GETTING RESULTS FAST
A guide to Shell Rapid Lubricants Analysis

Shell Marine Products
Discover how to maximise the utilisation, reliability and the profitability of your vessels

This booklet contains all the information necessary to enable ship’s engineers to utilise the benefits of the Shell Rapid Lubricants Analysis (RLA) service as part of a machinery condition monitoring system.

Please read the information carefully before taking or dispatching samples. It may save time and improve the value of our service to you. We are confident that you will find the Shell RLA system a valuable and effective tool for maintaining your ship’s machinery.
INTRODUCTION TO SHELL RAPID LUBRICANTS ANALYSIS

Shell RLA is an oil condition monitoring service that helps you to keep your vessels running smoothly by identifying potential oil or equipment failures before they become critical.

It acts an early-warning system that aims to give you peace of mind knowing that your equipment and lubricants are in optimum working order.

The Shell RLA service is available to all Shell Marine Products customers worldwide.

BENEFITS AT A GLANCE

Analysing used oil is widely acknowledged as a key tool to help manage preventive and predictive maintenance. Many leading shipping companies utilise Shell RLA as an important part of their planned and predictive maintenance strategies to help deliver:

- greater equipment reliability and reduced downtime through early diagnosis of potential faults
- quick and timely results
- lower machine repair costs
- high standards of safety
- precise monitoring of operating efficiency.

Industry analysis suggests that the return on investment within the industry sector can be up to 14 times the investment spent on an oil condition monitoring service.

WHAT OUR SHELL RLA CUSTOMERS SAY

“By implementing the recommendations from Shell’s lubricant experts, we have been able to run trouble-free operations on the flash gas compressor over the past two years. The main bearings of the flash gas unit have not failed, and we are fully satisfied with the technical services and support provided by Shell Marine Products.”

Japan Vietnam Petroleum Co. Ltd
Regular oil analysis enables trends in oil condition to be determined:
- Trends will indicate if the state of lubricating oil is staying safely in equilibrium or if it is moving towards condemning limits.
- Before condemning limits are reached, recommendations will often be given for corrective action.

Regular oil analysis facilitates equipment condition monitoring; for example:
- A sudden increase in trends of wear metals may indicate component failure
- The presence of cooling water treatment additives may indicate leakage
- Poor air filtration may also be detected.

Original equipment manufacturers usually prescribe the oil sampling frequency in their equipment documentation, so following these sampling frequency guidelines is recommended.

In the absence of an original equipment manufacturer’s guide for the required oil sampling frequency, the general guidelines shown in Table 1 should be followed. These are based on actual operational hours or a time-elapsed schedule (months).

### Equipment
<table>
<thead>
<tr>
<th>Suggested sampling points</th>
<th>Sample frequency (hours or months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil pump delivery</td>
<td>1,500/three months</td>
</tr>
<tr>
<td>Oil cooler outlet</td>
<td>1,500/three months</td>
</tr>
<tr>
<td>Engine inlet line</td>
<td>500/six months</td>
</tr>
<tr>
<td>Returning line to</td>
<td>2,000/three months</td>
</tr>
<tr>
<td>hydraulic oil reservoir</td>
<td></td>
</tr>
<tr>
<td>Oil pump delivery</td>
<td>2,000/three months</td>
</tr>
<tr>
<td>Heat transfer system</td>
<td>2,000/three months</td>
</tr>
<tr>
<td>Fitted sampling device</td>
<td>2,000/six months</td>
</tr>
<tr>
<td>Sump</td>
<td>2,000/six months</td>
</tr>
<tr>
<td>Inspection door</td>
<td>2,000/six months</td>
</tr>
<tr>
<td>Return to gravity</td>
<td>2,000/three months</td>
</tr>
<tr>
<td>Compensation tank</td>
<td></td>
</tr>
</tbody>
</table>

### Table 1: Guidelines for oil sampling frequency
**SAMPLING FREQUENCY**
The following factors will affect sampling frequency:
- The fluid environment’s severity, for example, high loads, temperatures and speeds, continuous operation, duty cycle and moisture (start-stop) will influence sampling frequency.
- If a machine is new or near to overhaul, more samples should be taken.
- If the probability of failure is high, more samples should be taken.
- As the oil approaches the end of its useful life, the rate of degradation increases, which means more samples should be taken.
- To ensure safe operation of the vessel, critical equipment should be regularly sampled to reduce the risk of failure.

