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SIGNUM
OIL ANALYSIS

Signum Oil Analysis

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

A successful oil analysis programme can:

- Insure equipment reliability
- Reduce maintenance costs
- Lower the total lifetime cost of lubrication

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

Signum Oil Analysis provides informative reports on the condition of lubricants and equipment backed by the unmatched flexibility, expertise, and quality assurance of ExxonMobil.

Flexibility

Perform many tasks more efficiently with Signum Oil Analysis online capabilities.

Expertise

Through global Original Equipment Manufacturer (OEM) relationships and hands-on lubrication experience, ExxonMobil supports your maintenance activities.

Quality and Consistency

Make decisions with confidence by leveraging the quality assurance offered by ExxonMobil.

Establishing a Successful Oil Analysis Programme

Oil analysis is most effective as a trending tool to monitor equipment and lubricant conditions over time. An analysis of a timeline of data provides insight to help maximise equipment life and reliability while reducing maintenance costs.

Success begins when you commit the resources necessary to execute an oil analysis programme.

Steps 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 Programme
6. Respond to the Analysis Results
7. Measure Programme Results Versus Goals and Metrics
8. Review and Modify Programme
9. Document Savings

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.

Tactical Steps

What 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.

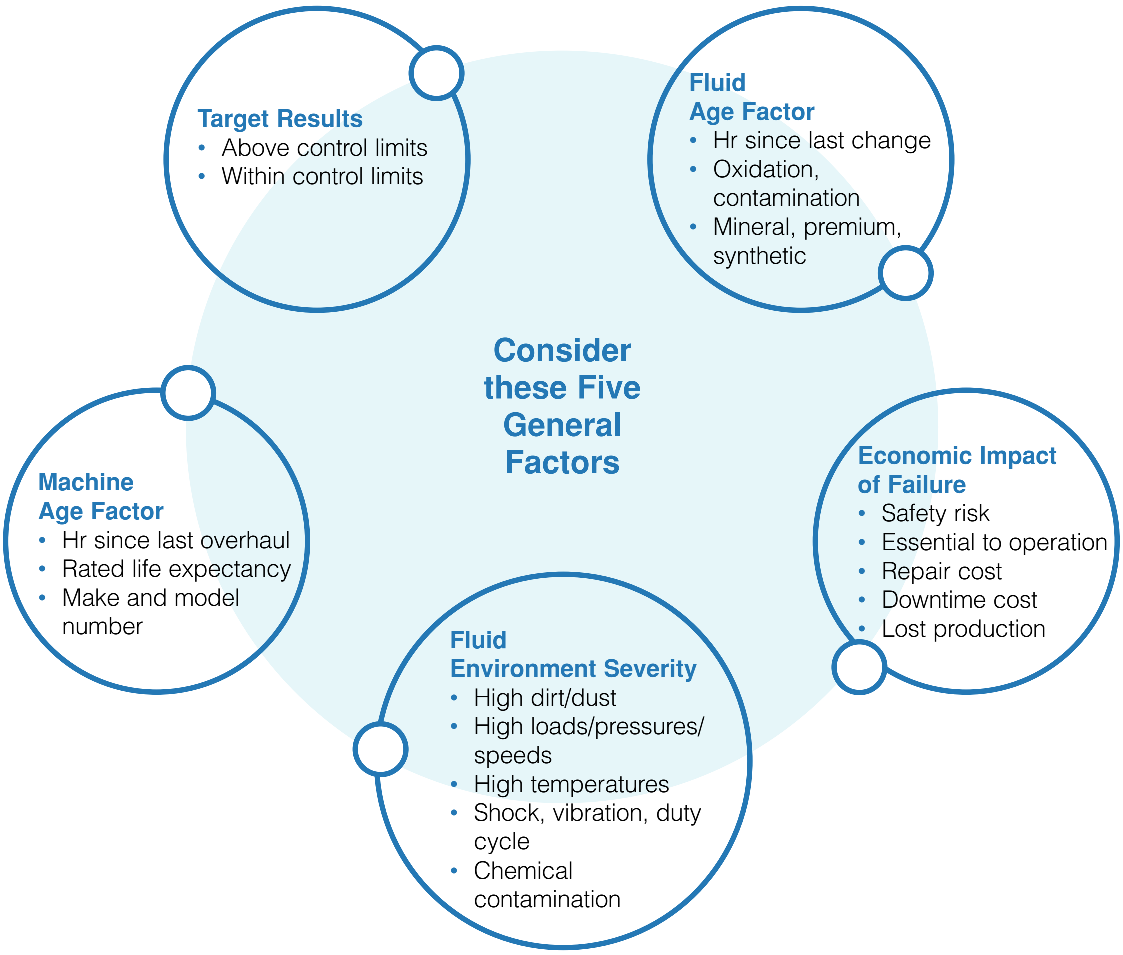
Typical Marine applications for oil analysis include:

- Auxiliary Engines
- Cam Shaft Systems
- Compressors (Air/Refrigeration)
- Deck Gear Drives
- Deck Hydraulics
- Gas Turbines
- High-Speed Diesel Engines
- Medium-Speed Diesel Engines
- Purifiers
- Reduction Gears
- Slow-Speed Engines System Oil
- Steering Gear Hydraulics
- Stern Tubes
- Thrusters
- Turbochargers

Tactical Steps to Utilising Signum Oil Analysis

1. What to sample
2. When to sample
3. How to sample
4. Inspecting your sample
5. Sampling and shipping instructions
6. Retrieving results
7. Interpreting results and reports

Sampling Considerations



When to Sample

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 the guidelines of classification societies' guidelines, such as DNV, Lloyds 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

Sample Point	Frequency
High-Speed Diesel Engines	250-500 hours
Medium-Speed Diesel Engines	1000-2000 hours
Slow-Speed Engines System Oil	1000-2000 hours
Gas Turbines	250-500 hours
Steering Gear Hydraulics	500-2000 hours
Reduction Gears	250-500 hours
Cam Shaft Systems	250-500 hours
Thrusters	500-500 hours
Stern Tubes	1000-2000 hours

Marine Supporting Equipment

Sample Point	Frequency
Auxiliary Engines	500-1000 hours
Turbochargers	1000-2000 hours
Compressors (Air/Refrigeration)	3 to 6 months
Purifiers	1000-2000 hours
Deck Hydraulics	3 to 6 months
Deck Gear Drives	3 to 6 months

How to Sample

Start with a representative sample to obtain accurate analysis results.

