical trend of equipment performance. If you don't have OEM-recommended sample interval guidelines, refer to the table below for general guidance in establishing initial sample frequency.

Industrial/plant equipment		Off-highway equipment		On-highway equipment	
Application	**Frequency**	**Application**	**Frequency**	**Application**	**Frequency**
Landfill gas engine	250 hours	Diesel engine	250 hours	Diesel engine	25,000 km or 15,000 mi.
Generator engine	500 hours	Wheel motor	250 hours	Transmission	500 hrs, 40,000 km, or 25,000 mi
Natural gas engine	500 hours	Differential/gear	500 hours	Hydraulic system	500 hrs, 40,000 km, or 25,000 mi
Paper machine lube system	Monthly	Hydraulic system	500 hours		
Turbine	Monthly	Transmission	500 hours		
Compressor	3 months	Final drive	1,000 hours		
Gear drive	3 months				
Hydraulic system	3 months				

Selecting a Mobil℠ Lubricant Analysis service

Visit mobil.com »

Analysis options*

Mobil℠ Lubricant Analysis provides you with analysis options based on your equipment's application and the desired analysis service level.

These service level options use the 4-ounce (120 ml) bottle kit.

Service option	Description
Essential analysis ◆	Delivers the essential application-specific analysis to help you assess equipment wear, contamination and oil condition
Enhanced analysis ◆◆	Delivers additional enhanced tests for more comprehensive analysis (e.g., hydraulic/circulating systems-particle count, particle quantifier index; or engines - base number, particle quantifier index)
Elite analysis ◆◆◆	Delivers a unique level of testing for limited applications that operate under demanding conditions (e.g., precision hydraulic applications)

Extended service analysis options*

The criticality of maintaining operations may require an advanced level of analysis. These extended service analysis options (available only for select applications) are designed to support equipment reliability decisions.

For extended service level options, use the metal 1 liter tin kit.

Service option	Description
Suitability for continued use analysis (SCU)	Performs additional tests to determine whether the in-service oil is suitable for continued use (e.g., rotation pressure vessel oxidation test (RPVOT), foam, demulsibility). Recommended on an annual frequency.
Varnish prediction analysis (VPA)	Performs additional tests to identify indicators of varnish in critical systems (e.g., membrane patch colorimetry (MPC), RULER – phenolic, and RULER - amine). Recommended on a quarterly or annual frequency.
Maximum service analysis (MSA)	Combines the analysis of suitability for continued use and varnish prediction analysis to help improve reliability and detect problems before they result in costly downtime or expensive repairs. Recommended on a quarterly or annual frequency.

* Analysis may vary by laboratory, product supplied or oil condition. For more information about choosing the analysis service that best fits your needs, contact your ExxonMobil representative or visit mobilserv.mobil.com.

How to:
Obtain sample kits

1. Determine the analysis options required for your program goals
2. Identify the Mobil service level for your analysis*
3. Request the appropriate Mobil sampling kit

Request Mobil℠ Lubricant Analysis kits from your authorized ExxonMobil Distributor or local ExxonMobil representative.

Taking a representative sample

When, where, and how you sample impacts the quality of your results.

To obtain accurate analysis, start with a representative sample. Sample at a consistent frequency, from the same sample location, using proper sampling techniques. For best results:

1. Establish a sampling schedule.

- **Integrate the schedule** with your planned maintenance.
- **Sample from the same sampling point** and at a consistent sample interval.
- **Sample at operating temperature** through a sampling valve, vacuum pump or sampling tube. Use caution when oil is above 120°F (50°C).

2. Follow good housekeeping techniques.

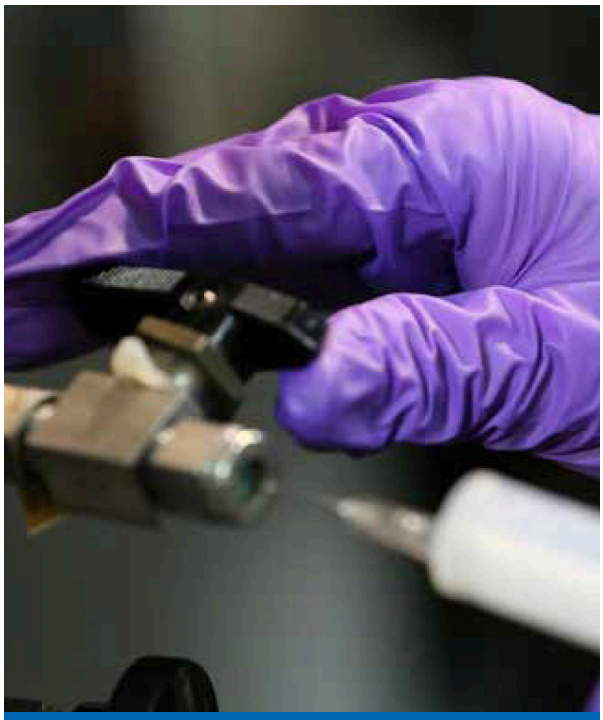
The laboratory's analysis is looking for particles in your oil sample less than 8 microns in size, which are not typically visible to the eye (See: Points to consider - How big is a micron?).

