Mobil Serv™
Lubricant Analysis

Mobil Serv℠ Lubricant Analysis technical guide

Energy lives here™

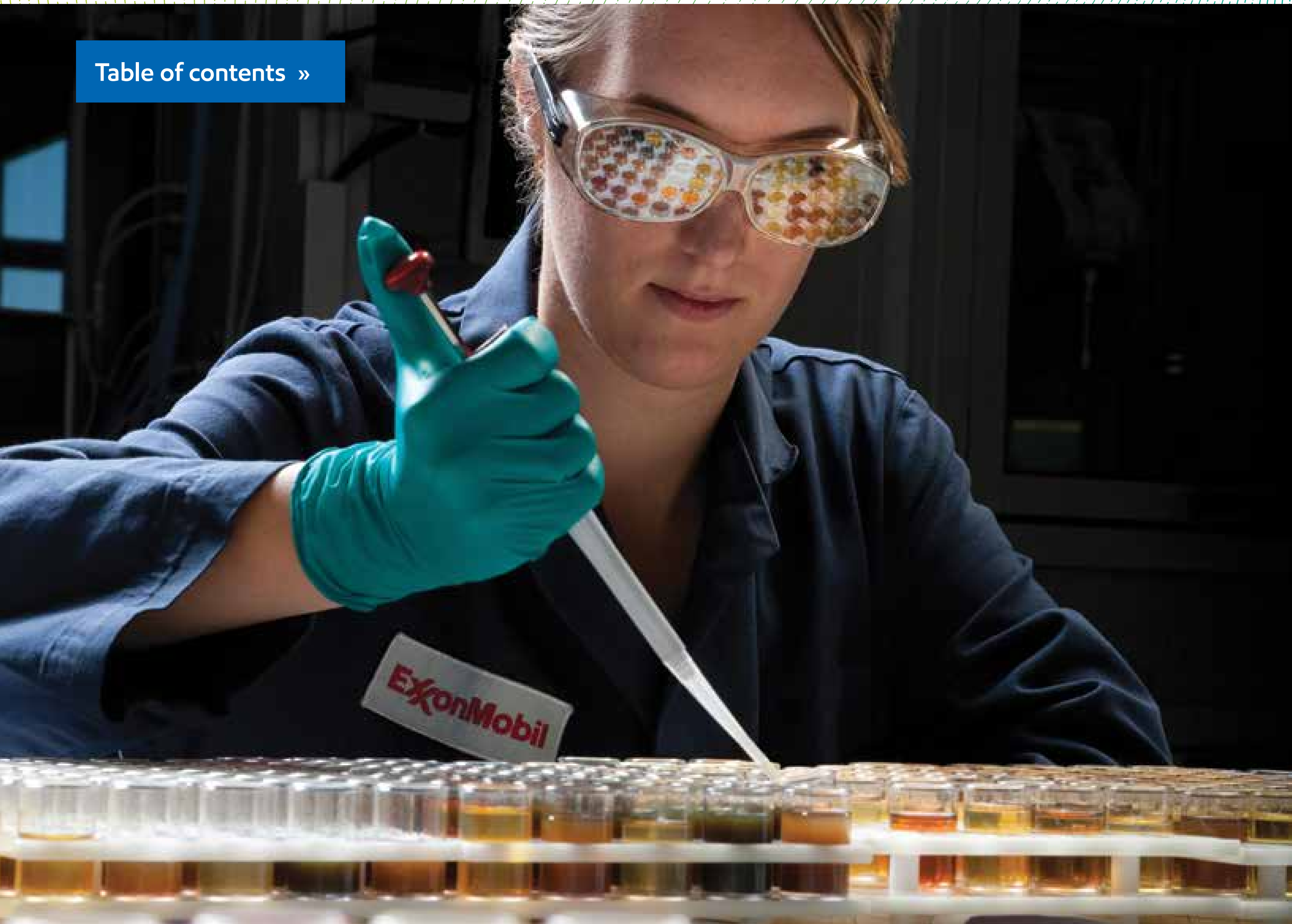


Table of contents

How to:

Get help

Mobil Serv℠ Lubricant Analysis 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 Technical Help Desk email address here:

Technical Help Desk »

Mobil Serv^{SM} Lubricant Analysis: Condition-monitoring fundamentals

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

- Improve equipment reliability
- Reduce maintenance costs
- Enhance equipment life

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

Mobil Serv 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 Serv 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 maintenance programme.

How to:

Establish and maintain a successful oil analysis programme

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 programme
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 established scheduled intervals.

Determine what to sample — Consider the five general factors listed below when you select equipment for the programme and set sample frequency. Additionally, refer to your OEM manual for guidance on specific equipment and recommended sample frequency.

Typical marine applications for oil analysis include:	
▪ Main engines	▪ Purifiers
▪ Auxiliary engines	▪ Reduction gears
▪ Cam shaft systems	▪ Slow-speed engines system oil
▪ Compressors (air/refrigeration)	▪ Steering gear hydraulics
▪ Deck gear drives	▪ Stern tubes
▪ Deck hydraulics	▪ Thrusters
▪ Gas turbines	▪ Turbochargers

Consider these five general factors

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

What and when to sample (cont.)

Determine when to sample — The goal of sample frequency is to achieve a regular pattern of sampling. This establishes a credible historical trend of machine performance.

- Follow OEM-recommended sample intervals for your equipment.
- Follow classification societies' guidelines, such as DNV, Lloyd's Register and ABS.
- In the absence of OEM guidelines, refer to the tables below for general guidance in establishing initial sample frequency.

Marine propulsion equipment		Marine supporting equipment	
Sample point	**Frequency**	**Sample point**	**Frequency**
High-speed diesel engines	250-500 hours	Auxiliary engines	500-1,000 hours
Medium-speed diesel engines	1,000-2,000 hours	Turbochargers	1,000-2,000 hours
Slow-speed engines system oil	1,000-2,000 hours	Compressors (air/refrigeration)	3-6 months
Gas turbines	250-500 hours	Purifiers	1,000-2,000 hours
Steering gear hydraulics	500-2,000 hours	Deck hydraulics	3-6 months
Reduction gears	250-500 hours	Deck gear drives	3-6 months
Cam shaft systems	250-500 hours		
Thrusters	500 hours		
Stern tubes	1,000-2,000 hours		
Thrusters	3 months		

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 correct 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 that are not visible to the naked eye. Cleanliness is essential.

- **Wear proper safety equipment** while sampling – safety glasses, gloves, etc.
- **Use only new Mobil Serv℠ 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 midway 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 normalise the analysis trend. Ensure sample details are entered, including sampling date, hours on oil and equipment.

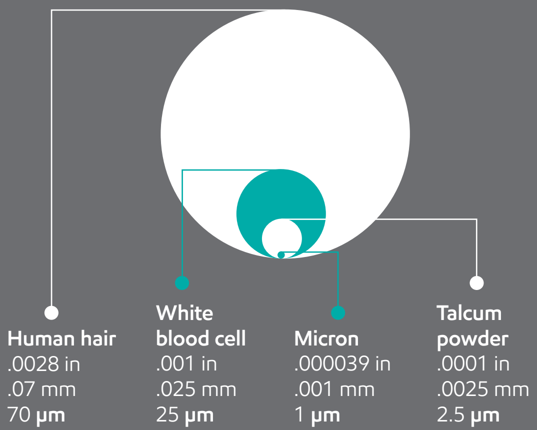
Sample at a consistent frequency from the correct sample location using proper sampling techniques.