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

For best results:

A. Establish a Sampling Schedule

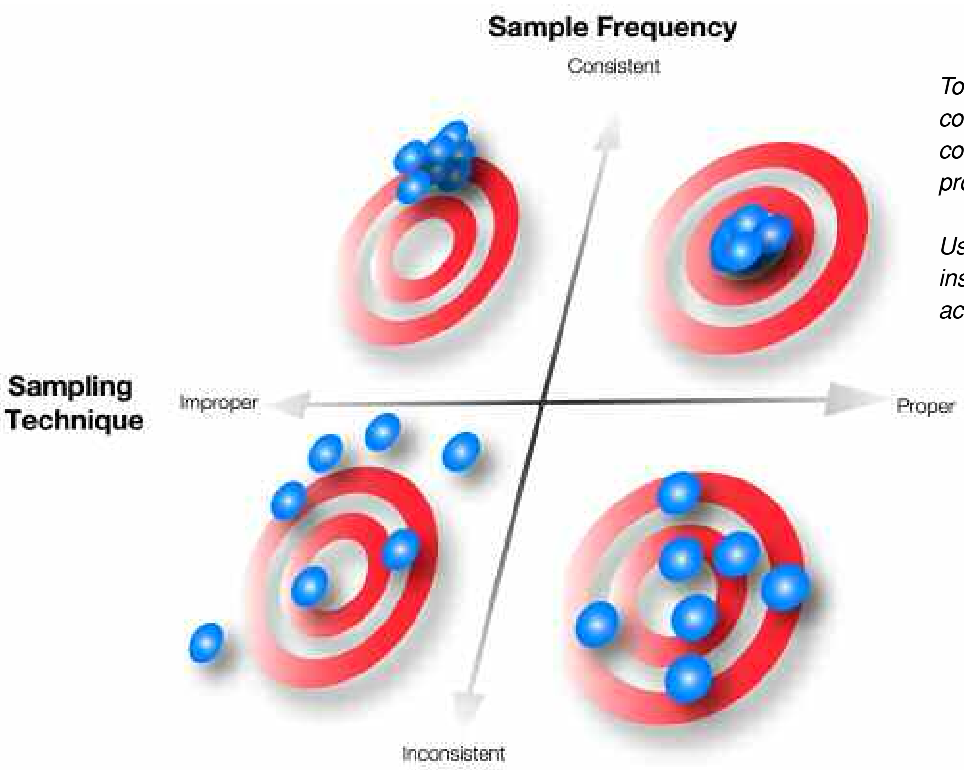
- Set-up a sampling schedule.
- Take samples at a consistent interval and location.
- Sample as close to operating temperature as safely as possible.

B. Follow Good Housekeeping Techniques

- Inspect work environment for safe operating conditions.
- Clean the area around the Sample Point.
- Use only approved sample bottles.

C. Record Sample Details

- Print sample labels online or use downloadable PDF label files with your pre-printed labels.
- Record equipment and sample details.
- Include Oil-in-Use, Sample Date, hour on oil and equipment, etc.
  - — Use pre-printed labels



To hit the target, sample at a consistent frequency from the correct sample location using proper sampling techniques.

Using preprinted labels helps insure that you obtain the most accurate data.

How to Sample *(continued)*

Sample Locations

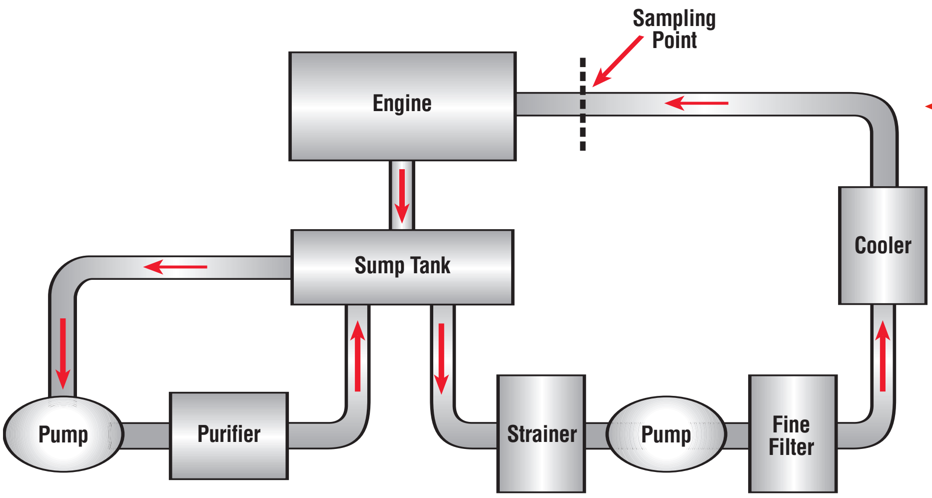
The maximum benefit of the Signum Oil Analysis programme can only be obtained if a truly consistent and representative sample is taken. **Do not take a cold sample!**

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 Signum sample bottle.

The primary recommended sampling points are detailed on pages 5 to 7.

Main Engine, Auxiliary Generator Engines

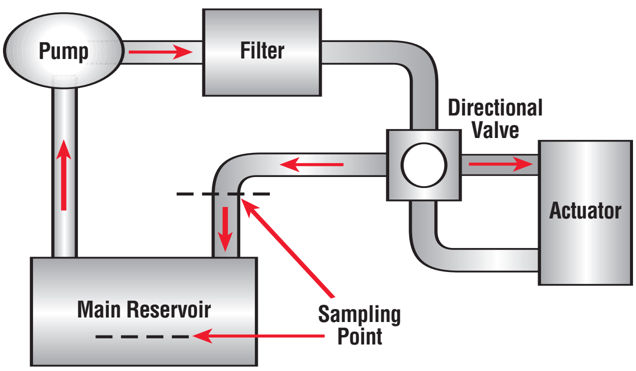
Prior to oil entering engine, between the cooler and the engine.



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

Hydraulic Systems

From system return line or midpoint of main reservoir.

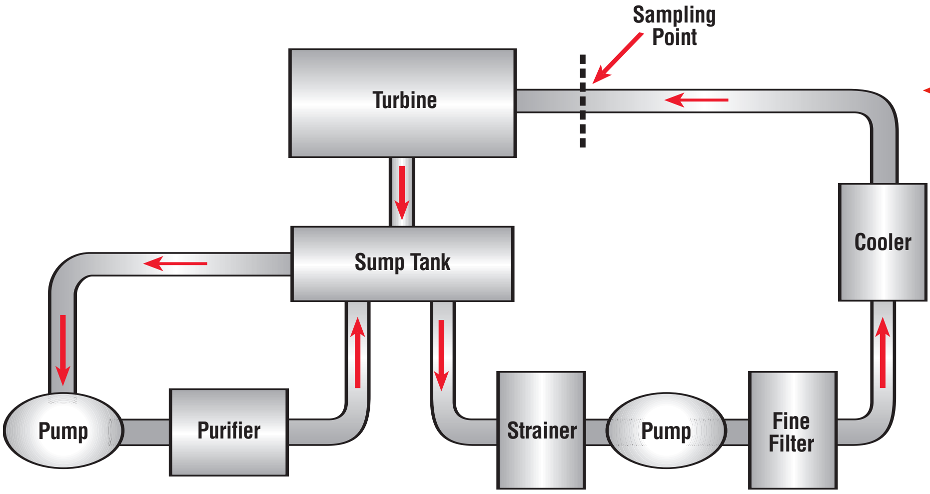


The sample must be taken when oil is in circulation and machinery and oil are at operating temperature.

How to Sample *(continued)*

Steam Turbines

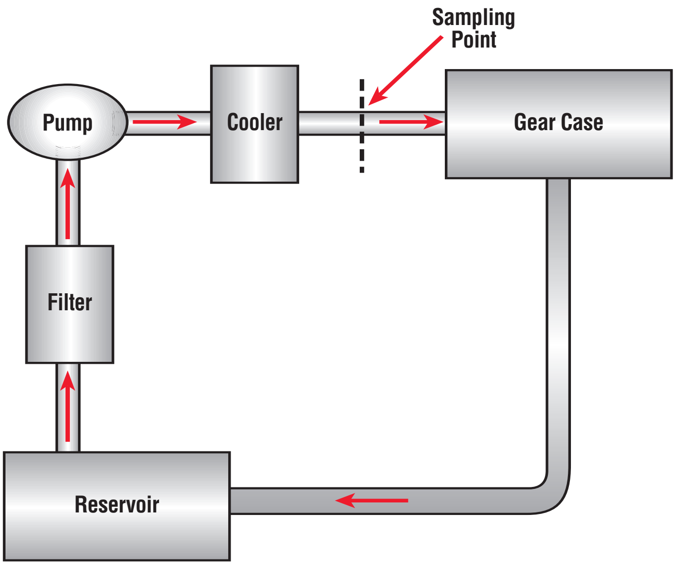
Prior to oil entering turbine, usually between the cooler and the turbine.