**ALWAYS TAKE A REPRESENTATIVE SAMPLE**
The quality of the oil sample and the information on the sample label are critical to the accuracy of the Shell RLA report.
We therefore recommend:
- Always taking samples from the same point. Adhesive labels for sample point identification are available from your Shell Marine Products representative.
- Ensuring that the total quantity of oil in circulation is approximately the same during each sampling.
- Sampling only when the oil is at its operating temperature and the machine is running.
- Purging the sample connection thoroughly until hot oil flows before taking a sample.
- Drawing samples into a clean container.
- Filling the Shell RLA sample bottle 80% full, thereby leaving an air space, and sealing the bottle tightly.
- Making sure that a second sample bottle is used for oil samples that need the ISO 4406 cleanliness test. Use the label from the lower half of Section 3 for this sample bottle.
- Always observing the appropriate safety guidelines.

**SAMPLING TIPS**
- Areas where lubricant flow is restricted or where contaminants and wear products tend to settle or collect should be avoided as sampling points.
- Always take the sample in the cleanest conditions to avoid contaminating the sample.
- Always use the Shell RLA sample bottles supplied by Shell and make sure that they are unopened and that the exterior is clean.
- Always clean the sampling kit immediately after use.
- After taking samples, check to make sure that the bottles are tightly closed.
- Avoid direct sampling from the engine oil sump.
- Avoid sampling from the purifier suction or discharge lines unless you intend to check purifier efficiency.
- Avoid sampling from places where the oil may be stagnant or have little or no flow such as small auxiliary pipelines, sumps, the drain ends of filters and coolers.
- Avoid sampling while the machinery is stopped.

**RECOMMENDED SAMPLING POINTS**

**Engines**
- Before the lubricating oil filters on the main supply line.

**Hydraulic systems**
- The middle of the main reservoir or system return line.

**Steam turbines**
- The main supply line before the turbine (preferably after the cooler).

**Compressors**
- Take samples just after shutdown with the compressors isolated from the system or use a designated sample valve.

**Gear cases**
- The main supply line before the turbine (preferably after the cooler).

**Stern tubes**
- The drain valve or sample cock. Make sure that all free water or sediment/debris is flushed out before taking the sample.

**Splash-lubricated systems**
- The mid-point of the reservoir.
- Splash-lubricated systems, and splingering and flood-lubricated components are best sampled from drain plugs but only after considerable flushing.
- Similarly, permanent valves should be wiped clean and then flushed before sampling to ensure that any debris is excluded from the sample.

**SAMPLING FROM CIRCULATION SYSTEMS**
- For circulating systems, one of the best sampling locations is a live zone before the filters where contaminants and wear debris are most concentrated. This usually means sampling from fluid return or drain lines.
- For systems where the oil drains back to a sump without being directed through a line (such as in engines), draw from the pressure line downstream of the pump (before the filter).
- Permanent sampling points should be at elbows in pipe runs in preference to straight sections. This will help to ensure that the flow regime at the sample point is turbulent and that wear and contaminant particles do not drop out of suspension.

<table>
<thead>
<tr>
<th>Wear particle concentration (µm)</th>
<th>Wear particle size (µm)</th>
<th>Viscosity at 40°C (mm²/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>115</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>140</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>175</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>205</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>236</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>266</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>280</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>315</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>346</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>376</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>400</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>430</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>460</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>490</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>520</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>550</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>625</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>700</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>775</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>850</td>
</tr>
</tbody>
</table>

**Viscosity at 100°C (mm²/s)**

- 100
- 220
- 320
- 460
- 680
- 1,000

**Wear particle size (µm)**

- 70 W
- 75 W
- 80 W
- 85 W

**Kinematic viscosity table**

- 10
- 20
- 30
- 40
- 50
- 60
- 60
- 85
- 85
SAMPLE LABELS

All machinery must be pre-registered to avoid delaying sample analysis. Shell RLA vessel and machinery codes can only be issued by Shell.

Complete the sample label in full with all the relevant information, as detailed in the section “Sample label identification”. Ensure that the machine details are exactly as written in the lubrication survey or the Shell RLA machinery list.

1. Check that an air space has been left above the sample and that the seal is tight.
2. Detach the sample label from top of Section 3 and attach to the sample bottle.
3. A second sample bottle is required for oil samples that need lubrication survey or the Shell RLA machinery list.
4. Only use the lower label in Section 3 for sample requiring ISO 4406 cleanliness testing (particle counting).
5. Put Section 2 of the label and the sample bottle into the envelope.
6. Using the map from the step-by-step guide, select the relevant equipment details are exactly as written in the “Sample label identification”. Ensure that the relevant information, as detailed in the section complete the sample label in full with all the information.
7. Check Plus test suites are suitable for most equipment with a medium impact of failure.
8. All courier charges must be paid by the vessel’s staff or agent on dispatch, as Shell will not accept charges for sample transportation to Shell RLA laboratories.