Points to consider

Contamination analysis

Laboratory analysis typically targets contaminants < 8 microns, which is 5x 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)?



Sample locations

Sample locations

The maximum benefit of the Mobil Serv℠ Lubricant Analysis programme can only be obtained if a truly consistent and representative sample is taken. **Do not take a cold sample!**

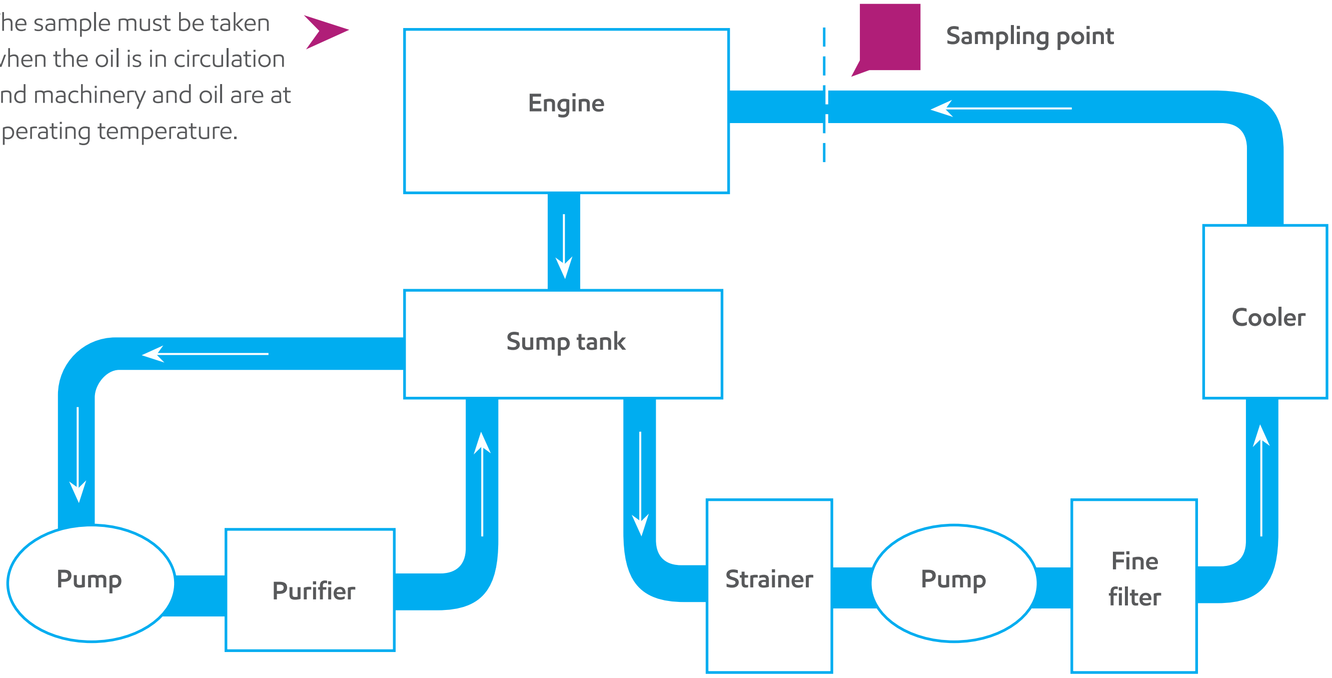
When taking a sample, first draw-off one (1) litre of oil to clear the sampling connection of any stagnant oil that may be resting there and not in circulation. Oil should then be drawn into the sampling container, which can then be used for filling the Mobil Serv℠ sample bottle.

The primary recommended sampling points are detailed here:

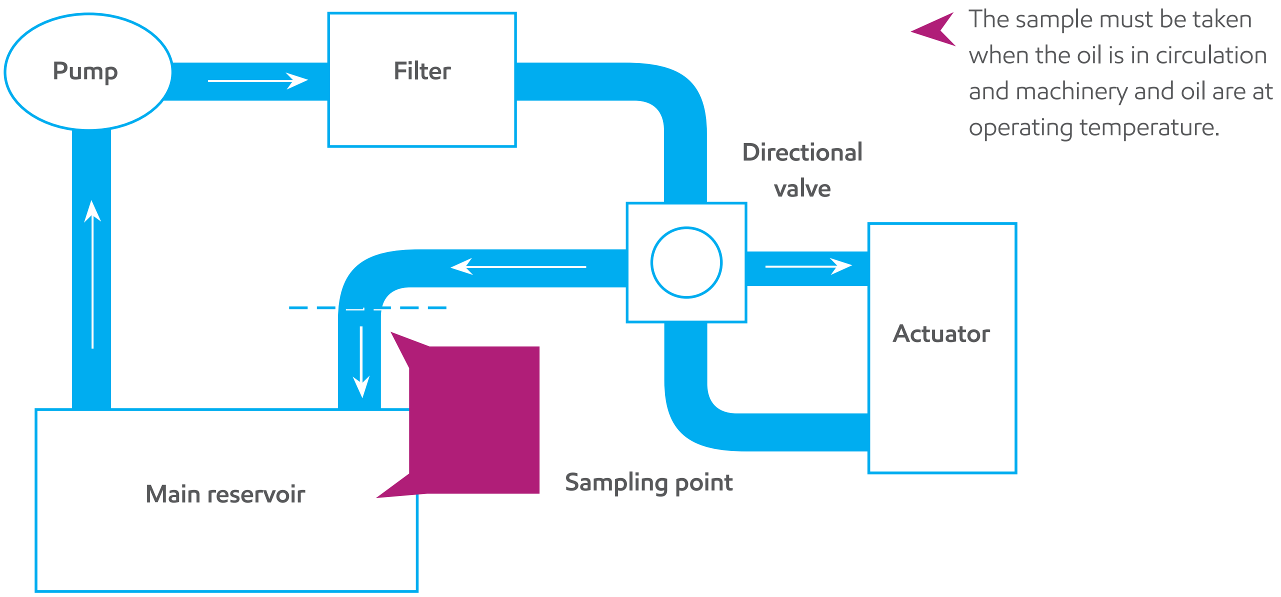
Main engine, auxiliary generator engines

Prior to oil entering engine, between the cooler and the engine.