- **Wear proper safety equipment** while sampling (safety glasses, gloves, etc.).
- **Use only new sample bottles** and keep the lids on until taking a sample.
- **Clean** the area around the sample point or drain plug.
- **Flush the new sample bottle** with the oil to be sampled before collecting the final sample for submission. For particle count analysis, best to fill/flush the bottle three times prior to final sample for submission.
- **Avoid sampling from the drain plug**, where it's difficult to obtain a representative sample. If unavoidable, sample when the oil is still warm and about mid-way through the draining process.
- **Do not use degreasing agents to clean** sampling equipment. Traces of these substances can affect the analysis results.

3. Record equipment and sample details.

Document this data to help improve your results interpretation and normalize the analysis trend. Ensure sample details are entered, including date, hr/mi/km on oil and equipment, etc.

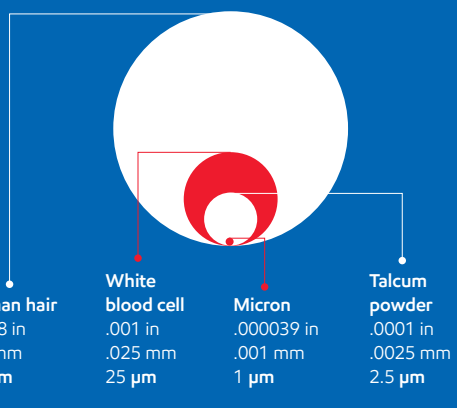
Sample at a consistent frequency from the correct sample location using proper sampling techniques.



Points to consider
Contamination analysis

Laboratory analysis typically targets contaminants < 8 microns, which is five times smaller than what is visible with the human eye. Visible particles or water in a sample reflect the possibility of abnormal equipment conditions and corrective action is recommended.

How big is a micron (µm)?

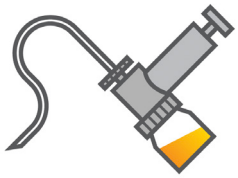


Sampling and scanning instructions

Take a sample

When taking a sample, remember to:

- Update or add asset registration data online
- Ensure area where sample will be taken is clean
- Sample as close to operating temperature as is safely possible
- Enter equipment operating details



Use Mobil sample bottle and draw a representative oil sample from the sample point.

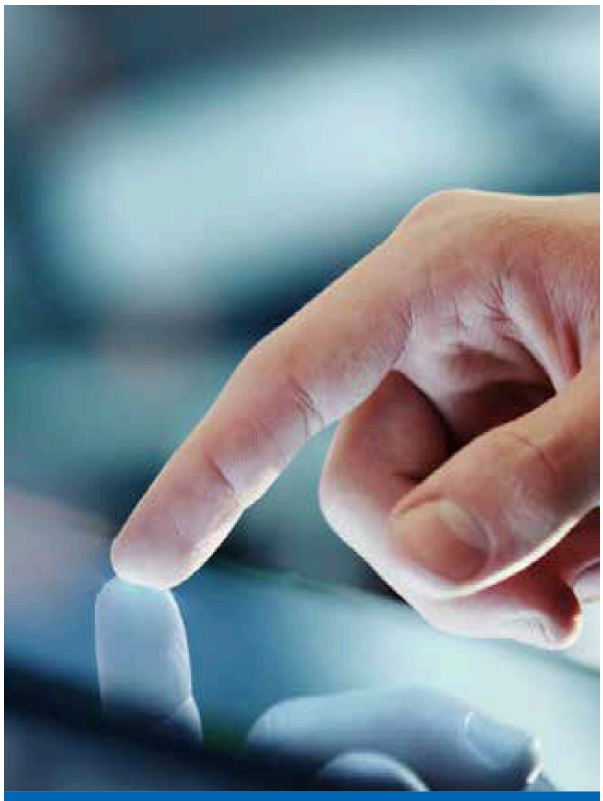
⚠ Use caution when oil temperature is above 120°F (50°C)

Secure the cap to the sample bottle. Visually inspect the sample for particulate, water or other contaminants.

⚠ If contamination is visible, do not submit the sample. Take corrective action. Resample once the condition is corrected.

Mobil[SM] Lubricant Analysis offers two options for registering your samples. You can print the bottle label, or you can use the faster, easier, scan-and-go sample registration method.

Submitting a sample instructions »



Points to consider

Document equipment/ maintenance data

Trend identification is important to understanding oil analysis results. You should include critical equipment and maintenance information (e.g., date sampled, hr/mi/km, makeup oil, etc.) with your sample submission. This data allows you to normalize the analysis trends to enhance your sample results assessment.

How to:

Save 192 labor hours per year

Using the Mobil scan and go sampling process, a Texas alumnia production plant reported* reducing its sample preparation time by 66% - an average of 192 fewer labor hours per year.

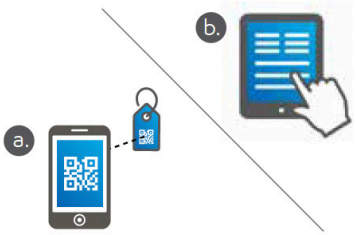
This process efficiency helped reduce labor time, generating an annual total cost savings of US $9,600.