COMPLETING THE LABEL

Sample label identification

To reduce delays in processing used oil samples, Shell Marine Products has created a label that aims to reduce the information required to the bare minimum while enabling customers to build up a meaningful database of used oil analysis results for their machinery.

Missing vessels names, Shell RLA vessel and machine codes will cause delays in analysis.

Filling in the label

- To complete the sample labels, follow the directions shown on the sample label (Figure 1).
- For routine samples, use the top label of Section 3.
- Only use the lower label in Section 3 for samples requiring cleanliness testing (particle counting) according to ISO 4406.
- Sections 2 and 3 are vital to ensuring the correct identification of your sample.

Note that incorrectly completed labels will lead to samples being registered in the laboratories as “unidentified”. An unidentified sample cannot be analysed.

TEST SUITES

SIMPLIFIED TEST SUITES

Shell RLA offers the test suites shown in Table 2.

This arrangement provides good flexibility and enables you to select best test suites for your machinery:

- Check test suites are suitable for most equipment with a medium impact of failure.
- Check Plus test suites offer advanced diagnosis at equipment level and an enhanced test sequence suitable for equipment that is critical to the safe operation of a vessel.

Table 2: Shell RLA test suites

<table>
<thead>
<tr>
<th>Test Suite</th>
<th>Viscosity at 40°C</th>
<th>Viscosity at 100°C</th>
<th>TBN</th>
<th>TAN</th>
<th>Clean ISO 4406</th>
<th>Water (Total)</th>
<th>Water (ppm)</th>
<th>Flash point (°C)</th>
<th>ICP</th>
<th>Dispersancy (Ic/DP/MD)</th>
<th>WPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Check</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Shaft Check³</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>System Check</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Frigde Check⁴</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Gas Engine Check⁵</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Turbine Check</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>EMD Engine Check</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Cylinder Check</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hydraulic Check</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Gear Check</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Thruster Check</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Thermal Check</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Grease Check</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Engine Check Plus</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>System Check Plus</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hydraulic Check Plus³</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Gear Check Plus</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Thruster Check Plus</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>NR Stern Tube Check Plus⁶</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Note: Cleanliness Particle Count (ISO 4406) requires 2 RLA sample bottles to be sent.*

1. Zinc and phosphorus in ppm
2. Oxidation using infrared spectroscopy
3. Calcium in ppm
4. Zinc in ppm
5. Lubrication survey or the Shell RLA machinery list
6. Includes oxidation and nitration by infrared spectroscopy

Figure 1: Filling in the sample label

Note: MSDS Information: http://www.epc.shell.com/
Website: http://www.shell.com/marine
EXPLAINING THE SHELL RLA TESTS

VISCOSITY

The viscosity of a fluid is a measure of its resistance to flow and is directly affected by its temperature. Oil viscosity decreases with an increase in temperature and increases with a drop in temperature. Kinematic viscosity is expressed in millimeters squared per second (mm²/s) and is measured at 100°C for diesel engine oils and 40°C for other applications.

The viscosity of lubricating oil may change in service as a result of deterioration, contamination or both. Insolubles, oxidation and mixing with a higher viscosity grade oil will increase oil viscosity. Fuel or water contamination may either increase or decrease oil viscosity.

A decrease in oil viscosity is of greater significance than an increase because full film lubrication may not be achieved if the viscosity is too low. For engine oil, the limiting value is generally not so critical and viscosity may be allowed to increase by as much as 50% above the fresh oil’s value in certain applications. It should be noted that if systems run with high-viscosity oils, there might be an increase in system pressure that could result in component failure, for example, of the seals. Increased temperatures may also be noted.

FLASH POINT IN ENGINE OILS

The flash point is the temperature at which a vapour above a liquid will ignite when a flame is applied under standard conditions. The standard method used in Shell RLA is the closed cup method. The flash point is reported in degrees Celsius.

A drop in the closed flash point indicates that the oil is contaminated by fuel. This may be accompanied by a corresponding drop in viscosity, though with heavy fuel no significant change may be apparent.

As a general guide, it is advisable to check for fuel leaks when the lubricant’s flash point drops to less than 190°C. If the sample contains water, it may not be possible to obtain a flash point figure.

The likelihood of a low flash point and therefore the risk of ignition are greatest in used engine oils, particularly for those engines operating on distillate fuels.

TOTAL BASE NUMBER (TBN) – ENGINE OILS

The TBN, which is expressed in milligrams of potassium hydroxide per gram of oil (mg KOH/g), is the alkaline reserve formulated into an oil to neutralise the acidic products of combustion derived from the sulphur in the fuel.

With Shell Rapid Lubricants Analysis, the TBN determined by the perchloric acid method provides a measure of the effective additive content and the oil’s ability to neutralise acids.