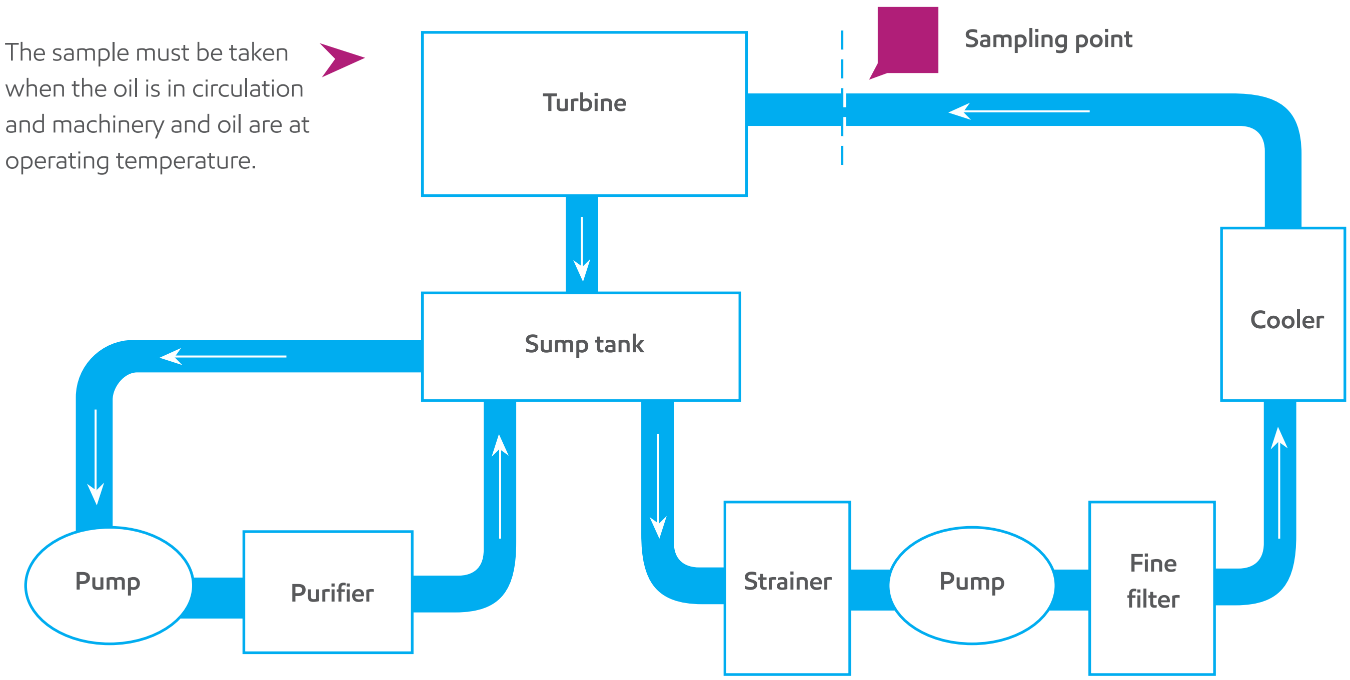
The sample must be taken when the oil is in circulation and machinery and oil are at operating temperature.



Hydraulic systems
From system return line or midpoint of main reservoir.

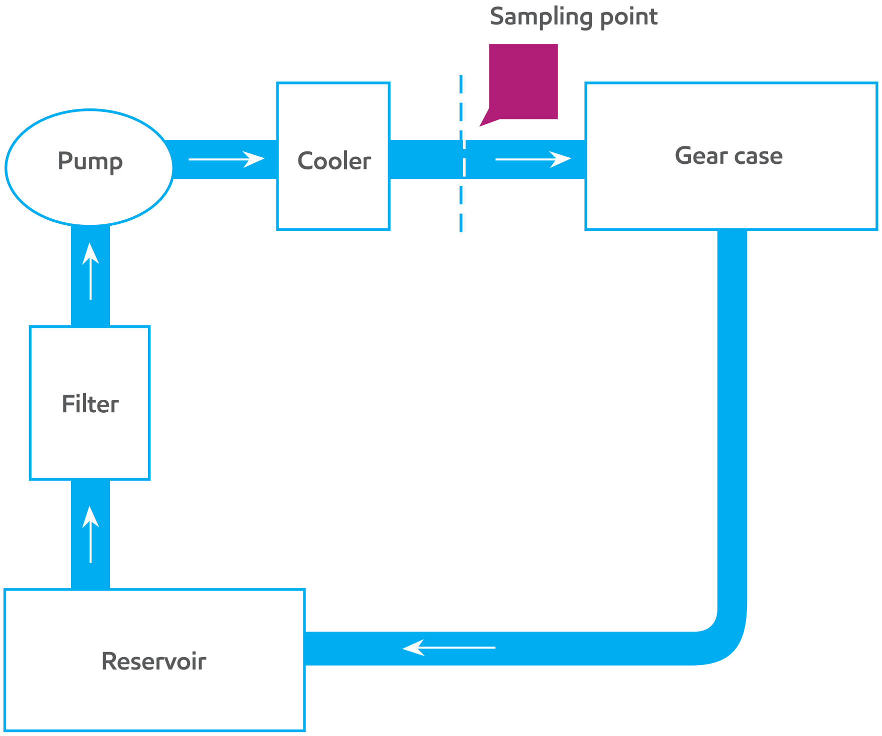


Steam turbines
Prior to oil entering turbine, usually between the cooler and the turbine.



Gear cases

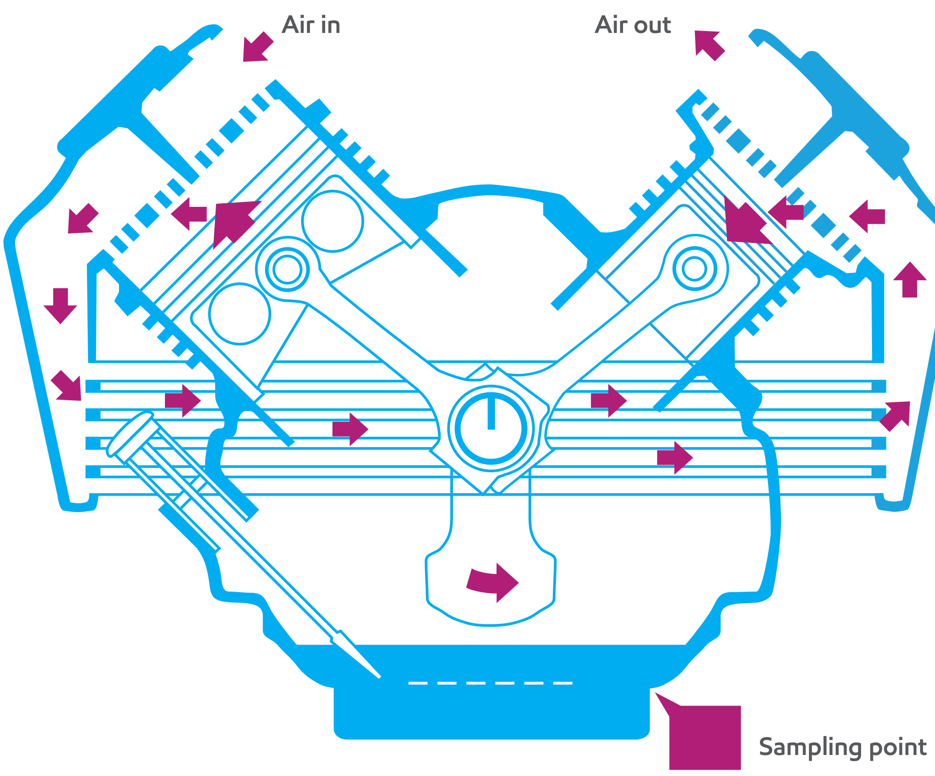
Prior to oil entering the gear case, usually between cooler and gear case.



The sample must be taken when the oil is in circulation and machinery and oil are at operating temperature.

Compressors

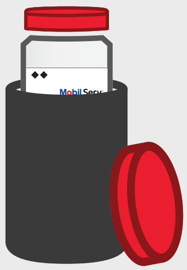
Reservoir midpoint from crankcase.