*This proof of performance is based on the experience of a single customer. Actual results can vary depending upon the type of equipment used and its maintenance, operating conditions and environment, and any prior lubricant used.

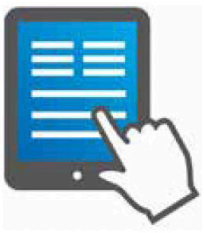
Submitting a sample - Scan-and-go method

The scan-and-go method can save you time, improve the accuracy of your data and expedite your sample through the laboratory. Scan and go steps may be completed on a computer or mobile device using a keyboard, a compatible web-cam or scanner and the Mobil Sample Scan App.

Scan the bottle ID



Assign sample bottle to an asset:
a. Scan asset tag, or
b. Select asset from list



Document operating and maintenance information (date, hr/mi/km, etc.)

OR

Submitting a sample - Label printing

Select assets to print

Print your sample labels

Document operating and maintenance information (date, hr/mi/km, etc.)
a. Be sure to use a ballpoint pen when adding this data
b. Print clearly on the label
c. Avoid smudging the data so that it can be read correctly when it arrives in the lab

Ensure one bottle ID is displayed when applying the sample label

Packing and mailing

1. Use Mobil Lubricant Analysis sample materials
2. Do NOT tape sample bottle lids
3. Place the sample bottle into the mailing container and secure the cap
4. Affix the preprinted mailing label to the mailer
5. Mail your sample immediately

Inspecting your sample

A great deal of information can be gathered simply by looking at the sample. Inspect each sample carefully before submitting it for analysis.

Clarity
Clarity is an excellent indicator of contamination. A lubricant in good condition is clear and bright. Haziness or cloudiness indicates materials like water, wax, machine coolant, refrigerant, or incompatible lubricant are present. In some cases, the agent causing the haze or cloud actually forms a separate layer at the bottom of the container or on top of the oil.

Sediment and particulate
Sediment and particulate tell more of the story. Non-magnetic sediment in an otherwise clear and bright sample may suggest dirt, dust, or sand contamination. Magnetic particulate could indicate rust or a more severe wear situation (See: Points to consider - Visible Contamination).

Submitting your sample

The Mobil[SM] Lubricant Analysis laboratory is committed to providing complete and accurate analysis results. Your results are available online, typically within one to two business days after receiving your sample.

You can improve turnaround time by following these steps:

1. Utilize scan-and-go sampling method. Ensure you scan the sample bottle QR code and assign to an asset before shipment.

2. Use approved shipping materials provided in the sample kit.

3. Mail your sample immediately.

4. Mail samples via Overnight/Courier Service or use First Class/ Priority delivery.

Points to consider
Visible Contamination

Take corrective action, do not submit your sample to the laboratory if contamination (water, dirt, metal, etc.) is visible. Visible contamination indicates an abnormal condition and also can damage laboratory equipment, resample once the condition is corrected.

Interpreting your analysis results

Mobil[SM] Lubricant Analysis provides an unparalleled knowledge of ExxonMobil lubricants through decades of experience and close OEM relationships. Our strong heritage of hands-on application expertise provides you a reliable analysis. The overall assessment focuses on three areas that help identify:

- Equipment condition
- Contamination
- Lubricant condition

Your Mobil Lubricant Analysis report provides an an easy to read, color-coded performance assessment with one of the following ratings:

Alert – Conditions exist that exceed acceptable limits or require corrective action. Steps should be taken to confirm and correct the condition.

Caution – Conditions are present that may require monitoring or diagnosis to minimize impact on equipment and lubricant performance.

Normal – Equipment, contamination, and lubricant conditions are within an acceptable range.

Sample comments are provided on the report to help identify potential problems, list possible causes, and recommend actions for follow-up.