In service, the TBN of lubricating oil will fall from its original value to an equilibrium value, where it normally remains unless conditions change. The factors that influence the equilibrium level are mainly changes in the fuel sulphur content: a high-sulphur fuel will cause a drop in TBN.

If the rate of TBN depletion is too great and the oil charge requires changing, consideration should be given to replacing the charge with a lubricating oil of a higher initial TBN or using a higher TBN oil for top-up.

A decrease in lubricating oil consumption will cause a fall in the equilibrium TBN, whereas a rise in lubricating oil consumption results in a rise in the equilibrium TBN. Different original equipment manufacturers specify minimum levels of TBN for their equipment, but as a general guide, the TBN should not be allowed to fall below 50% of that of new oil.

The system oil in cross-head engines may suffer from an increase in TBN. This can be attributed to cylinder oil draining finding into the system.

WATER CONTENT

Water contamination is initially determined by a hot plate crackle test. If this gives positive results, the oil is analysed to quantify the water content. Traces of water in lubricating oil are inevitable; for example, there may be salt water from leaking oil coolers or fresh water from separate water seal malfunctions, coolers, cylinder cooling jackets or atmospheric condensation. Water affects the viscosity of oil and may form an emulsion with the oil. Water in oil may cause lubrication failures and corrosion problems. In reciprocating machinery, it will cause bearing fatigue that may result in bearing damage or failure.

It is therefore desirable to minimise the water content in lubricant by setting and draining or centrifuging. In general, if the levels in Table 3 are exceeded, action should be considered to identify and stem the ingress of water and to reduce the overall water content. It should be noted that stem tubes may tolerate up to 5% water for short periods when normal mineral-based lubricants are used and up to 20% when emulsifying lubricants are used. IACS and class limits are used in Shell stern tube analysis.

WATER屏幕 crackle test

<table>
<thead>
<tr>
<th>Location of oil</th>
<th>Water content limit (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>System oil</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Hydraulic oil systems</td>
<td>&lt;0.2</td>
</tr>
<tr>
<td>Stern tube oil systems</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Crankcase in trunk-piston engines</td>
<td>&lt;0.2</td>
</tr>
<tr>
<td>Steam turbine and gearing systems</td>
<td>&lt;0.1</td>
</tr>
</tbody>
</table>

Table 3: Limits for water in lubricant
TOTAL ACID NUMBER (TAN) – USUALLY NON-ENGINE OILS

The TAN is a measure of the total acids present in the lubricating oil. In non-engine oil, these are normally derived from oxidation of the oil (weak acids). In diesel engine oil, however, acidic products of fuel combustion (strong acids) may also be present.

The rate at which the TAN changes is more important than the absolute value and can indicate whether the system oil is liable to deteriorate rapidly and consequently form sludge and lacquer. Where a straight mineral oil or a non-oxidation-inhibited oil is used, the TAN should not be allowed to exceed 3.0 mg KOH/g. The usual acids formed by the oxidation of oil do not attack ferrous metals or white metal but can cause corrosion of copper or lead bearings.

WEAR PARTICLE INDEX (WPI)

The WPI is determined using a test that measures the amount of paramagnetic material in a sample. The most common paramagnetic material found in oil samples from marine machinery is iron; therefore, the WPI correlates very closely to the total iron content in a sample. The WPI test can be beneficial, as one of the weaknesses of ICP spectroscopy is that its sensitivity to iron is low. The WPI test can detect iron particles in used oil and may result in the formulation of sludge, which can lead to excessive component wear.

ADDITIONS TO OILS

Additives called dispersants are used in engine oil to hold carbon particles in suspension. They do this by enveloping the carbon particles and preventing them from joining together to form sludge.

元素的分析使用ICP光谱可以检测到14种不同的元素，从颗粒测量小于0.1微米的颗粒到24种不同的元素，从颗粒测量直径为5微米的颗粒。TAN旨在从润滑剂中检测可检测到的颗粒，其浓度范围从重量百分比到体积百分比。由于颗粒的表面为14种不同的元素，因此颗粒悬浮。它们通过包覆碳粒子来实现这一点。适用粒径小于5微米的颗粒可以被ICP检测到。}

INDUCTIVELY-COUPLED PLASMA (ICP) SPECTROSCOPY

Elemental analysis using ICP spectroscopy can detect up to 24 different elements, from particles measuring less than 5 µm in diameter, which are present in used oil through wear, contamination, or additives. Wear metals include iron, chromium, nickel, aluminum, copper, lead, and tin. Contaminant elements include silicon, sodium, and potassium. Multi-source metals include molybdenum, antimony, manganese and lithium. Additive elements include barium, magnesium, calcium, barium, phosphorous and zinc. Such elemental analysis is instrumental in determining the type and severity of the wear occurring within a unit.