The sample should not be taken when oil is in circulation if it is coming from the sump. The drain valve or plug should only be opened when the unit is stopped to prevent accidentally emptying the sump.

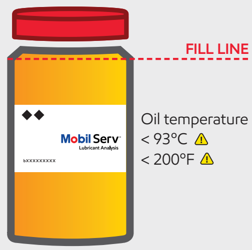
Sampling instructions: Label printing method

1



Remove sample bottle from mailing container.

2

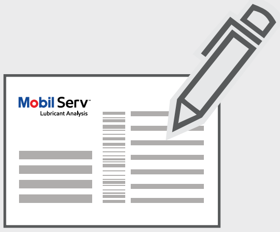


Using sample bottle, draw a representative oil sample from sample point. Secure bottle cap to the sample bottle.

3

Print label.

4



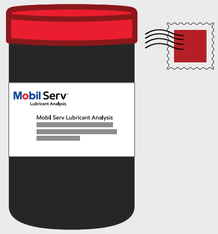
Complete oil and equipment hours, sample dates and other details on barcoded sample labels.

- Use a ballpoint pen and avoid smudging.
- Print clearly on the label.

5

Ensure one bottle ID is displayed when applying the sample label.

6



OR

Packing and mailing:

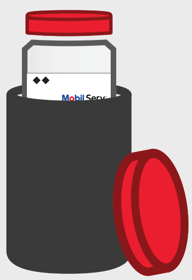
- Use Mobil Serv℠ Lubricant Analysis sample materials.
- Do NOT tape sample bottle lids.
- Place the sample bottle into the mailing container and secure the cap.
- Affix the preprinted mailing label to the mailer.
- Mail your sample immediately.

Submitting a sample: Scan-and-go method

On mobile devices, download the Mobil Serv℠ Lubricant Analysis Sample Scan app.
Steps 3-5 may be completed on a computer or mobile device.

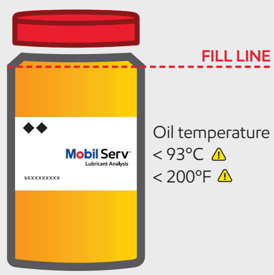
Save time — use the **Sample Scan** method.
No label printing required!

1



Remove sample bottle from mailing container.

2



Using sample bottle, draw a representative oil sample from sample point. Secure bottle cap to the sample bottle.

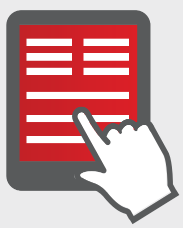
3

Assign sample bottle to asset:
- Scan asset tag, or
- Select asset from list.

4

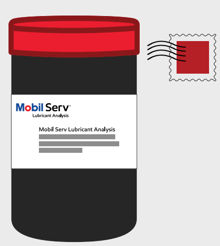
- Locate and select the bottle ID field.
- Scan or type bottle ID.

5



Complete oil hours and equipment hours, sample dates and other relevant details.

6



OR

Packing and mailing:
- Use Mobil Serv℠ Lubricant Analysis sample materials.
- Do NOT tape sample bottle lids.
- Place the sample bottle into the mailing container and secure the cap.
- Affix the preprinted mailing label to the mailer.
- 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 Serv℠ 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. Utilise scan-and-go sampling method. Ensure you scan the sample bottle QR Code and assign to an asset before shipping.
2. Use approved shipping materials indicated in the Mobil Serv℠ sampling kit.
3. Mail your samples at the next convenient port.

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.

Mobil Serv℠ Lubricant Analysis tests

The number of tests performed on an oil sample varies depending on the type of application.

Laboratory testing:
Test methods are conducted at the Mobil Serv℠ laboratory according to well-established procedures, and are supplemented by special analytical methods, such as gas chromatography, emission spectroscopy, Detecting Asphaltene Contamination (DAC) and others as required. The objective of Mobil Serv Lubricant Analysis is to ensure accurate, reliable, and efficient analysis and reporting.

Testing is normally completed within 24-48 hours from receipt of sample.

All samples are first thoroughly agitated to ensure homogeneity, and then visually inspected in terms of appearance and assessed in a combination of the following tests:

Viscosity:
Determined at 40°C for all types of non-engine oils. For engine oils we will measure viscosity at 100°C. As a general guideline, for lubricants where the viscosity is defined in SAE or ISO viscosity grades, a change of approximately +24 per cent from typical levels indicates the need for some corrective action. Corrective action is recommended when the change is in excess of +30 per cent.

Flash point:
Measured in a Setaflash Tester on a Flash/No Flash basis, with a cutoff point that correlates with 200°C in ASTM D92 (Cleveland Open Cup). Reported as PASS (above cutoff point) or LOW (equal or lower than cutoff point).

Total Base Number (TBN):
Reported as mg KOH/g. Minimum levels requiring corrective action are EITHER those specified by engine manufacturers OR those developed by ExxonMobil through many years of field experience.

Mobil Serv^{SM} Lubricant Analysis tests (cont.)

Water content:
Determined to the accuracy required in view of the stringent low limit set for this property. As general guidelines, a diesel engine oil is unequivocally fit for further use only if its water content is 0.2 mass per cent for cross-head engines and 0.3 mass per cent for medium-speed engines. Corrective action is suggested for higher levels and urged for content 0.3 and 0.5 mass per cent, respectively. Similarly, limits of 0.15 mass per cent are set for turbine and hydraulic oils, where the test is run only due to cloudy appearance. The nature of the water (fresh or salt) can be determined from the sodium and magnesium levels detected in the insolubles content (select non-engine applications and stern tubes).

Insolubles:
Measured in n-Pentane. The significance of insolubles content and required corrective action are usually assessed in relation to changes of other related parameters.

Soot content (engine oils):
An infra-red (IR) method is used to determine the soot content by percentage weight for diesel engine oils.

Total Acid Number (TAN):
Test run only for synthetic oils where oxidation by IR is not possible. This test measures acid buildup in oil and is only run for specific applications.

Oxidation by Infra-Red (IR):
This test method detects lubricant oxidation and is run for all samples except some synthetic based oils.

Elemental analysis:
Elemental analysis, by emission spectroscopy, detects the concentration of elements in units of parts-per-million (ppm). Particles with dimensions up to 8 microns (μm) are detected. Such particles are generated in the normal wear processes, or in corrosive regimes and in certain types of abrasive wear.

Elemental analysis is a valuable diagnostic tool for most situations. However, the detection efficiency for the spectrometer declines rapidly for larger particles. Elemental analysis is quite insensitive to particles of 8 μm or larger.

Typically, 19 elements are identified and measured on an ICPES (Inductively Coupled Plasma Emission Spectrometer). The test is generally run for the diagnosis of wear. It is supplementary to other analyses whenever it becomes necessary to contribute to a fuller understanding of the underlying causes of changes in certain lubricating oil properties. Additional elements may also be measured.

Mobil Serv℠ Lubricant Analysis tests (cont.)

Other sources of elements:

Several elements such as iron, copper, aluminium, zinc, silicon and nickel may derive from many other sources besides those listed in the chart below, the most likely being crankshaft, camshaft, valves, turbocharger casing, timing chain, pipework, cooler tubes, zinc-coated surfaces and sealing material.