Monitoring the trend

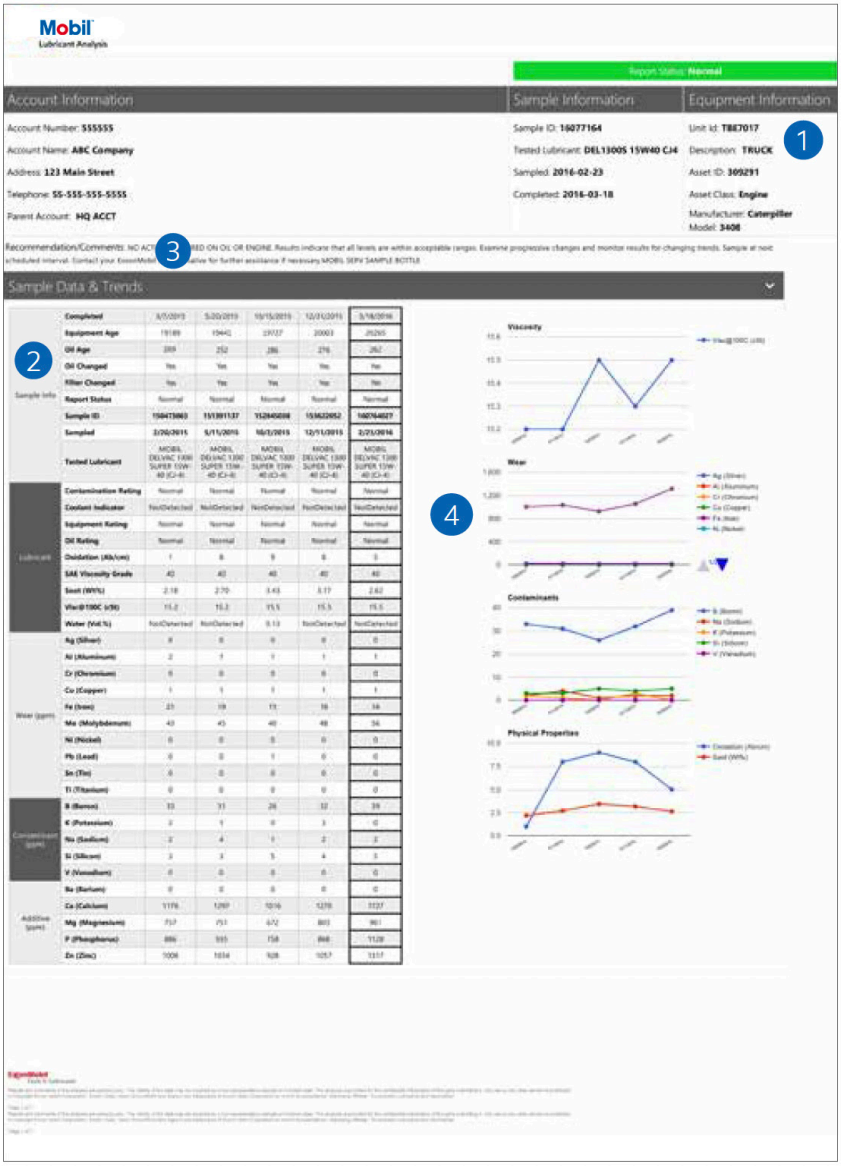
To assess your equipment condition:

1. **Interpret your analysis results** – Gain an understanding of your equipment's operating conditions and its lubricated components. Limits applied to each sample can vary based on your asset's registered manufacturer, model, application, and lubricant-in-service.
2. **Monitor the sample trend** – Trend identification is important to understanding oil analysis results. You should include critical equipment and maintenance information (e.g., date sampled, hr/mi/km, makeup oil, etc.) with your sample submission. This data allows you to normalize the analysis trends to enhance your assessment.
3. **Review the entire report** – Proper condition assessment requires a complete review of the report. Changes in equipment condition typically coincide with the presence of contamination or changes in lubricant properties.

Points to consider
Applied limits

Limits applied to each sample can vary based on your asset's registered manufacturer, model, application, and lubricant-in-service. In addition, the review process considers all report data and may correlate multiple results to determine an abnormal condition.

Mobil℠ Lubricant Analysis – Graphic sample report



1. **Equipment information** — Equipment data you provided during asset registration is used to interpret the analysis results. By including equipment manufacturer, model, and other operating parameters, an overall assessment can be made for your application.

2. **Sample data** — Operating data documented during the sample process provides critical information to help assess and interpret your equipment's condition. By including key information, like hr/mi/km and date sampled, you help establish data points that assist in condition trending.

3. **Results interpretation** — Proprietary control limits are applied based on your equipment's manufacturer, model, lubricant, and application. Sample comments are provided, as required, to help identify potential problems, list possible causes, and recommend corrective action.

4. **Analysis results** — The Mobil℠ Lubricant Analysis report provides an easy-to-read, color-coded display of your sample analysis results in order to:
   - Trend elements of equipment wear
   - Identify contaminants that may impact performance
   - Monitor lubricant condition

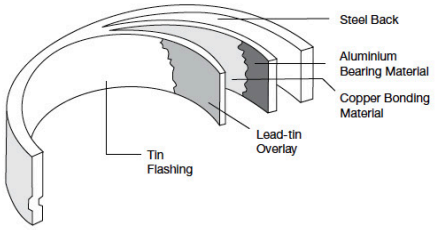
How to:
Confirm alerted conditions

Before replacing or shutting down equipment, confirm alert analysis conditions considering the following steps:

1. Review maintenance/operator records to identify condition.
2. Verify condition with other equipment monitoring tools – e.g., inspections, vibration, or thermography.
3. Utilize an on-site analysis test designed for the alerted condition.
4. Submit another sample to the laboratory for analysis.

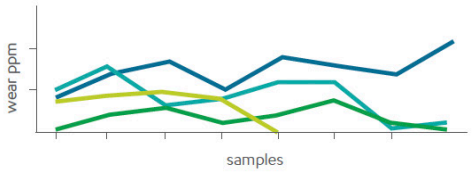
Understanding equipment condition

If you know what to look for in the analysis report, oil analysis can unlock a wealth of information about the condition of your equipment. You should understand the metallurgy of your components to respond to the trends in your analysis report. Reference your OEM material list to identify the metallurgical makeup of your components and to help evaluate sample results.