DISPERSANCY

Admixtures called dispersants are used in engine oil to hold carbon particles in suspension. They do this by enveloping the carbon particles and preventing them from joining together to form sludge. The rate of depletion of these additives is related to time and the rate of carbon generation by the engine, i.e., engine health, degree of blowby, fuel injection rates, etc.

To understand the impact of fuel quality and the operating condition of engines, Shell has developed unique technology to identify the level of contamination in oil and the oil dispersancy. This helps the engine users to take immediate corrective action if an abnormality is observed.

The index of contamination (IC) is the concentration of insoluble soot loading in a diesel engine oil charge and is expressed as weight percent. Such contaminants cause a rise in the viscosity of system oil and may result in the formation of sludge, which can lead to excessive component wear.

The merit of dispersancy (MD) indicates the ability of the lubricant in a diesel engine to carry combustion contaminants in suspension. It is expressed as a number from zero to 100. Providing an adequate dispersancy level is maintained, the amount of insoluble soot that can be tolerated increases and the diagnostician can make informed recommendations to the vessel’s engineer about the treatment of the remaining oil charge. The lubricant’s inability to maintain the contaminants in suspension may lead to deposits accumulating in the bottom of the crankcase and cause problems with filtration and/or purification equipment.

EXAMPLE

MD = 0 = poor dispersion: the insolubles are all concentrated in the centre of the oil spot in the test; the residues are flocculated. MD = 100 = excellent dispersion: the distribution of the insolubles on the filter paper is homogeneous.

The merit points (DP) figure reflects the overall condition of the oil, as it is a combination of the IC and the MD derived from the calculation DP = (100 – MD) × IC. A low DP (0 or close to 0) indicates slight contamination and excellent dispersancy. A high DP (approaching 100 or more) indicates heavy contamination and/or a poor dispersancy.

To understand the impact of fuel quality and the operating condition of engines, Shell has developed unique technology to identify the level of contamination in oil and the oil dispersancy. This helps the engine users to take immediate corrective action if an abnormality is observed.

The index of contamination (IC) is the concentration of insoluble soot loading in a diesel engine oil charge and is expressed as weight percent. Such contaminants cause a rise in the viscosity of system oil and may result in the formation of sludge, which can lead to excessive component wear.

The merit of dispersancy (MD) indicates the ability of the lubricant in a diesel engine to carry combustion contaminants in suspension. It is expressed as a number from zero to 100. Providing an adequate dispersancy level is maintained, the amount of insoluble soot that can be tolerated increases and the diagnostician can make informed recommendations to the vessel’s engineer about the treatment of the remaining oil charge. The lubricant’s inability to maintain the contaminants in suspension may lead to deposits accumulating in the bottom of the crankcase and cause problems with filtration and/or purification equipment.

EXAMPLE

MD = 0 = poor dispersion: the insolubles are all concentrated in the centre of the oil spot in the test; the residues are flocculated. MD = 100 = excellent dispersion: the distribution of the insolubles on the filter paper is homogeneous.

The merit points (DP) figure reflects the overall condition of the oil, as it is a combination of the IC and the MD derived from the calculation DP = (100 – MD) × IC. A low DP (0 or close to 0) indicates slight contamination and excellent dispersancy. A high DP (approaching 100 or more) indicates heavy contamination and/or a poor dispersancy.
Table 4: The origin of metals in engine oils

<table>
<thead>
<tr>
<th>Metal</th>
<th>Potential source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron (Fe)</td>
<td>Cylinder walls and liners; crank and camshafts; valve guides; rockers; rings; bearings; gears; shafts</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>Generally used as an alloy (Babbitt, copper-lead) in bearings; big-end and crankshaft bearings; and thrust washers</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>Usually alloyed in the form of brass, bronze or as sintered copper-lead; big-end and crankshaft bearings; bushings; oil coolers and cooler core tubes; thrust washers; fuel transfer pumps; and governor and wrist pin bushings. Copper-type anti-seize compounds</td>
</tr>
<tr>
<td>Chromium (Cr)</td>
<td>Commonly used as plating metal. Chrome-plated piston rings and valve stems. Chromatetreated cooling systems</td>
</tr>
<tr>
<td>Silicon (Si)</td>
<td>Dirt. Highly abrasive. Sources include inadequately filtered air due to cracked induction piping or hoses, or defective or incorrectly fitted air filters and gaskets. Dirty oil filling or sampling equipment. Incorrectly fitted or missing oil filler caps. Ineffective reservoir breathers. Also silicon-based gasket/joining compound and anti-foaming additive in some engine oils</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>Coolant leakage, water or using the same container for coolant as for oil</td>
</tr>
<tr>
<td>Aluminium (Al)</td>
<td>Pistons (scuffing, scoring or burning); aluminium bearings; alloy housing wear; and housing or rotor wear in turbochargers. May also be associated with high silicon levels in the form of clay or stone dust contamination</td>
</tr>
<tr>
<td>Tin (Sn)</td>
<td>Bearings; bushings; and thrust washers</td>
</tr>
</tbody>
</table>

Note: Fatigue wear, air inclusions and wear debris can affect results.