Main sources of elements (depending on environment)

● Greater (blue)
● Lesser (magenta)

			Fe Iron	**Cr** Chromium	**Mo** Molybdenum	**Cu** Copper	**Pb** Lead	**Ag** Silver	**Sn** Tin	**Al** Aluminum	**Ni** Nickel	**V** Vanadium	**Si** Silicon	**B** Boron	**Na** Sodium	**Mg** Magnesium	**P** Phosphorus	**Zn** Zinc	**Ba** Barium	**Ca** Calcium
Diesel engine	Cylinder liners Pistons, rings	Trunk	Greater	Greater	Greater					Greater										
		Crosshead	Greater	Greater		Greater	Greater													
	Bearings	Trunk				Greater	Greater	Greater	Greater	Greater										
		Crosshead				Greater	Greater		Greater	Greater										
	Stuffing box					Greater														
Gears		Reduction	Greater	Greater		Greater	Greater		Greater	Greater										
		Other	Greater	Greater		Greater	Greater													
Stern tube			Greater				Greater		Greater											
Hydraulic systems			Greater			Greater			Greater											
Fuel										Greater	Greater	Greater	Greater		Lesser					
Air			Lesser							Lesser			Greater		Greater					
Water		Sea													Greater	Greater				
		Cooling		Lesser									Lesser	Greater	Greater					
Lubricant additives													Greater				Greater	Greater	Greater	Greater

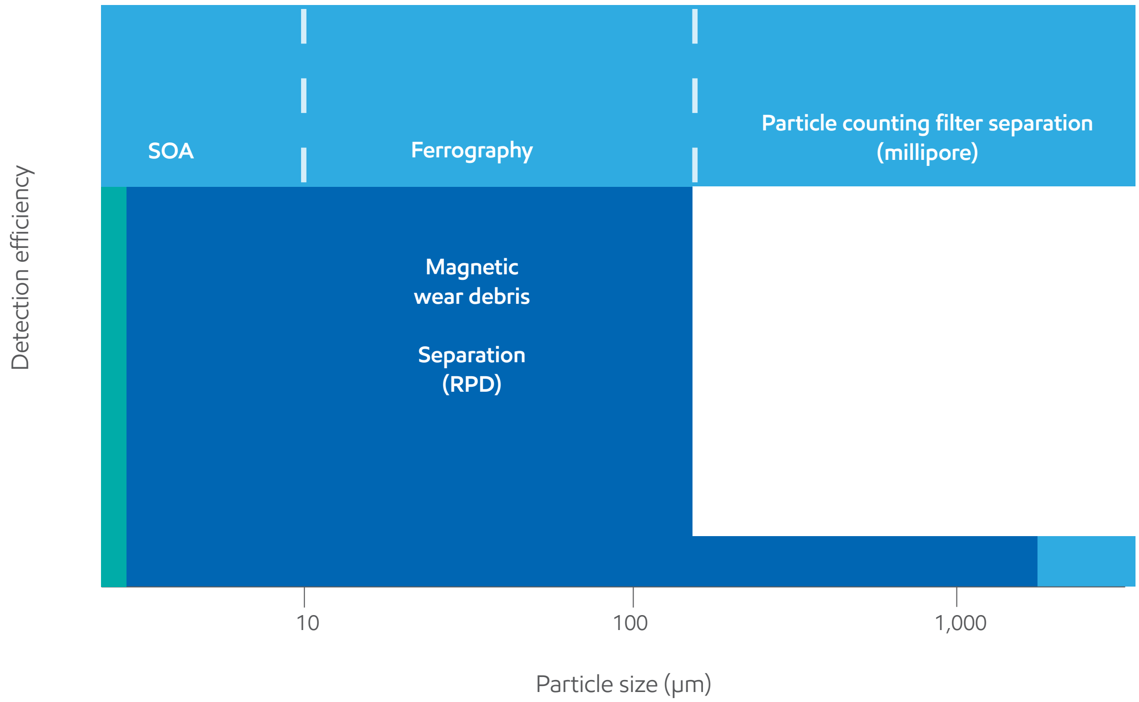
Mobil Serv℠ Lubricant Analysis tests (cont.)

Particle quantifier (PQ):
PQ helps detect metal fatigue failures and metal-to-metal contact not usually detectable by current spectrographic analysis.

PQ can help:
- Detect anti-friction bearing wear.
- Detect plain bearing wear before shafts seize.
- Detect early indications of piston scuffing before seizures occur.

PQ makes it possible to determine wear conditions at an early stage, which left undetected could cause catastrophic failures. The lab runs PQ on each sample to determine the presence of larger ferrous wear particles.

Application of different monitoring conditions



Note:

SOA – Spectroscopic oil analysis

RPD – Rotary particle depositor

Mobil Serv℠ Lubricant Analysis tests (cont.)

Detecting Asphaltenes Contamination (DAC):
ExxonMobil has developed a proprietary method that detects asphaltene levels in used engine oils for applications operating on residual fuel. This test uses advanced techniques to measure asphaltenes. The method is automatable and reports asphaltenes in wt. per cent.

The advantage of the DAC over other methods is that the most offending residual fuel component in used engine oils is measured directly. Older methods measure vanadium levels, which often trend with asphaltenes levels, but there are many exceptions. Vanadium in the oil does not adversely affect lube oil properties, so its direct measure has little value other than verifying that unburned fuel components are present and that they roughly correlate with asphaltenes. Measuring asphaltenes directly is preferred, since these molecules can affect engine and lubricant performance. These performance issues can lead to piston undercrown deposits and crankcase deposits.

Particle count:
Particle count is tested for all non-engine equipment except stern tubes and slow-speed crosshead engine system oils.
(see – Insolubles content testing.)

Oil cleanliness is a critical factor in running a hydraulic system and other non-engine components. Fine debris, both metallic and non-metallic, can interfere in the fine tolerances of the pumps, valves, etc., of the hydraulic hardware. Particle counting is a method of monitoring the system cleanliness. The most damaging are those between 6 and 14µm. Current thinking is that particles around 4µm can also cause damage; thus, we have incorporated this test option into our lab offering.

To better understand cleanliness, the large numbers generated by a particle count are referenced to size ranges in the standard ISO 4406. Range numbers (ISO Solid Contamination Code) are given to the number of particles greater than 4µm, greater than 6µm and those greater than 14µm. The additional dimension of particles greater than 4 µm is expressed: 22/20/17. Above this, consideration should be given to checking filters, cleaning or replacing the oil. The cleanliness code may also be expressed as an NAS classification (standard - NAS 1638). This relates to the number of particles over several ranges of particle size. For example, an NAS classification NAS 7 would be equivalent to an ISO code of xx/16/13.

Interpreting your analysis results

Mobil Serv℠ 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 Serv Lubricant Analysis report provides 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 minimise 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, hour since last change, etc.) with your sample submission. This data allows you to normalise 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.