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

Gear Cases

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

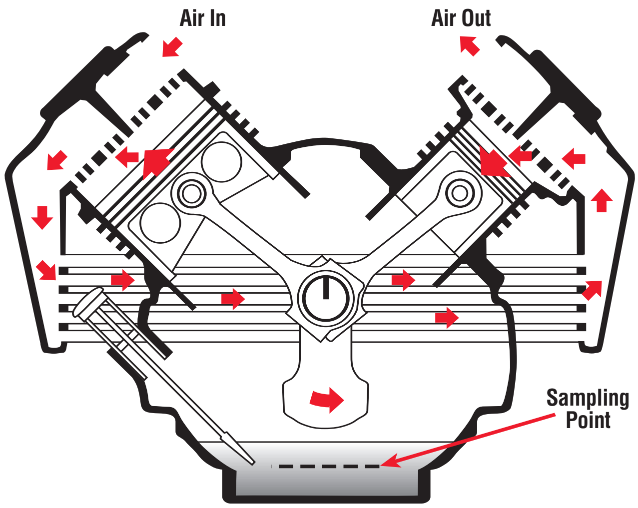


The sample must be taken when oil is in circulation and machinery and oil are at operating temperature.

How to Sample *(continued)*

Compressors

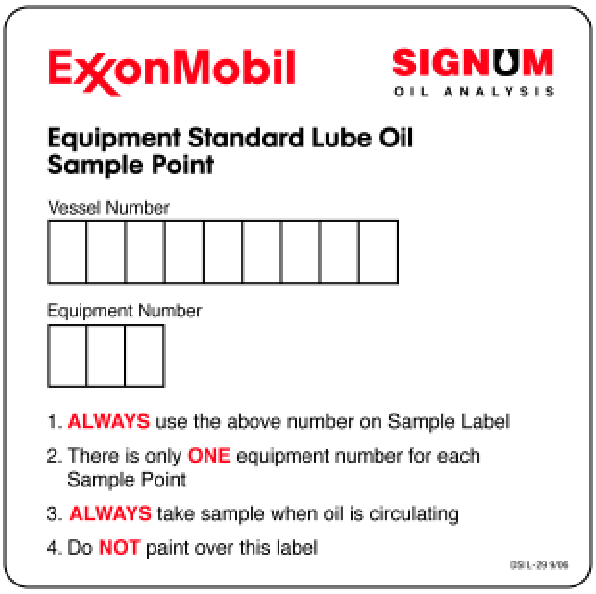
Reservoir midpoint from crankcase.



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

Signum Sample Point Label

Signum Sample Point Labels help insure sampling consistency that will result in analysis data accuracy.



Stickers are available from your local ExxonMobil Marine Lubricants representative. They are designed to be permanently affixed on the equipment near the sample point for identification.

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 for Non-Engine Samples

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 on 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 severe wear situation.

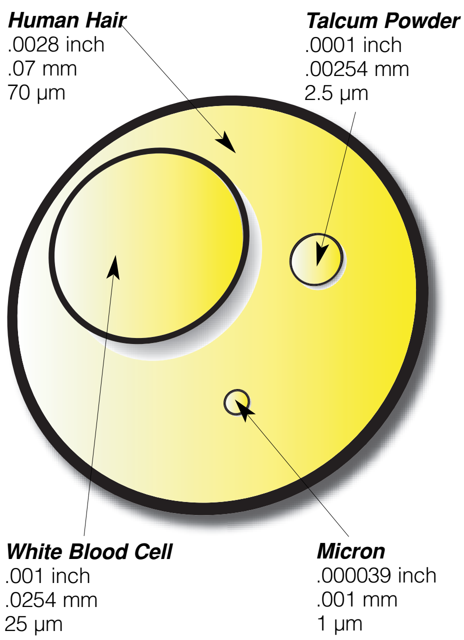
Take corrective action before sending sample to the laboratory if contamination (water, dirt, metal, etc.) is visible. Since large amounts of contamination in the oil can damage laboratory equipment, resample once the condition is corrected.

Points to Consider

Contamination Analysis

Laboratory analysis typically targets contaminants <8 microns, which is 5x smaller than what is visible with the human eye (see "How big is a micron?"). 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)?



Lower range of visibility with the naked eye is 40 µm.

Sampling and Shipping Instructions

Draw a sample using the equipment's sample valve or the sampling pump.

1.

Fill the sample bottle to the bottom of the bottle's neck. Do not overfill the sample bottle.

Fill line.

3b.

If unable to use Signum to print labels, complete the sample bottle label using a ball point pen. To insure an accurate oil analysis report, be sure all label information is complete.

2.

Detach the sample bottle. Be sure cap is securely tightened.

4.

Affix the completed label to the sample bottle.

3a.

SIGNUM
OIL ANALYSIS

Account: 170898
ABC Shipping

Vessel Number: 3255547
Ocean Anna

Equipment Number: 002
Aux Engine #1

Lubricant:
MOBILGARD M440

ME 3166122 30315760

ME 3166122 30315760 11

Total Equip. Hrs:	30000		
Hrs Since Last Overhaul:	10000		
Oil Service Hrs:	10000		
Oil Volume:	3500	LITRES	
Oil Used / 24 Hrs:	150	LITRES	
Date Sampled:	07/20/2010		
Date Landed:	07/22/2010		
Port Landed:	Singapore		
Compatibility Test:	☐ (Please check if applicable)		
Special Data Test Info			
Fd Rate l/engine/day:		Amb.Temp(C):	
KW at Sampling:		Rel Humid(%):	
Fuel Sulphur, Wt%:			

Print sample bottle label in Signum with complete label information.

Note: *It is highly recommended that all data fields be filled in on the sample bottle label.*

5.

Tighten the mailing container's cap. Affix the appropriate preprinted mailing label to the container, and place it in any post or mail box.

Retrieving Your Results

The Signum Oil Analysis laboratory is committed to providing complete and accurate analysis results. Your results are e-mailed or posted online typically within one to two business days after receiving your sample at the lab.

You can improve turnaround time by following these steps:

1. Mail your sample immediately.
2. Use approved shipping materials provided in the sample kit.
3. Use the online sample label printing feature which helps expedite your sample through the laboratory registration process.
4. Mail samples via Overnight/Courier Service or use First Class/Priority delivery.