Table 4: The origin of metals in engine oils

Metal Analysis by ICP Spectroscopy

Guidelines for wear metals

Normal wear metal levels may vary significantly between different types of equipment and different applications. The true value of oil analysis is in establishing a wear trend for each piece of machinery, its operating cycle and its operating environment. Remember, the absolute value of wear metals will vary with the oil-drain interval and oil top-up rate.

Spectroscopy

Spectrographic analysis is used to determine the elements in the oil. The presence of certain elements can uniquely identify additives and contaminants in the oil. It is, therefore, possible to deduce the identity of the oil, the type of any contamination and the condition of the machinery.

The elements measured using spectroscopy are described below.

Additives

The concentration of calcium, barium, phosphorus and zinc can serve as confirmation of the lubricant grade in use or as an indication of the addition of or contamination by other oil grades.

Phosphorus and zinc are normally associated with extreme-pressure or anti-wear additives. These additives rarely deplete before the oil becomes unfit for further use and, therefore, significant variations in their levels normally indicate that a different oil grade has been added.

Calcium and magnesium are normally associated with BN additives. These additives provide alkalinity, detergency and resistance to oxidation. Magnesium may also be present owing to water ingress. If this contamination is seawater, the ratio of magnesium to sodium will be approximately 1:3.

Barium is not used in Shell marine lubricants. It is, however, used in some diesel engine oils manufactured in Eastern Europe.

Wear metals

Iron, chromium, molybdenum and aluminium are found in the metal alloys used to manufacture components for the upper part of the engine. Lead, tin and copper are metals used in bearing materials in the lower part of the engine. See also Table 4.

Contaminants

Sodium, vanadium, aluminium and silicon are contaminants that may be related to fuel oil. The presence of silicon may also indicate contamination by airborne particles or dust due to a breakdown in air filtration systems. Sodium in conjunction with magnesium can be used to determine whether water contamination is seawater, cooling water or fresh water.

Boron is found in some types of inhibitor used in water cooling systems. Boron in a Shell lubricant may point to a coolant leak. However, certain Shell oils for high-speed diesel engines contain boron as part of the performance enhancement package.

The presence of certain elements can uniquely identify additives and contaminants in the oil. These additives provide alkalinity, detergency and resistance to oxidation. Magnesium may also be present owing to water ingress. If this contamination is seawater, the ratio of magnesium to sodium will be approximately 1:3.

Barium is not used in Shell marine lubricants. It is, however, used in some diesel engine oils manufactured in Eastern Europe.

Wear metals

Iron, chromium, molybdenum and aluminium are found in the metal alloys used to manufacture components for the upper part of the engine. Lead, tin and copper are metals used in bearing materials in the lower part of the engine. See also Table 4.

Contaminants

Sodium, vanadium, aluminium and silicon are contaminants that may be related to fuel oil. The presence of silicon may also indicate contamination by airborne particles or dust due to a breakdown in air filtration systems. Sodium in conjunction with magnesium can be used to determine whether water contamination is seawater, cooling water or fresh water.

Boron is found in some types of inhibitor used in water cooling systems. Boron in a Shell lubricant may point to a coolant leak. However, certain Shell oils for high-speed diesel engines contain boron as part of the performance enhancement package.

The possibility of extending the period between classification surveys is enhanced by regular oil analysis using Shell RLA. A satisfactory series of Shell RLA reports can help to satisfy the surveyor that all is well and that visual inspection can be deferred for a specified time. The time and cost savings will be readily apparent to the operator.

Shell’s team of marine diagnosticians draws on years of experience and knowledge in the interpretation of analysis results. The regular submission of samples enables historical data trends to be established. Close scrutiny of trend data identifies changes in the underlying condition of the lubricant. This enables the diagnostician to determine whether the trend is normal or otherwise.

Variations in the underlying trends of a lubricant’s measured properties give vital clues to its condition and of the equipment it lubricates. Trend analysis can be vital in preventing failure by means of early warning of detrimental machinery condition.

The use of used oil analysis to determine the condition of both the oil and machinery is not a new concept. The Shell RLA service began in 1980 and the principal tests remain the same today. The introduction of modern computerised analysis equipment and data handling systems has made regular routine sampling more economically viable, and the trend of results forms a good basis for ISM and IACS and classification society condition monitoring programmes.