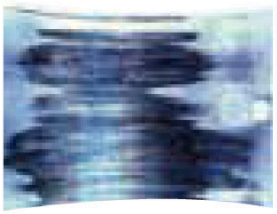


Understand metallurgy

Bearing wear example



Monitor elements



Plan maintenance

Points to consider

Normalize your data
Looking at the analysis data without considering time or distance may lead to inaccurate conclusions about condition severity. Evaluating the data trend relative to wear rate per hr/km/mi can enhance your assessment.

Makeup oil–effect on results
Equipment with high oil consumption may not return representative sample results. A potentially abnormal condition can be masked by escaping lubricant and by new lubricant makeup diluting the system volume. Record makeup oil during sampling process to include in your trend and sample assessment.

Typical equipment component metals

	Engine	Transmission	Differential	Final Drive
Aluminum (Al)	Pistons, bearings, blocks, housings, bushings, blowers, thrust bearings	Pumps, clutch, thrust washers, bushings, torque converter impeller	Thrust washers, pump bushings	Oil pump, thrust washers
Chromium (Cr)	Rings, roller/taper bearings, liners, exhaust valves	Roller/taper bearings	Roller/taper bearings	Roller/taper bearings
Copper (Cu)	Bushings (wrist pin, cam, valve-train), bearings, oil cooler, thrust washers, governor, oil pump	Clutches, steering discs, bushings, thrust washers, oil cooler	Bushings, thrust washers	Bushings, thrust washers
Iron (Fe)	Cylinders, block, gears, crankshaft, wrist pins, rings, camshaft, valve train, oil pump liners, rust	Gears, discs, housing bearings, brake bands, shift spools, pumps, PTO	Gears, PTO, shafts, bearings, housings	Gears, bearings, shaft, housing
Lead (Pb)	Bearings			
Nickel (Ni)	Bearings and valve stems			
Silver (Ag)	Bearings, wrist pin bushings (EDM)	Bearings	Bearings	Bearings
Tin (Sn)	Pistons, bearing overlay, bushings			

Understanding equipment condition

Typical equipment component metals (continued)

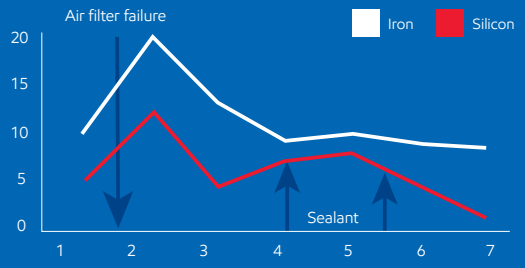
	Natural/landfill gas engine	Turbine (gas/steam)	Hydraulic/ circulation	Compressor	Gear drive	Paper oil machine
Aluminum (Al)	Pistons, bearings, blocks, housings, bushings, blowers, thrust bearings		Pump motor housing, cylinder gland	Rotors, pistons, bearings, thrust washers, block housing	Thrust washers, oil pump, bushings	
Chromium (Cr)	Rings, roller/taper bearings, liners, exhaust valves		Rods, spools, roller/ taper bearings	Rings, roller/ taper bearings	Roller/taper bearings	Bearings
Copper (Cu)	Bushings (wrist pin, cam, valve-train), bearings, oil cooler, thrust washers, governor, oil pump	Bearings, oil cooler	Pump thrust plates, pump pistons, cylinder glands, guides, bushing, oil cooler	Wear plates, bushings, wrist -pin bushings, bearings (recips.), thrust washers	Thrust washers, bushings, oil cooler	Bearings cages, bushings, oil cooler
Iron (Fe)	Cylinders, block, gears, crankshaft, wrist pins, rings, camshaft, valve train, oil pump liners, rust	Bearings	Pump vanes, gears, pistons, cylinder bores, rods, bearings, pump housing	Camshaft, block, housing, bearings, shafts, oil pump, rings, cylinder	Gears, bearings, shaft	Bearings, gears, housings
Lead (Pb)	Bearings	Bearings	Bearings	Bearings		Bearings
Silver (Ag)	Bearings, wrist pin bushings (EDM)	Bearings	Bearings	Bearings	Bearings	
Tin (Sn)	Pistons, bearing overlay, bushings	Bearings	Bearings	Pistons, bearings, bushings		Bearings
Titanium (Ti)		Bearings, turbine blades				

Points to consider

Interpreting silicon

The presence of silicon is often the reason for an increase in wear metals (see graph). If, however, high wear metals are not indicated, then the silicon or dirt may have been introduced during sampling oil from a non-abrasive silicon (e.g., silicone-based sealant, silicone defoamant, siloxane from fuel gas, or silicon rubber).

Understanding silicon conditions



Understanding contamination

Contamination is a primary cause of component wear or failure. You should identify the source and take corrective action to remedy the contamination; doing so will ultimately help extend component and lubricant life while improving equipment reliability. Three general sources of contamination include:

1. **Built-in contamination** – Contamination from component manufacturing process or from the installation process.

2. **Self-generated contamination** - Contamination from system components worn or damaged by other contamination particles.

3. **External ingression** - Contamination from external sources.