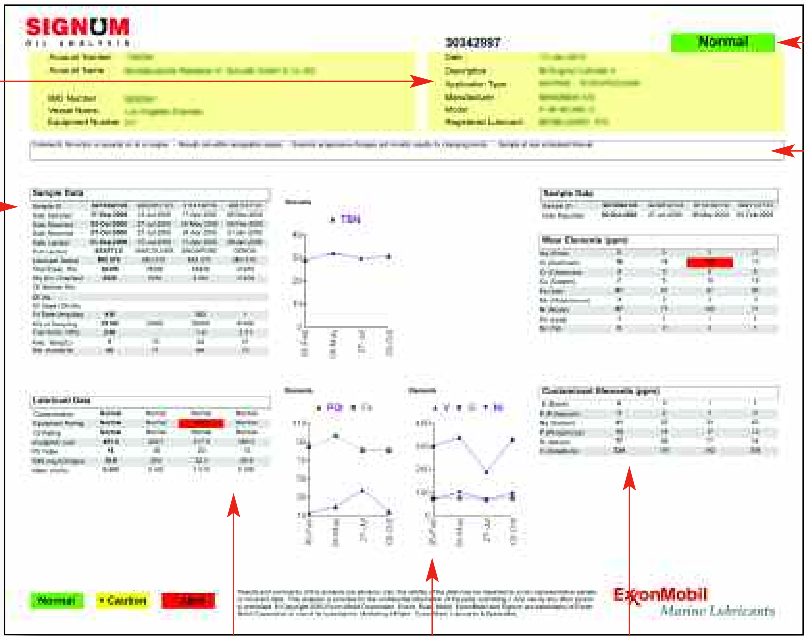
Signum Oil Analysis — Graphic Sample Report

Sample Point Data

Sample point data that you provide during registration is used to interpret the analysis results. By including equipment manufacturer, model, and other operating parameters, a better overall assessment can be made for your application.

Sample Label Data

A completed sample label provides critical information for processing and interpreting your equipment's condition. By including key data, like equipment hours and date sampled, you help establish reference points that assist in condition trending.



Results Interpretation

Proprietary control limits are applied based on your equipment manufacturer, equipment model, lubricant, and application. Sample comments are provided, as required, to help identify potential problems, list possible causes, and recommend actions for follow-up.

Analysis Results

The Signum Oil 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*

Signum Oil Analysis

When your sample is processed, the laboratory handles each bottle as a unique and important item. Each sample is coded, labeled, and tracked through the entire process. By the time test results are available your equipment lubricant sample has directly benefited from our knowledge of ExxonMobil lubricants, decades of OEM relationships, and a strong heritage of hands-on application expertise. Sample comments are provided, as required, to help identify potential problems, list possible causes and recommend actions for follow-up.

Interpreting Your Analysis Results

Signum Oil Analysis programme 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 Condition
- Lubricant Condition

Your Signum Oil Analysis report provides an easily readable, 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.

To assess your equipment's 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 Sample Point'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 sample information (e.g. date sampled, hr/mi/km, make-up oil, etc.) on the sample label. 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.

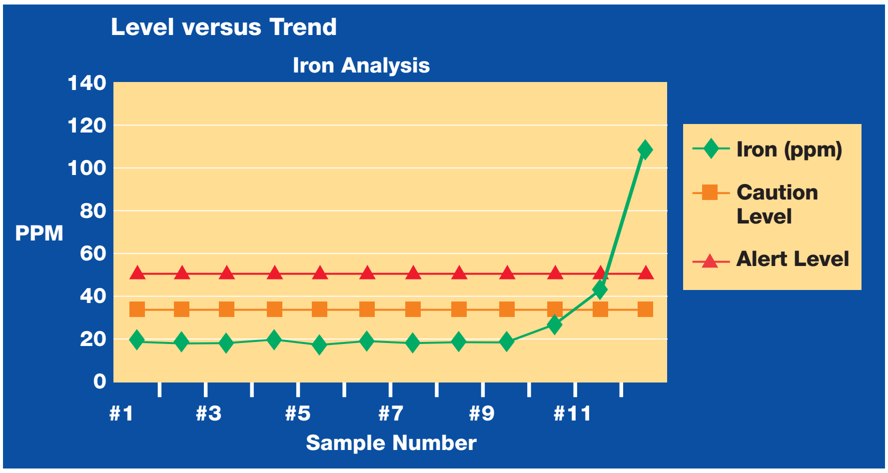
Sample comments are provided to help identify potential problems, list possible causes, and recommend actions for follow-up.

Interpreting Your Analysis Results *(continued)*

Extracting the Maximum Benefit from Oil Analysis

A. Collect and prepare the raw data, using statistical, baseline and current data to define the level and the trend of the current results. Signum 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.



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.

Chart generated using spreadsheet software.

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

C. 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

Interpreting Your Analysis Results *(continued)*

D. 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 — i.e. 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.

Points to Consider

Applied Limits

Limits applied to each sample can vary based on your Sample Point'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.

Marine Oil Analysis Laboratory Test Slates

KEY	
X	Normal test
C	Condition test
FS	Fuel Specific test; Distillate Fuel engines receive Gas Chromatography (i.e., Mobilgard 12 series, Mobilgard ADL series, Delvac series), Residual Fuel engines receive Flash Point (i.e., Mobilgard M series)
TBNS	Total Base Number (TBN) Specific test for scrapedown samples only. If sample's TBN is below 10, run Strong Acid Number (SAN) test.
PS	Product Specific test; Synthetic oils receive Total Acid Number (TAN) test and Mineral oils receive Oxidation by IR test
L	Lab Specific test run only at Pernis laboratory

NOTE: The following test slates are only run at Pernis laboratory:

1) Engine w/ DAC
2) Scrapedown
3) Hydraulic w/ SAN/TAN/pH
4) Grease

ENGINE OILS	Engine	Engine w/ DAC	Scrapedown
Viscosity @ 100°C	X	L	L
Water, Disp. (Infrared)	X	L	
Karl Fisher, Water			X
Total Base Number	X	L	L
Flash Point (SETA)	FS	FS	
Oxidation	X	L	
Soot	X	L	
Fuel Dilution by Gas Chromatography	C	C	
Analytical Ferrography	C, L	C, L	C, L
Particle Quantifier	X	L	L
Detecting Asphaltene Contamination		L	
Strong Acid Number			TBNS, L
Compatibility	C, L	C, L	
Metals	X	L	L
Aluminium	X	L	L
Boron	X	L	L
Chromium	X	L	L
Copper	X	L	L
Iron	X	L	L
Lead	X	L	L
Nickel	X	L	L
Silicon	X	L	L
Sodium	X	L	L
Tin	X	L	L
Vanadium	X	L	L
Zinc	C	C, L	C, L
Potassium	X	L	L
Molybdenum	X	L	L
Silver	X	L	L