Lubricants are integral parts of all engines and most machinery. The very specialised nature of these machines and the harsh conditions under which they frequently operate put considerable demands on a lubricant.

As the lubricant is in contact with most of the highly stressed areas of a machine, it can provide information that, when correctly interpreted, can assist in the identification of deteriorating components and reduce the risk of untimely breakdown.
DIAGNOSIS AND REPORTING

DIAGNOSIS
Shell Marine Products use a multidisciplinary team of specialist diagnosticians with expertise in marine engineering and lubricants to interpret the analysis results reported by the Shell RLA laboratories. However, remember that the advice given by the Shell Marine Products diagnosticians is reliant on two-way communication between Shell Marine Products and the customer, site or vessel.

Shell Marine Products uses advanced algorithms with a database containing over 30 years of data to identify samples requiring human intervention. These data, along with the information on maintenance, etc., provided by the customer, enable Shell Marine Products to make an informed assessment on the health of a particular machine/lubricant combination.

Products to make an informed assessment on the health of a particular machine/lubricant combination.

Shell Marine Products uses advanced algorithms with a database containing over 30 years of data to identify samples requiring human intervention. These data, along with the information on maintenance, etc., provided by the customer, enable Shell Marine Products to make an informed assessment on the health of a particular machine/lubricant combination.

Shell Marine Products use a multidisciplinary team of specialist diagnosticians with expertise in marine engineering and lubricants to interpret the analysis results reported by the Shell RLA laboratories. However, remember that the advice given by the Shell Marine Products diagnosticians is reliant on two-way communication between Shell Marine Products and the customer, site or vessel.

PRODUCTS

Reports

Shell RLA reports indicate the condition of oil or equipment of a particular sample through traffic light signals.

Normal – no action

Attention – monitor and take action

Action – needs immediate action

THE SHELL RLA REPORT

Shell RLA reports include:
- customer and equipment details
- equipment and oil running hours
- physicochemical parameters
- contaminants
- wear metal analysis
- additive levels
- trends of the past five reports
- graphical trends
- comments from the marine expert on all the reports that need action.

Shear RLA reports for all “normal” samples will be available within hours of sample receipt at the laboratory. Samples requiring retests are excluded.

TYPICAL FAILURES AND CAUSES

ENGINES

<table>
<thead>
<tr>
<th>Failure</th>
<th>Symptoms</th>
<th>Potential cause</th>
<th>Effect</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degraded lubricant</td>
<td>High level of soot and NOx in gas engines; additive depletion</td>
<td>Overheating; low oil consumption; increased contamination (cooling system problem; mechanical problem)</td>
<td>Increased wear; potential failure</td>
<td>Check cooling system, change oil</td>
</tr>
<tr>
<td>Contamination by abrasive particles</td>
<td>High silicon; high particle count; high wear metals</td>
<td>Problem with air filter; poor storage and handling of lubricant</td>
<td>Increased wear (tool bearings; piston/cylinder); potential failure</td>
<td>Change of filter</td>
</tr>
<tr>
<td>Excessive wear</td>
<td>High wear metals [Al, Cu, Fe, Cr, Pb, Sn]</td>
<td>Effect of another failure type (water ingress, pollution, fuel dilution, overheating)</td>
<td>Shorter engine life</td>
<td>Check whole system</td>
</tr>
<tr>
<td>Excessive oil contamination</td>
<td>High oil content (IC/MD/FD fuel)</td>
<td>Problem with fuel system; incomplete combustion; exhaust gas recirculation</td>
<td>Increased wear; potential failure</td>
<td>Check fuel system; check purifier operation</td>
</tr>
<tr>
<td>Water ingress</td>
<td>High water content; low flash point; fuel present</td>
<td>Head gasket leak; oil cooler leak</td>
<td>Water displacing lubricant; increased wear; potential failure</td>
<td>Repair leak; check purifier operation</td>
</tr>
<tr>
<td>Fuel dilution (distillates)</td>
<td>Low viscosity; low flash point; fuel present</td>
<td>Problems with fuel system (incomplete combustion)</td>
<td>Increased wear; potential failure</td>
<td>Repair fuel system</td>
</tr>
<tr>
<td>Fuel dilution (residues)</td>
<td>High viscosity; vanadium and nickel present</td>
<td>Problems with fuel system (incomplete combustion)</td>
<td>Increased wear; potential failure</td>
<td>Repair fuel system; change oil; check purifier operation</td>
</tr>
</tbody>
</table>