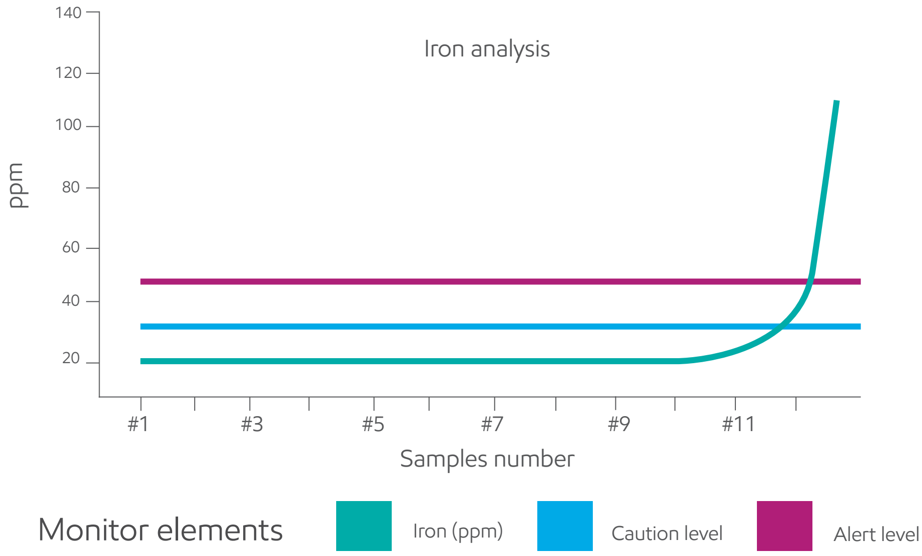
Extracting the maximum benefit from oil analysis

1. Collect and prepare the raw data, using statistical, baseline and current data to define the level and the trend of the current results. Mobil Serv℠ provides alarms for both level and trend.

Level: The amount of a parameter in comparison to different status alarms.
— Level alarms are derived from statistical data knowledge, OEM guidance and experience for each measured parameter.

Trend: The rate of change of amount of a parameter in comparison to different status alarms.
— Trend alarms are customised for each specific piece of equipment for each parameter being analysed.

Level versus trend



The caution and alert bars represent levels. The geometric rate of wear increase represents the trend.
Both the trend and the level indicate that this is a severe problem.

2. Combine the trend and level status to determine an overall equipment and lubricant condition indicator.

3. Evaluate the data by combining results to develop patterns that indicate potential abnormal equipment and/or lubricant conditions.

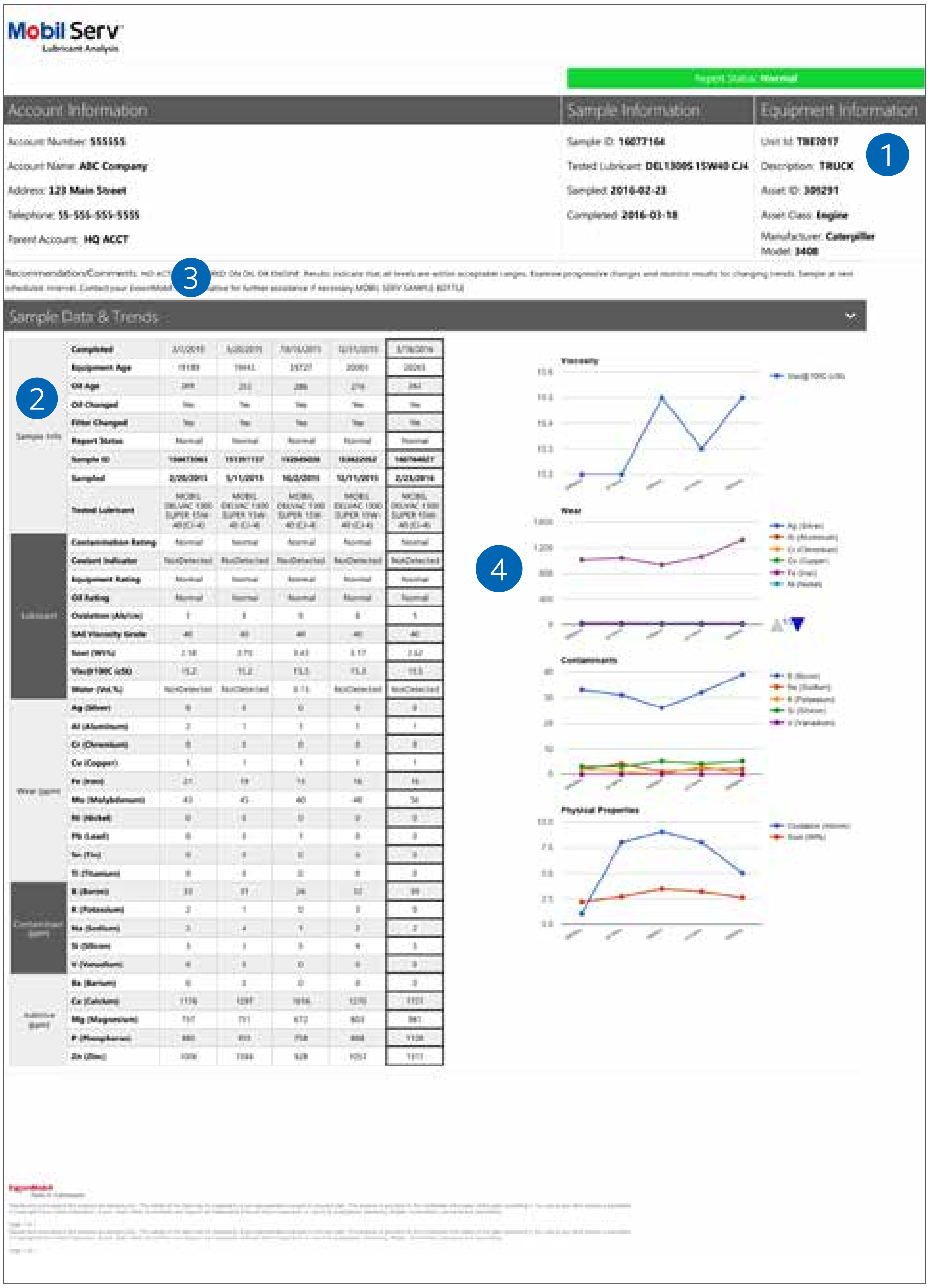
— Example: Silicon + iron + chrome + aluminium on a diesel engine indicates a dirt ingestion problem and wear of the cylinder liner and piston rings
— Verify the problem (use other predictive maintenance techniques, such as temperature and vibration, consult experts, etc.)
— Identify the root cause of the problem to develop the best maintenance solution

4. Confirm alert analysis conditions prior to replacing or shutting down equipment.

Consider these confirming steps before taking action:

1. Review maintenance/operator records to identify condition.
2. Verify condition with other equipment monitoring tools.
3. Utilise an on-site analysis test designed for the alerted condition.
4. Submit another sample to the laboratory for analysis.

Mobil Serv℠ 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 hour since last change 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 Serv℠ 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

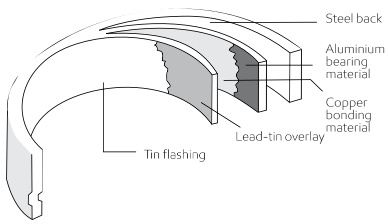
Before replacing or shutting down equipment, confirm alert analysis conditions considering the following steps:

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

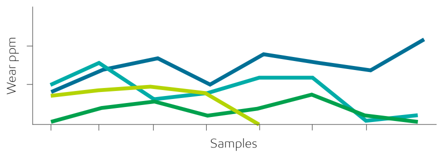
Understanding equipment condition

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 help evaluate sample results.