NON-ENGINE OILS	Air Compressor	Gas/ Refrigeration Compressor	Gas Turbine	Circulating	Circulating – Heat Transfer	Circulating – Stern Tube	Hydraulic	Hydraulic w/ SAN/TAN/pH	Gear Drive	Steam Turbine	Fresh Oil Tank	Grease
Viscosity @ 40°C	X		X	PS	X	PS	PS	L	PS	X	PS	
Viscosity @ 40°C Degassed		X										
Viscosity @ 100°C											PS	
Water, Hot Plate	X	X	X	X		X	X	L	X	X	X	
Karl Fischer, Water	C	C	C	C	X	C	C	C	C	C	C	L
Total Base Number											PS	
Flash Point (Closed Cup)					X							
Oxidation	PS	PS	PS	PS	X	X	PS	PS	PS	X		
Insolubles					L	L						
Analytical Ferrography	C, L	C, L	C, L	C, L		C, L	C, L	C, L	C, L	C, L		
Particle Quantifier	X	X	X	X		X	X	L	X	X		L
Particle Count (4μm, 6μm,14μm)	X	X	X	X			X	L	X	X		
Strong Acid Number								L				
Total Acid Number	PS	PS	X	PS	L		PS	L	PS	X		
pH								L				
Micro Carbon Residue					L							
Compatibility	C, L	C, L	C, L	C, L	C, L	C, L	C, L	C, L	C, L	C, L	C, L	
Metals	X	X	X	X	X	X	X	L	X	X	X	L
Aluminium	X	X	X	X	X	X	X	L	X	X	X	L
Boron	X	X	X	X	X	X	X	L	X	X	X	L
Chromium	X	X	X	X	X	X	X	L	X	X	X	L
Copper	X	X	X	X	X	X	X	L	X	X	X	L
Iron	X	X	X	X	X	X	X	L	X	X	X	L
Lead	X	X	X	X	X	X	X	L	X	X	X	L
Nickel	X	X	X	X	X	X	X	L	X	X	X	L
Silicon	X	X	X	X	X	X	X	L	X	X	X	L
Sodium	X	X	X	X	X	X	X	L	X	X	X	L
Tin	X	X	X	X	X	X	X	L	X	X	X	L
Vanadium	X	X	X	X	X	X	X	L	X	X	X	L
Zinc											PS	
Potassium	X	X	X	X	X	X	X	L	X	X	X	L
Molybdenum	X	X	X	X	X	X	X	L	X	X	X	L
Silver	X	X	X	X	X	X	X	L	X	X	X	L

NOTE: The test schedules and tests are subject to change and are meant as a general guide only.

Signum Oil 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 Signum 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 Signum Oil Analysis is to insure 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 insure homogeneity, 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 ISO-VG grades, a change of approximately +24% from typical levels indicates the need for some corrective action. Corrective action is recommended when the change is in excess of +30%.

Flash Point

Measured in a Setaflash Tester on a Flash/No Flash basis, with a cut-off point which correlates with 200°C in ASTM D-92 (Cleveland Open Cup). Reported as PASS (above cut-off point) or LOW (equal or lower than cut-off 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. Typically the ExxonMobil "lower border limits levels" are:

7	TBN for Mobilgard 450 NC
10	TBN for Mobilgard 12 Series
11	TBN for Mobilgard ADL Series
20	TBN for Mobilgard M30 Series
25	TBN for Mobilgard M40 Series

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 % for cross-head engines and ≤0.3 mass % for medium-speed engines. Corrective action is suggested for higher levels and urged for content ≥0.3 and ≤0.5 mass % respectively. Similarly, limits of 0.15 mass % 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.

Signum Oil Analysis Tests *(continued)*

Insolubles Content (Select non-engine applications and stern tubes)

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 a diesel engine oils.

Total Acid Number (TAN)

Test run only for synthetic oils where oxidation by IR is not possible. This test measures acid build up in oil and is only run for specific applications such as Frank Mohn deep well hydraulic systems.

Oxidation by Infra-Red (IR)

This test method detects lubricant oxidation and is run for all samples except some synthetic based oils.

Elemental Analysis

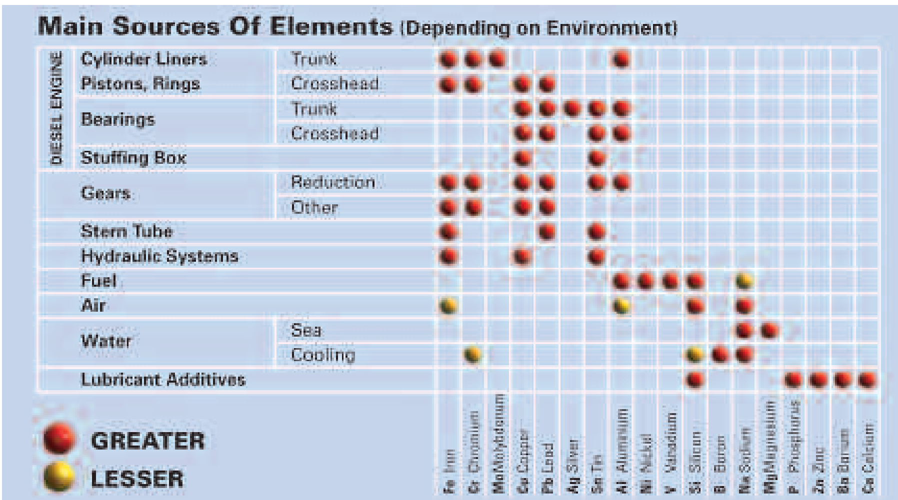
Elemental Analysis, by emission spectroscopy, detects the concentration of elements in units of parts-per-million (ppm). Particles with dimensions up to eight microns (μm) are detected. Such particles are generated in the normal wear processes or in corrosive regimes and in certain types of abrasive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

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.



Signum Oil Analysis Tests *(continued)*

Particle Quantifier (PQ)

PQ helps detect metal fatigue failures and metal-to-metal contact not usually detectable by current spectrographic analysis. In addition, the lab utilises PQ as a trigger to run an analytical ferrogram.

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. If the PQ reaches an alarm point, the lab will conduct analytical ferrography tests.

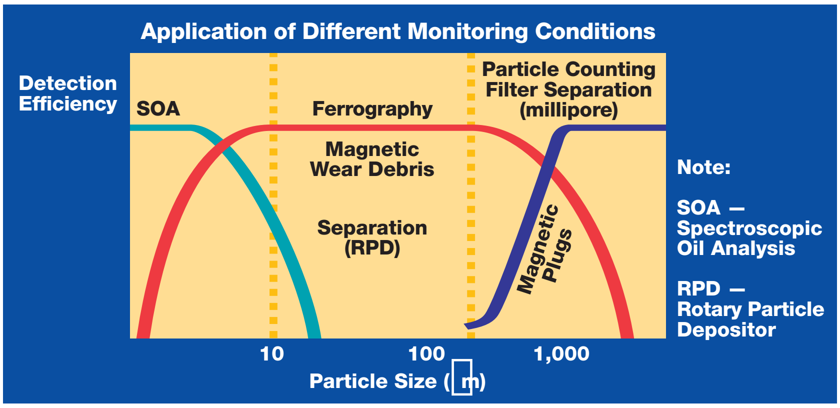
Analytical Ferrogram

Triggered based on PQ results. Analytical Ferrogram classifies debris in the oil sample, both the quantity and quality, to help determine the severity and nature of wear mode.

Analytical ferrography provides a useful complement to Elemental Analysis. This is especially true when an abnormal wear mode might suggest serious damage to the machinery is in progress or imminent. It reliably detects particles from 10 µm to over 100 µm, typical of some of the more destructive types of abnormal wear processes. The technique yields both quantitative and descriptive information about the particles in the lubricant.

Conditions such as:

- Normal rubbing wear from piston scuffing.
- Metallic fatigue of highly stresses surfaces.
- Spherical particles indicating fatigue cracks in roller bearings.
- Laminar particles from gears or roller bearings.
- Cutting and corrosive wear particles.
- Oxide particles including rust.
- Non-ferrous metallic particles.
- Non-metallic crystalline and amorphous particles.



Signum Oil Analysis Tests *(continued)*

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 new test uses advanced techniques to measure asphaltenes. The method is automatable and reports asphaltenes in wt.%.