GEARS

<table>
<thead>
<tr>
<th>Failure</th>
<th>Symptoms</th>
<th>Potential cause</th>
<th>Effect</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contamination by abrasive particles</td>
<td>High silicon; high particle count; high wear metals</td>
<td>Clogged or damaged air breather; wrong lubricant for application and/or overheating</td>
<td>Increased wear; potential failure</td>
<td>Replace air breather or filter; change oil</td>
</tr>
<tr>
<td>Excessive wear</td>
<td>High wear metal debris</td>
<td>Effect of another failure type (water ingress, pollution, wrong product and/or overheating)</td>
<td>Increased wear; potential failure</td>
<td>Check whole system; change oil</td>
</tr>
<tr>
<td>Degraded lubricant</td>
<td>Increased viscosity; increased TAN</td>
<td>Overheating; oil thermally degraded and at the end of its useful life</td>
<td>Increased wear; potential failure</td>
<td>Change oil</td>
</tr>
<tr>
<td>Wrong lubricant</td>
<td>Product out of viscosity grade and/or additive metals not typical</td>
<td>Wring lubricant for application or product mixed with another product and/or grade</td>
<td>Increased wear; potential failure</td>
<td>Check lubricant used; change oil</td>
</tr>
</tbody>
</table>

HYDRAULICS

<table>
<thead>
<tr>
<th>Failure</th>
<th>Symptoms</th>
<th>Potential cause</th>
<th>Effect</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contamination by abrasive particles</td>
<td>High silicon; high particle count; high wear metals</td>
<td>Clogged or damaged air breather; wrong lubricant for application and/or overheating</td>
<td>Increased wear; potential failure</td>
<td>Replace air breather or filter; change oil</td>
</tr>
<tr>
<td>Degraded lubricant</td>
<td>Increased TAN; increased viscosity</td>
<td>Overheating; oil thermally degraded and at the end of its useful life; problem with oil cooler</td>
<td>Increased wear (due to increased viscosity)</td>
<td>Check system for overheating; check oil cooler; change oil</td>
</tr>
<tr>
<td>Wrong lubricant</td>
<td>Product out of viscosity grade and/or additive metals not typical</td>
<td>Wring lubricant for application or product mixed with another product and/or grade</td>
<td>Increased wear (due to inappropriate viscosity grade)</td>
<td>Check lubricant used; change oil</td>
</tr>
<tr>
<td>Excessive wear</td>
<td>High wear metals [Al, Cu, Fe, Cr, Pb, Sn]</td>
<td>Effect of another failure type (water ingress, pollution, wrong product and/or overheating)</td>
<td>Shorter equipment life</td>
<td>Check whole system; change oil</td>
</tr>
</tbody>
</table>
SHELL LABORATORIES

Shell Laboratories are available in six key locations to ensure customers worldwide can benefit from Shell RLA and get the fastest analysis of their oil and equipment condition. The Shell Marine laboratory in China will open on 1 November 2012.

CONTACT US

Americas: (USA)
Shell Marine Laboratory
Rapid Lubricants Analysis
7898 Zionsville Road
PO Box 68983
Indianapolis IN 46268-2177
United States of America
Phone: 00 1 317 808 3750

Europe: (EU)
Shell Marine Laboratory
Rapid Lubricants Analysis
Inward Way, Rossmore Business Park
Ellesmere Port
Cheshire CH65 3EN
United Kingdom
Phone: 00 44 151 350 6727

India: (IN)
Shell Marine Laboratory
Rapid Lubricants Analysis
A-77, Road No. 16
Wagle Industrial Estate
India
Phone: 00 91 22 61517838

Singapore: (SG)
Shell Marine Laboratory
Rapid Lubricants Analysis
3, Toh Tuck Link
Singapore 596228
Phone: 00 65 637 90266

China: (CN)
Shell Marine Laboratory
Rapid Lubricants Analysis
No. 88 Pugong Road
Shanghai Chemical Industrial Park
Shanghai 210507
China
Phone: 00 86 216712 0411

Australia: (AU)
Shell Marine Laboratory
Rapid Lubricants Analysis
10 Reid Road
Perth International Airport
Newburn WA 6105
Australia
Phone: 00 61 893 733 609

FIND OUT MORE

Please contact your local Shell Marine Products representative to take advantage of our first-class lubricants service or visit www.Shell.com/marine/technical

For product technical data sheets (TDS) or material safety data sheets (MSDS), please visit www.epc.shell.com

© Shell International Petroleum Company Limited 2012. All rights reserved.
This publication is intended to provide a summary/comment/review of aspects of the subject matter covered. It does not purport to be comprehensive or legal or other professional advice.

This publication contains a number of logos and trademarks or service marks (potential or otherwise). All trademarks are the property of their respective owners. Reproduction of the content of this publication is strictly prohibited without prior written consent from Shell International Petroleum Company Limited.