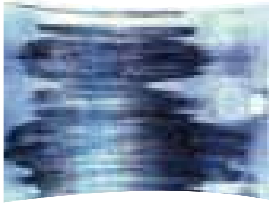
Understand metallurgy



Bearing wear example



Monitor elements



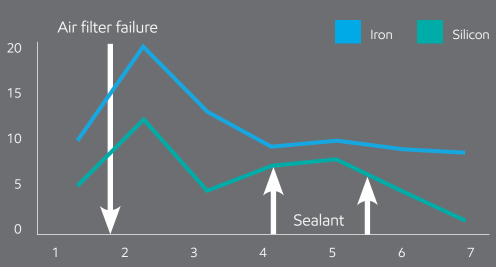
Plan maintenance

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 equipment condition (cont.)

Typical equipment component metals

	Natural gas engine	Turbine (gas/steam)	Hydraulic/ circulation	Compressor	Diesel engine	Gearing
Aluminum (Al)	Pistons, bearings, blocks, housings, bushings, blowers, thrust bearings		Pump motor housing, cylinder gland	Rotors, pistons, bearings, thrust washers, block housing	Pistons, bearings, blushings, blocks, housings, thrust bearings	Pumps, clutch, thrust washers, torque converter impeller, oil pump
Chromium (Cr)	Rings, roller/taper bearings, liners, exhaust valves		Rods, spools, roller/ taper bearings	Rings, roller/ taper bearings	Rings, roller/taper bearings, exhaust valves	Roller/taper 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	Wrist pin bushings, bearings, cam bushings, oil cooler, valve-train, bushings, thrust washers, governor, oil pump	Clutches, steering disks, bushings, thrust washers, oil cooler
Iron (Fe)	Cylinders, block, gears, crankshaft, wrist pins, rings, camshaft, valve train, oil pump liners	Bearings	Pump vanes, gears, pistons, cylinder bores, rods, bearings, pump housing	Camshaft, block, housing, bearings, shafts, oil pump, rings, cylinder	Cylinders, block, gears, crankshaft, wrist pins, rings, camshaft, valve train, oil pump liners	Gears, discs, housing, bearings, brake bands, shift spools, pumps, PTO, shaft
Lead (Pb)	Bearings	Bearings	Bearings	Bearings	Bearings	
Silver (Ag)					Bearings, wrist pin bushing (EMD)	
Tin (Sn)	Pistons, bearing	Bearings	Bearings	Pistons, bearings, bushings	Pistons, bearing overlay, bushings	
Titanium (Ti)		Bearings, turbine blades				

Identifying 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	Source
Nickel	Residual fuel contamination
Magnesium (Mg)	Sea water, additive
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.

Identifying contamination

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

Remedies for typical contaminants

Contaminant	Description	Condition	Effect	Remedy
Distillate fuel dilution	Distillate 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
Soot	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
Insolubles (solids)	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
Residual fuel asphaltene contamination detection (DAC)	DAC directly measures the % of asphaltenes in used oil using chemometrics and spectroscopy.	Leaking fuel line, injectors or pumps, blow-by	Bearing and cylinder wear, piston undercrown deposits and piston crown burning	Determine the source of fuel ingression (lines, leaking pumps, injectors)
PQ Index	Good indication of the nature and severity of the wear metal or foreign contaminant or lubricant breakdown.	Overload, overhead, poor sealing	Metal fatigue, cutting wear particles, abrasive, erosion, adhesive or corrosive wear	Drain flush system and determine the cause of wear or contamination
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

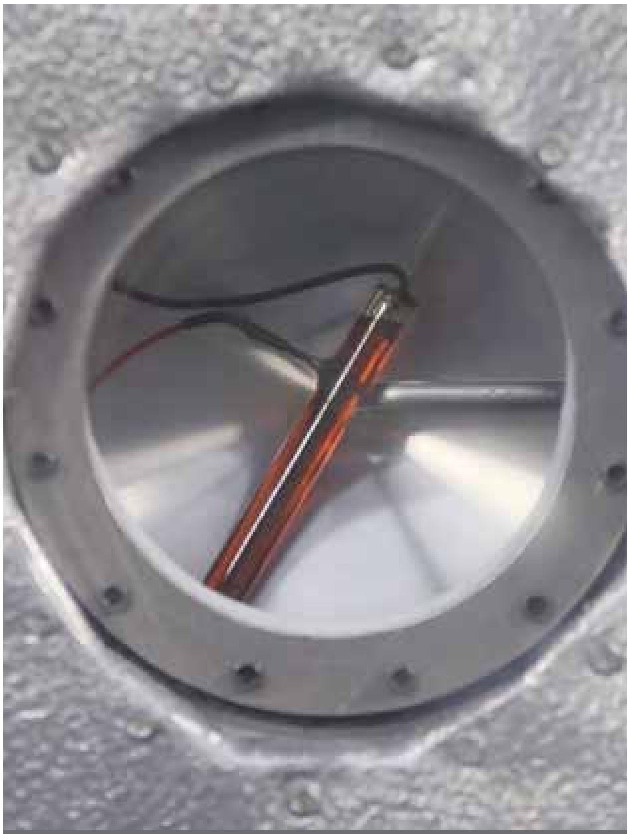
Understanding lubricant condition

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.

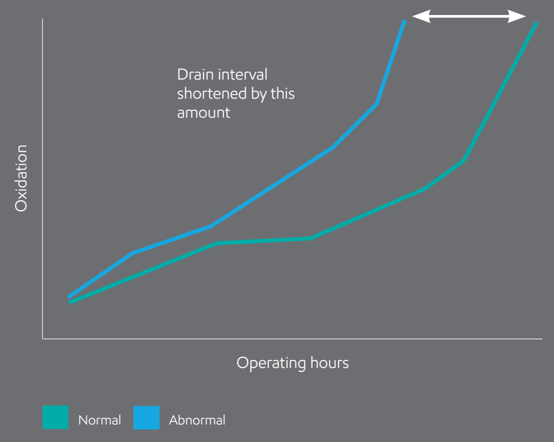
The following elements can help identify lubricant condition:

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 (cont.)

Remedies for typical contaminants

Contaminant	Description	Condition	Effect	Remedy
Total Acid Number (TAN) high	Acid number is a measurement of the buildup of harmful acidic oxidation compounds produced by oil degradation.	High sulphur 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
Total Base Number (TBN) low	Base number is a measurement of an oil's ability to neutralise harmful acidic compounds produced during the combustion process.	Overheating, overextended oil drain, improper oil in service, high sulphur fuel	Increased wear rate, acid buildup in oil, oil degradation, increase in sludge formation	Evaluate oil drain intervals, verify "new" oil base number, verify oil type in service, change oil, test fuel quality
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	Use oil with oxidation inhibitor additives, shorten oil drain intervals, check operating temperatures, check fuel quality, evaluate equipment use versus design, evaluate operating conditions
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	Check air-to-fuel ratio, check for incorrect oil grade, inspect internal seals, check operating temperatures, check for leaky injectors, check for loose crossover fuel lines, evaluate operating conditions
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	Check air-to-fuel ratio, check for incorrect 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