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 prefered, since these molecules can affect engine and lubricant performance. These performance issues can lead to piston under crown deposits and crank case 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 4μm 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 a NAS classification (standard - NAS 1638). This relates to the number of particles over several ranges of particle size. For example a NAS classification NAS 7 would be equivalent to an ISO code of xx/16/13.

Signum Oil Analysis Tests *(continued)*

Compatibility Tests

During Switchovers of competitive vessels to ExxonMobil Marine Lubricants, compatibility testing can be performed to insure that ExxonMobil and competitive products are compatible. The two oils are thoroughly mixed in equal proportions and the mixture is heated to approx. 80°C for 24 hours. In addition, the mixture is visually checked for separation.

Details for conducting compatibility tests, where required, are provided in General Guidelines for Switchover to ExxonMobil Marine Lubricants (pages 25 to 27).

Sample Size: Please note a separate 125ml sample is required for compatibility testing.

Cylinder Oil Scrapedown Analysis for Slow-Speed Crosshead Diesel Engines

By analysing scrapedown oil collected from the scavenge space, a technique pioneered by ExxonMobil, shipboard personnel are able to monitor the condition of the engine's cylinders and detect changes as they occur. Scrapedown Oil Analysis provides comprehensive laboratory testing and analysis of the oil sample, and offers onboard testing tools that enable ship's engineers to quickly detect substantive changes in cylinder condition. It offers a technically advanced approach to safely optimising cylinder oil feed rates.

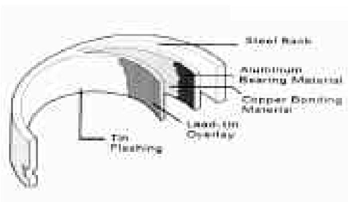
Onboard testing, using the Mobilgard Scrapedown Analyser and Signum Onboard Test Kit, provides quick, on-site readouts of the oil's most important properties relative to the engine's cylinder operating condition. The Mobilgard Scrapedown Analyser instantly measures and displays the iron content of a used cylinder oil sample. The Signum Onboard Test Kit monitors lubricants for alkalinity retention (TBN), water contamination and changes in viscosity. Data is entered and stored in the Mobilgard Scrapedown Analyser Logbook which allows you to store results, graph trends and analyse relationships between variables.

Interpretation Tips

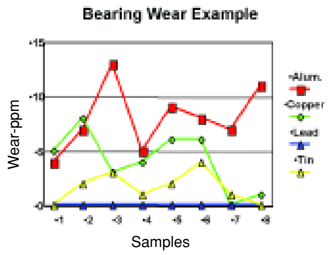
Understanding Equipment Condition

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.

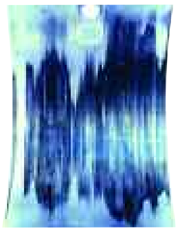
You should understand the metallurgy of your components to respond to the trends in your analysis report. Consult with your OEM or ExxonMobil representative to identify the metallurgical make-up of your components, help evaluate sample results, plan maintenance and then take action.



Understand Metallurgy



Monitor Elements



Take Appropriate Action

Points to Consider

Make-up Oil — Effect on Results

Equipment with high oil consumption will not typically return representative sample results. A potentially abnormal condition can be masked by escaping lubricant and by new lubricant make-up diluting the system volume. Record Make-up Oil on your sample label to include in your trend and sample assessment.

Typical Equipment Component Metals

	Natural Gas Engine	Turbine (Gas/Steam)	Hydraulic/ Circulating	Compressor	Diesel Engine	Gearing
Aluminium (Al)	Pistons, Bearings, Bushings, Blocks, Housings, Bushings, Blowers, Thrust Bearings		Pump Motor Housing, Cylinder Gland	Rotors, Pistons, Bearings, Thrust Washers, Block Housing	Pistons, Bearings, Bushings, Blocks, Housings, Bushings, Blowers, Thrust Bearings	Pumps, Clutch, Thrust Washers, Bushings, Torque Converter Impeller, Oil Pump
Chromium (Cr)	Rings, Roller/ Taper Bearings, Exhaust Valves		Rods, Spools, Roller/Taper Bearings	Rings, Roller/Taper Bearings	Rings, Roller/Taper Bearings, Exhaust Valves	Roller/Taper Bearings
Copper (Cu)	Wrist Pin Bushings, Bearings, Cam Bushings, Oil Cooler, Valve-Train Bushings, 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 Discs, 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, Rust	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, Bearings, Bushings	Bearings	Bearings	Pistons, Bearings, Bushings	Pistons, Bearing Overlay, Bushings	
Titanium (Ti)		Bearings, Turbine Blades				

Understanding Equipment Condition *(continued)*

Gasoline, Diesel and 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
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 hr can enhance your assessment.

Understanding Lubricant Condition

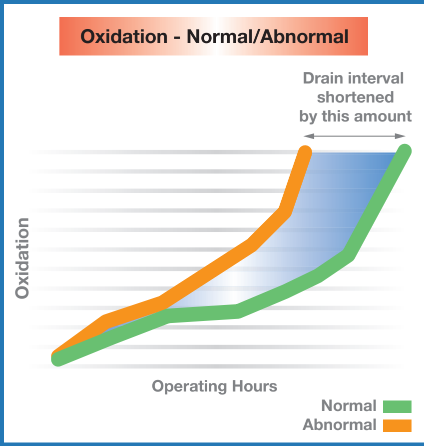
A lubricant performs a variety of functions in your application. The most important functions include friction control and efficient power transmission. Maintaining the physical properties of the lubricant helps extend the equipment's reliability and the life of the lubricant.

Remedies for Abnormal Lubricant Conditions

	Description	Condition	Effect	Remedy
Total Acid Number High	Acid Number is a measurement of additives and the build up of harmful acidic 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, Drain Oil
Base Number Low	Base Number is a measurement of an oil's ability to neutralise harmful acidic compounds produced during combustion process.	Overheating, Overextended Oil Drain, Improper Oil in Service, High Sulphur Fuel	Increased Wear Rate, Acid Build-up 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 By-Products/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		Additive Shear, Fuel Dilution, Improper Oil Grade	Overheating, Poor Lubrication, Metal to Metal Contact, Increased Operating Costs	

Points to Consider

Impact of Oxidation on Lubricant Life



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

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 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 rebuild process.
2. **Self-Generated Contamination —** Contamination from system components worn or damaged by other contamination particles.
3. **External Ingression —** Contamination from external sources.

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, 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 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	Insure Injectors are Working Properly, Check Air Induction/Filters, Extended Oil Drain Intervals, Check Compression, Avoid Excessive Idling, Inspect Operating Conditions, Check Fuel Quality
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, Change 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 Make-up 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)
Analytical Ferrography	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

The following elements can help identify contamination:

Element	Source
Nickel	Residual Fuel Contamination
Magnesium (Mg)	Sea Water, Additive
Potassium (K)	Coolant
Sodium (Na)	Coolant, Sea Water, Additive
Silicon (Si)	Dirt, Dust, Sealant, Additive, Silicone Defoamant, Refining Catalyst
Vanadium (V)	Residual Fuel Contamination

Signum Oil Analysis Field Support

Whether interpreting analysis results, or solving a lubricant-related problem, you can count on our team of marine professionals to take a proactive approach to offering support.