The following elements can help identify contamination:

Element	Potential source
Boron (B)	Coolant, possible oil additive
Chlorine (Cl)	Landfill gas contaminant
Potassium (K)	Coolant
Sodium (Na)	Coolant, road salt, additive
Silicon (Si)	Dirt, dust, sealant, additive, silicone defoamant, siloxane from fuel gas
Vanadium (V)	Residual fuel contamination

Points to consider
Coolant contamination

Indications of coolant (ethylene or propylene glycol mixed with water) can appear as water, sodium, potassium, or boron elements (typical coolant additives).

The water phase of coolant may be removed during operation, leaving only a trace element of coolant additive to reveal this potentially serious problem.

Understanding contamination

Use this chart to better understand common contaminants, their effects and remedies.

Contaminant	Description	Condition	Effect	Remedy
Fuel dilution	Fuel dilution reduces viscosity and can accelerate wear. Unburned fuel may indicate a fuel system leak or incomplete combustion	Extended idling, stop and go driving, defective injectors, leaking fuel pump or lines, incomplete combustion, incorrect timing	Metal-to-metal contact, poor lubrication, cylinder/ ring wear, depleted additives, decreased oil pressure, reduced fuel economy, reduced engine performance, shortened engine life	Check fuel lines; check cylinder temperatures, worn rings, leaking injectors, seals, and pumps; examine driving or operating conditions; check timing; avoid prolonged idling; check quality of fuel; repair or replace worn parts
Fuel soot	Fuel soot provides an indication of engine combustion efficiency	Improper air-to-fuel ratio, improper injector adjustment, poor quality fuel, incomplete combustion, low compressions, worn engine parts/rings	Poor engine performance, poor fuel economy, harmful deposits or sludge, increased component wear, carbon deposits, clogged filters	Ensure injectors are working properly, check air induction/ filters, check compression, avoid excessive idling, inspect driving/ operating conditions, check fuel quality, check operating conditions
Insoluble or visible particles	Solid particles in the lubricant that were ingested or internally generated	Extended oil drain interval, environmental debris, wear debris, oxidation byproducts, leaking or dirty filters, fuel soot	Shortened equipment life, filter plugging, poor lubrication, engine deposits, formation of sludge, accelerated wear	Drain oil, flush system, check operating environment, reduce oil drain interval, change filters
Particle count high	Particle count provides a measure of contaminant levels in the oil	Defective breather, environmental debris, water contamination, dirty filters, poor makeup oil procedure, entrained air, worn seals	Erratic operation, intermittent failure, component wear, valve sticking, oil leakage	Filter new oil, evaluate service techniques, inspect/replace oil filters, inspect/replace breather, high pressure system flush, evaluate operating conditions
Particle quantifier (PQ) index	PQ index measures the mass of metallic (ferromagnetic) particles in the sample	Wear debris, shock/ overloading conditions, metallic contamination, dirty filters	Metal-to-metal contact, shortened equipment life, intermittent failure	Replace worn parts, inspect/ replace filters, inspect/clean reservoir magnets, evaluate operating conditions
Ultra centrifuge (UC) rating high	Ultra centrifuge rates the soluble sub-micron contaminants that can be precursors to system deposits (scale 0-8).	High operating temperature, overloading condition, overextended oil drain, improper oil in service	Erratic operation, intermittent failure, harmful deposits or sludge, valve sticking, shortened oil life	Evaluate operating conditions, shorten oil drain intervals, evaluate equipment use versus design, use oil with oxidation inhibitor additives, flush system
Water/coolant	Water/coolant is a harmful contaminant that can cause significant damage to internal parts, e.g., bearings	Low operating temperature, defective seals, new oil contamination, coolant leak, improper storage, condensation	Engine failure, high viscosity, improper lubrication, corrosion, acid formulation, reduce additive effectiveness	Tighten head bolts, check head gasket, inspect heat exchanger/oil cooler, evaluate operating conditions, pressure check cooling system, check for external sources of contamination

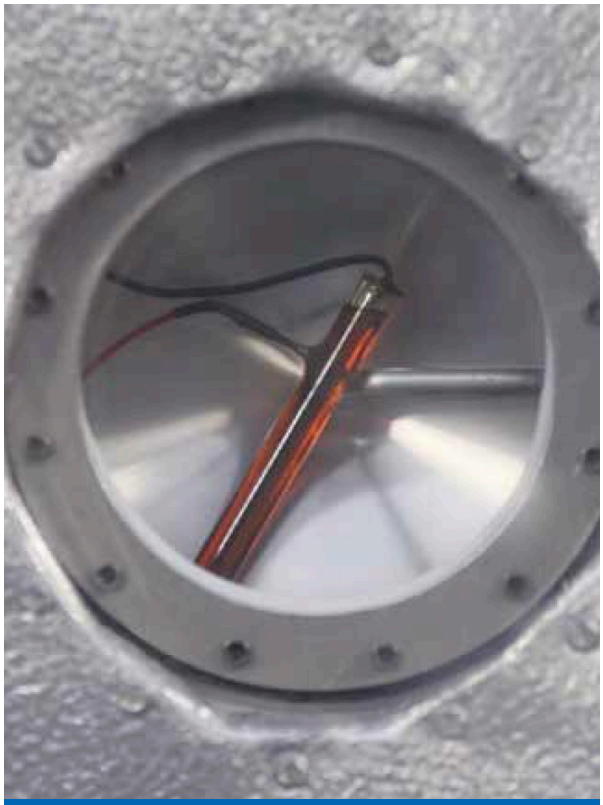
Understanding lubricant condition

A lubricant performs a variety of functions in your application. The most important functions include friction control, wear protection and efficient power transmission.