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

Points to consider

Normalise your data

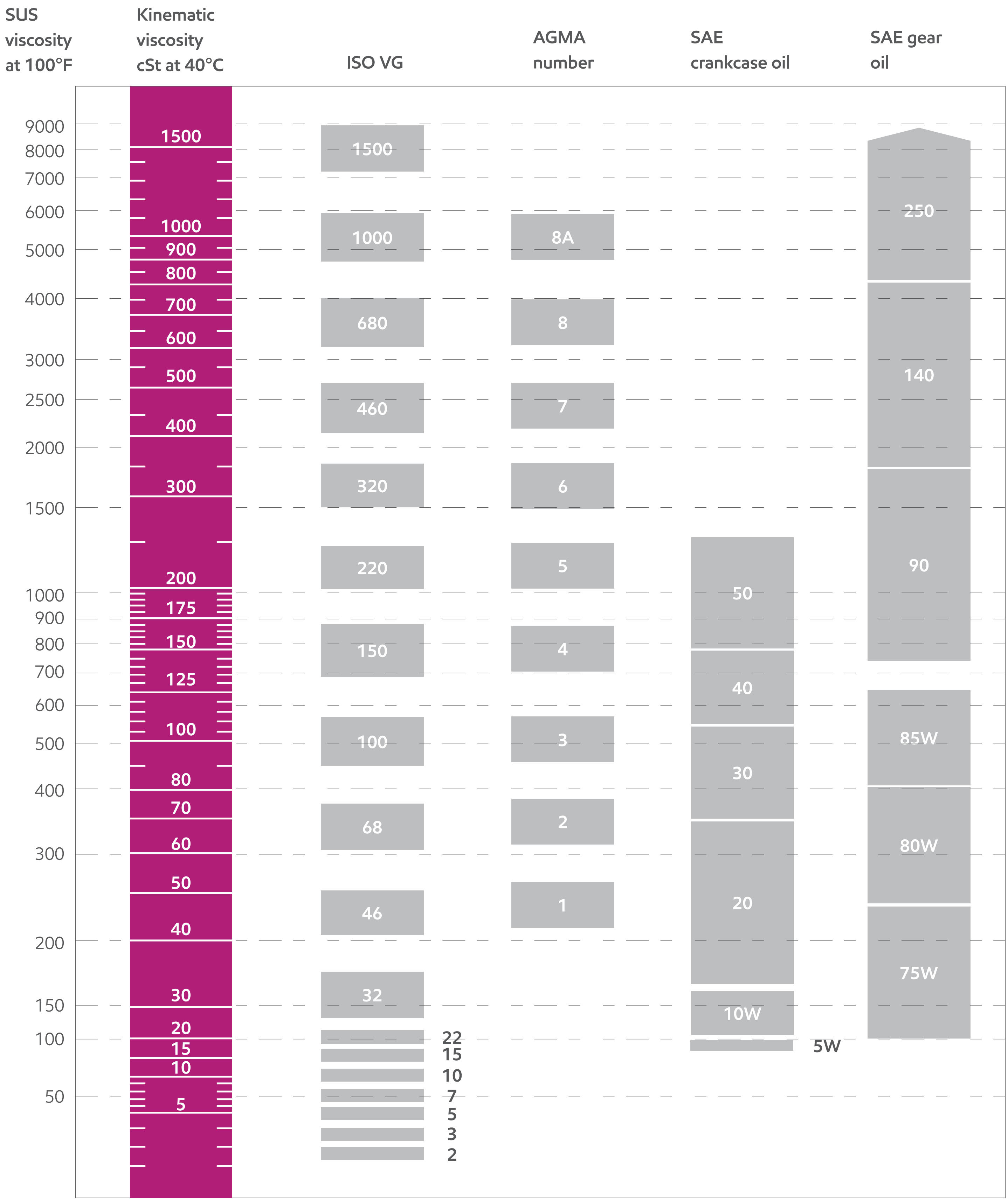
Looking at the analysis data without considering time or distance may lead to inaccurate conclusions about condition severity. Evaluating the data trend relative to wear rate per hour can enhance your assessment.

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.

Lubricant viscosity grade comparisons

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



Marine technical topic

Guidelines for switchover to ExxonMobil marine lubricants

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When switching to ExxonMobil marine lubricants, it is important to have a good understanding of the oils in use to ensure there will be no problems when potentially combining lubricants.

Five different circumstances related to switching and mixing lubricants are explained below. Please contact ExxonMobil for further advice and assistance if needed.

1. Mixing two mineral oils
Mixing different mineral oils is generally low risk due to the similarity of the chemical hydrocarbon structure of all base oils. We still advise mixing our lubricant with the minimum amount of competitor oils.

2. Mixing mineral oils with synthetic oils
Mixing synthetic oils with mineral oils is not recommended because doing so dilutes or suppresses the superior properties of synthetic oils. Some types of synthetic oils have different structures to mineral oils, leading to compatibility problems.

3. Mixture of different synthetic oils
The risk of incompatibility between synthetic oils of the same base oil type is relatively low if they have the same basic chemical structure — such as polyalphaolefins or the same ester type. Synthetic oils of different base oil types should never be mixed, and we do not recommend mixing different brands of synthetic oils for the following reasons:

- Synthetic oils are generally used in high-performance equipment and are tailor-made for the specific application.
- Mixing two different oil brands may compromise lubricant performance.
- Used oil contains contaminants and impurities from the machinery operation that can cause instability when mixed with new oil.

4. Mixture of different grease products
Different brands of grease generally combine well, as long as their soap components are compatible — such as two brands of grease each having a lithium base. However, if the soap base is not known, the grease should not be mixed.

5. Mixing different marine engine lubricants
Base oils for marine engine oils usually have a chemically similar structure that typically does not lead to compatibility problems. It is always advisable to minimise mixing different oil brands, and ideally the products should be kept in segregated storage. However, it is recognised that this is not always possible.

Marine technical topic

ExxonMobil

Storage and handling

Best practices and guidelines for marine lubricants

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Best practice benefits

In order to ensure that lubricants and greases can deliver their maximum performance, they must be stored and handled correctly, both shore-side and on board vessels. Poor handling, storing and dispensing methods can cause the products to deteriorate or become contaminated, which can result in machinery damage and potentially avoidable maintenance issues.

Problems can arise due to:

- Container damage
- Water contamination from rain, seawater or condensation
- Dirty dispensing equipment
- Exposure to dust and dirt
- Mixing different brands or types of lubricant
- Exposure to excessive heat or cold
- Products exceeding their shelf life

Best practice guidelines

ExxonMobil has produced lubricant handling, storing and dispensing guidelines to help users avoid the most common lubricant-related issues.

Handling

Drums and pails should only be moved using the correct lifting equipment to avoid container damage, drops and spills. Containers should only be filled in clean conditions.

Storage

Use a cool, dry, indoor storage area for lubricants and greases, avoiding environments that can reach extreme temperatures. The ideal storage range is 5-50°Celsius, but users should contact their ExxonMobil representative for specific product recommendations. Drums and pails must be securely tied, properly labelled and checked regularly for any signs of leakage.

If drums have to be stowed on deck, they should be stored on pallets to raise them off the deck with bungs forward. If this is not possible, drums should be tilted in order to avoid water settling around the bungs. Always cover with tarpaulin.

Dispensing

Use the first-in, first-out storage principle; check container labels to ensure the oldest products get used first. Clean drums and pails before opening and use clean dispensing equipment. Do not mix products and always replace lids and bungs properly after opening.

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