Many members of the ExxonMobil Marine Lubricants team spent time at sea as marine engineers, so the technical advice they offer is based on their own real-world experience. They have the skills to help you develop a responsible course of action for your fleet's lubrication and maintenance.

Technical Help Desk

Offering you an easy, uncomplicated way of doing business is a top priority. That is why we have created a global Technical Help Desk to assist our marine lubricants customers.

Staffed by lubrication specialists, the Technical Help Desk is your resource for fast, reliable answers to questions about Signum Oil Analysis, marine lubricants and basic marine lubricant-related problems.

You can reach our Technical Help Desk by telephone, 8:00 am – 5:00 pm, and via e-mail. *(See box below for specific phone numbers and e-mail address.)*

Assistance is available Monday - Friday, 8:00 am - 5:00 pm, in the local Help Desk time zones.
PLEASE NOTE GMT GUIDELINES.

Americas	+1 718 354 1392 *Toll-Free:* +1 866 328 8036* **Only valid in the U.S.*	GMT -5 hours
Asia Pacific	+86 21 24075692	GMT +8 hours
Europe, Africa, Middle East	+420 2 21456618	GMT +1 hour
E-Mail ***(All Countries)***	marinelubetech@exxonmobil.com	

General Guidelines for the Switchover to ExxonMobil Marine Lubricants

General information about mixtures of competitive oil brands:

Mixture of Mineral Oils

This generally implies a low risk only due to the similarity of the chemical hydrocarbon structure of all base oils.

Mixture of Mineral Oils with Synthetic Oils

It is not recommended in principle because any mixture with mineral oils dilutes or suppresses the superior properties of synthetic oils. In addition, some types of synthetic oils are totally different in structure to mineral oils which can cause compatibility problems.

Mixture of Synthetic Oils

The risk of incompatibility between synthetic oils of the same type is relatively low (same basic chemical structure i.e. polyalphaolefins or same ester type).

However, synthetic oils are generally used in high performance equipment and are tailor-made for the specific application. Therefore we do not recommend mixing two different oil brands. In addition, used oil fillings contain operation-related impurities that can cause an instability of the mixture. Never mix synthetic oils of a different type. Please contact ExxonMobil for assistance.

Mixture of Grease

Two brands of grease are miscible in general, as long as their soap components are compatible (i.e. Lithium base, with Lithium base etc.). If the soap base is unknown, the grease should not be mixed. Please contact the grease manufacturer in any case where mixing is unavoidable.

Marine Engine Lubricants

Base oils for marine engine oils usually have a chemically similar structure that does not necessarily imply compatibility problems. Only in rare cases have we experienced additive incompatibilities.

In order to provide you the highest possible convenience, we will run, on request, compatibility tests for the main grades in our laboratory. An ExxonMobil representative can call on board to assist you in the switchover procedure.

We generally recommend minimising the storage volume prior to the mixing of two lubricant brands. Please consult ExxonMobil in case this is not possible.

During Switchovers of competitive vessels to ExxonMobil Marine Lubricants, compatibility analysis can insure those ExxonMobil and competitive products are compatible. Often, it is not clearly understood why you are requested to obtain **two samples** of each competitively lubed engine. The reason why you are requested to take two samples is as follows:

General Guidelines for the Switchover to ExxonMobil Marine Lubricants *(continued)*

1) There are **TWO** distinct and different Compatibility tests.
   a) For NEW oils from storage tanks, the test does not require very much sample. The laboratory is looking for any precipitation of additive chemistry with a 50/50 mix of the competitive oil and the new ExxonMobil marine lubricant.
   b) For USED dirty oils from Engines the laboratory requires a complete FULL bottle (i.e. no air in bottle) of the used competitive oil JUST for the compatibility test. This is mixed 70/30 Used/New.
2) We recommend that **TWO** bottles are **ALWAYS** landed when requesting compatibility for **THREE** reasons.
   a) The Lab has enough sample to run BOTH Compatibility and Routine analysis, no matter what the original request was. Then, there is enough sample left to rerun or do additional testing.
   b) We would ALWAYS recommend doing routine analysis on USED Engine oil as well as Compatibility. We could get a Compatibility Test result, which says "NOT COMPATIBLE". However when you look at the physical results the reason normally for this result was because the oil not fit for service i.e. High Water, High Soot, High Oxidation, Low TBN etc. Thus, the result was not a compatibility issue but very dirty or unsuitable oil.
   c) **More is better than less.** We sometimes get requests to complete additional testing or re-testing. Our requested volume insures we always have an adequate amount of sample.

To expedite this procedure and to assist our laboratories in insuring that the correct analysis is conducted we suggest following the example listed below:

You have taken two samples for compatibility from:

MV Name: ***Ocean Anna***

Vessel Number: ***3255547***

Owner: ***ABC Shipping***

Equipment: ***Aux Engine 1***

Equipment Number: ***002***

Lubricant: ***Mobilgard M440***

Date Sampled: ***July 20, 2010***

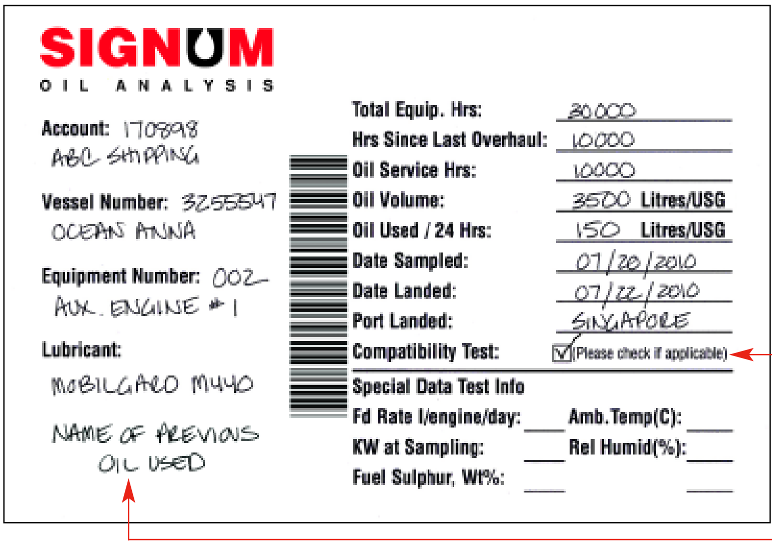
Date Landed: ***July 22, 2010***

Port Landed: ***Singapore***

Compatibility needs to be run for Mobilgard M440 and the previous oil used.