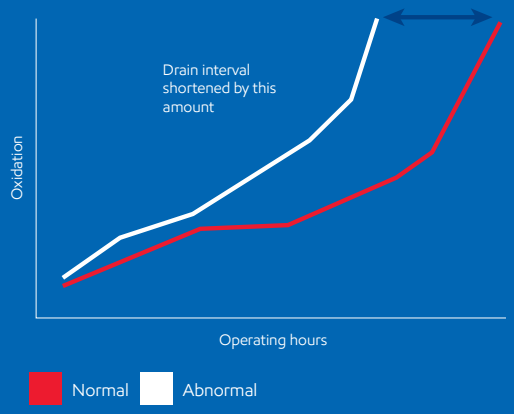
Maintaining the physical properties of the lubricant is important to extending the equipment's reliability and the life of the lubricant.

The following elements can help identify lubricant condition:

Element	Potential source
Barium (Ba)	Antiwear, corrosion inhibitor, detergent
Calcium (Ca)	Antiwear, corrosion inhibitor, detergent, dispersant, rust inhibitor, anti-oxidant
Magnesium (Mg)	Antiwear, corrosion inhibitor, detergent, dispersant, rust inhibitor
Molybdenum (Mo)	Antiwear, anti-friction
Phosphorus (P)	Antiwear, corrosion inhibitor, detergent, extreme pressure
Zinc (Zn)	Anti-oxidant, antiwear, corrosion inhibitor



Points to consider
Impact of oxidation on lubricant life



Understanding lubricant condition

Use this chart to better understand abnormal lubricant conditions, their effects and remedies.

	Description	Condition	Effect	Remedy
Acid number (AN) high	Acid number is a measurement of the buildup of harmful acidic oxidation compounds produced by oil degradation	High sulfur fuel, overheating, excessive blow-by, overextended drain intervals, improper oil	Corrosion of metallic components, promotes oxidation, oil degradation, oil thickening, additive depletion	Evaluate oil drain interval, confirm type of oil in service, check for overheating, check for severe operating conditions, identify and remove contaminants, drain oil
Base number (BN) low	Base number is a measurement of an oil's ability to neutralize harmful acidic compounds produced during combustion process	Overheating, overextended oil drain, improper oil in service, high sulfur fuel	Increased wear rate, acid buildup in oil, oil degradation, increase in sludge formation	Evaluate oil drain interval, full or partial renewal of the oil charge is recommended, check engine operating condition, remove contaminants
Nitration	Nitration is a measure of the amount of nitrogen by- products in the oil. Nitration quantification can provide invaluable insight into the likelihood of deposit formation from oil breakdown	Improper scavenge, low operating temperature, defective seals, improper air-to-fuel ratio, abnormal blow-by	Accelerated oxidation, acidic by-products formed, increased cylinder and valve wear, oil thickening, combustion area deposits, increased acid number	Increase operating temperature, check crankcase venting hoses and valves, ensure proper air-to-fuel mixture, perform compression check or cylinder leak-down test
Oxidation	Oxidation quantification can provide invaluable insight into the likelihood of deposit formation from oil breakdown	Overheating, overextended oil drain, improper oil in service, combustion byproducts, blow-by	Shortened equipment life, lacquer deposits, oil filter plugging, increased oil viscosity, corrosion of metal parts, increased operating expenses, increased component wear, decreased equipment performance	Evaluate oil drain interval, full or partial renewal of the oil charge is recommended, check operating condition, remove contaminants
Viscosity high	Viscosity is a measurement of a fluid's resistance to flow at a given temperature relative to time	Contamination soot/ solids, incomplete combustion, oxidation degradation, leaking head gasket, extended oil drain, high operating temperatures, improper oil grade	Harmful deposits or sludge, restricted oil flow, engine overheating, increased operating costs	Verify lubricant was labeled correctly, check air-to-oil grade, inspect internal seals, check operating temperatures, check for leaky injectors, check for loose crossover fuel lines, evaluate operating conditions, check oxidation trend
Viscosity low	Viscosity is a measurement of a fluid's resistance to flow at a given temperature relative to time	Additive shear, fuel dilution, improper oil grade	Overheating, poor lubrication, metal-to- metal contact, increased operating costs	Verify lubricant was labeled correctly, check air-to-oil grade, inspect internal seals, check operating temperatures, check for leaky injectors, check for loose crossover fuel lines, evaluate operating conditions