General Guidelines for the Switchover to ExxonMobil Marine Lubricants *(continued)*

The sample bottle labels should be filled out as follows:



SIGNUM
OIL ANALYSIS

Account: 170898
ABC SHIPPING

Vessel Number: 3255547
OCEAN ANNA

Equipment Number: 002-
AUX. ENGINE # 1

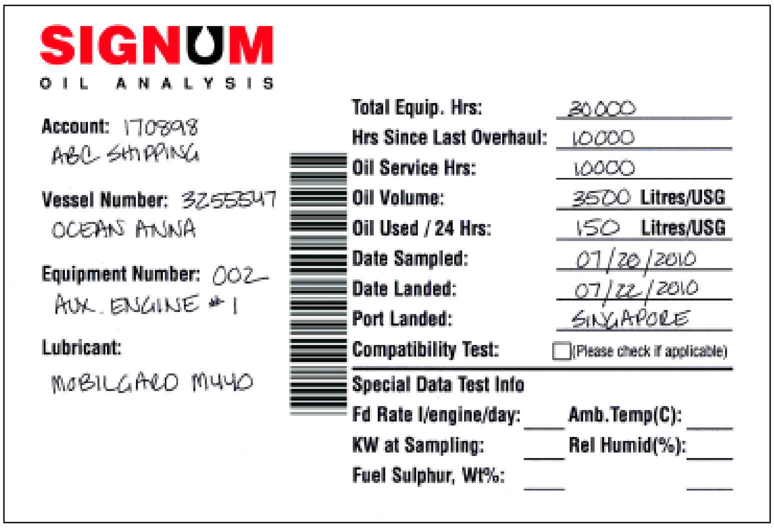
Lubricant:
MOBILGARD M440

NAME OF PREVIOUS OIL USED

Total Equip. Hrs: 30000
Hrs Since Last Overhaul: 10000
Oil Service Hrs: 10000
Oil Volume: 3500 Litres/USG
Oil Used / 24 Hrs: 150 Litres/USG
Date Sampled: 07/20/2010
Date Landed: 07/22/2010
Port Landed: SINGAPORE
Compatibility Test: ☑ (Please check if applicable)
Special Data Test Info
Fd Rate l/engine/day: ____ Amb.Temp(C): ____
KW at Sampling: ____ Rel Humid(%): ____
Fuel Sulphur, Wt%: ____

Check box if "Compatibility Test" is needed.

Under "Lubricant,"
1. List current oil in use
2. Previous oil used



SIGNUM
OIL ANALYSIS

Account: 170898
ABC SHIPPING

Vessel Number: 3255547
OCEAN ANNA

Equipment Number: 002-
AUX. ENGINE # 1

Lubricant:
MOBILGARD M440

Total Equip. Hrs: 30000
Hrs Since Last Overhaul: 10000
Oil Service Hrs: 10000
Oil Volume: 3500 Litres/USG
Oil Used / 24 Hrs: 150 Litres/USG
Date Sampled: 07/20/2010
Date Landed: 07/22/2010
Port Landed: SINGAPORE
Compatibility Test: ☐ (Please check if applicable)
Special Data Test Info
Fd Rate l/engine/day: ____ Amb.Temp(C): ____
KW at Sampling: ____ Rel Humid(%): ____
Fuel Sulphur, Wt%: ____

If possible, tape or attach both samples together so that the laboratories can process the samples more efficiently. We hope that this will further emphasise the importance of proper sampling to insure that our analysis results are meaningful and complete.

Onboard Test Kits

Onboard test kits are a valuable component of equipment monitoring programmes. Use of these kits enables you to identify potential problems early, confirm alerted conditions, avoid expensive equipment overhauls, and minimise repair costs.

Signum Oil Analysis onboard test kits offer:

- Timely results on specific test parameters
- Easy-to-use test materials and instructions
- Portable technology for on-site equipment testing
- Easy-to-read digital display

Signum Oil Analysis – Onboard Test Kit offers a range of oil analysis tests (Viscosity, Water-in-Oil, Base Number) designed to monitor a specific parameter or to confirm a suspect oil condition. The tests are suitable for most conventional and synthetic oils in marine applications.

Order Information

To order onboard test kits, contact your customer service representative.

For technical questions about Signum Oil Analysis, please contact the Marine Technical Help Desk for assistance. You will find contact details on page 24.

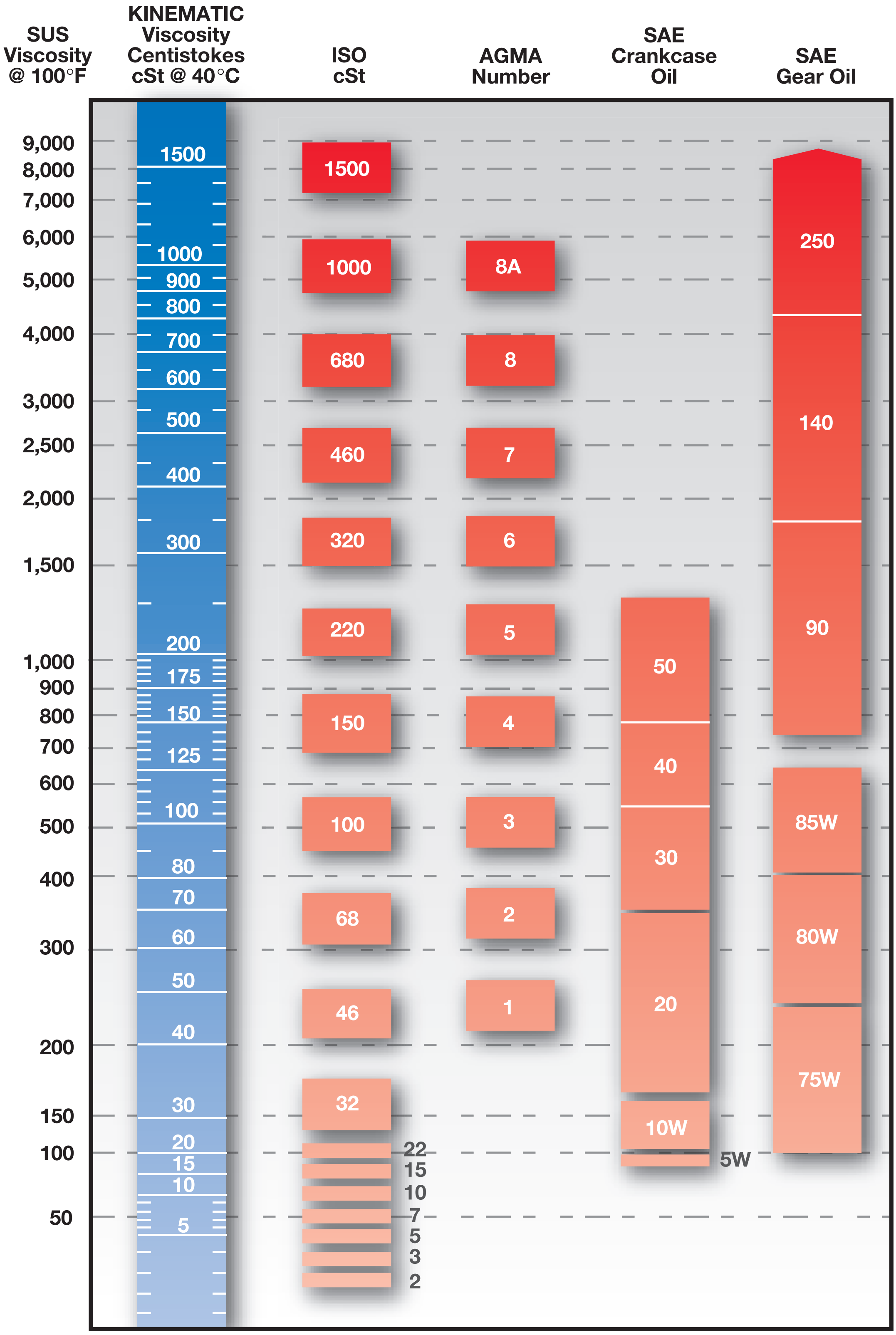
Points to Consider

On-Site Tests

On-site tests are designed to measure only a single parameter. Use them as a supplement to your oil analysis programme — not as a substitute. A comprehensive laboratory analysis is recommended as part of effective equipment monitoring.

Lubricant Viscosity Grade Comparisons

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



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