Engine operating conditions

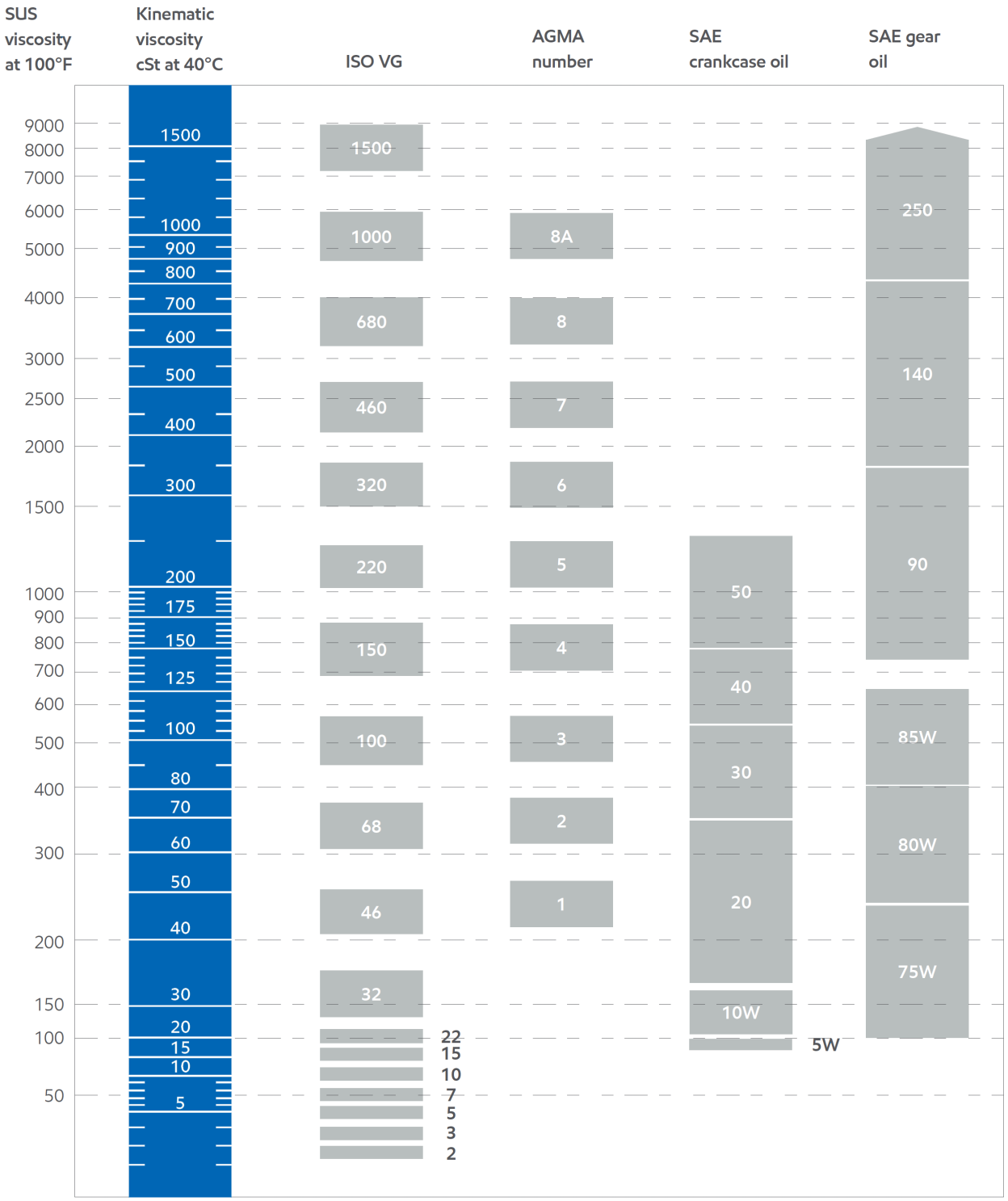
Gasoline, diesel, natural gas, landfill/digester gas
You can be better prepared to take corrective action before equipment fails if you understand the potential sources of abnormal engine conditions.

Potential sources of abnormal engine conditions:

Condition	Potential source
Crankcase deposits	High oil temperature, low oil temperature, poor combustion, poor oil filtration, blow-by, condensation, leaking water jacket, clogged crankcase breather or vent, excessive oil spray, inadequate piston cooling
High oil consumption	Worn or stuck rings, ineffective oil ring control, low oil viscosity, high oil pressure, leakage, worn pistons or cylinders, excessive bearing clearance, high oil level (crankcase), high crankcase vacuum, high oil feed rate to cylinders, normal in landfill/digester gas applications
High oil temperature	Continuous overload, insufficient jacket water cooling, clogged oil cooler, clogged oil lines, sludged crankcase, overheated bearing, incorrect oil viscosity, insufficient oil in pump or crankcase, insufficient oil circulation, improper timing
Improper combustion	Unsuitable fuel, insufficient air, low water jacket temperature, sticking, leaking, or plugged injectors, unbalanced cylinder load, low injection pressure, incorrect injection timing, low compression pressure, leaking or sticking intake or exhaust valves, low load
Ring sticking	Poor oil quality, continuous overload operation, high oil level (crankcase), high crankcase vacuum, high oil feed rate to cylinders, worn or weak rings, insufficient ring side clearance, worn pistons, distorted pistons or cylinders, high or low jacket water temperature, gas with high siloxane content

Lubricant viscosity grade comparisons

For use as a general guide only. Viscosities are based on a 95 VI Oil.



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