TG003. LUBRICANT SAMPLING, TESTING & ANALYSIS

"Conducting regular and proper sampling is an essential part of an effective oil analysis programme that can lead to accurate diagnoses and corrective actions to mitigate abnormal conditions".

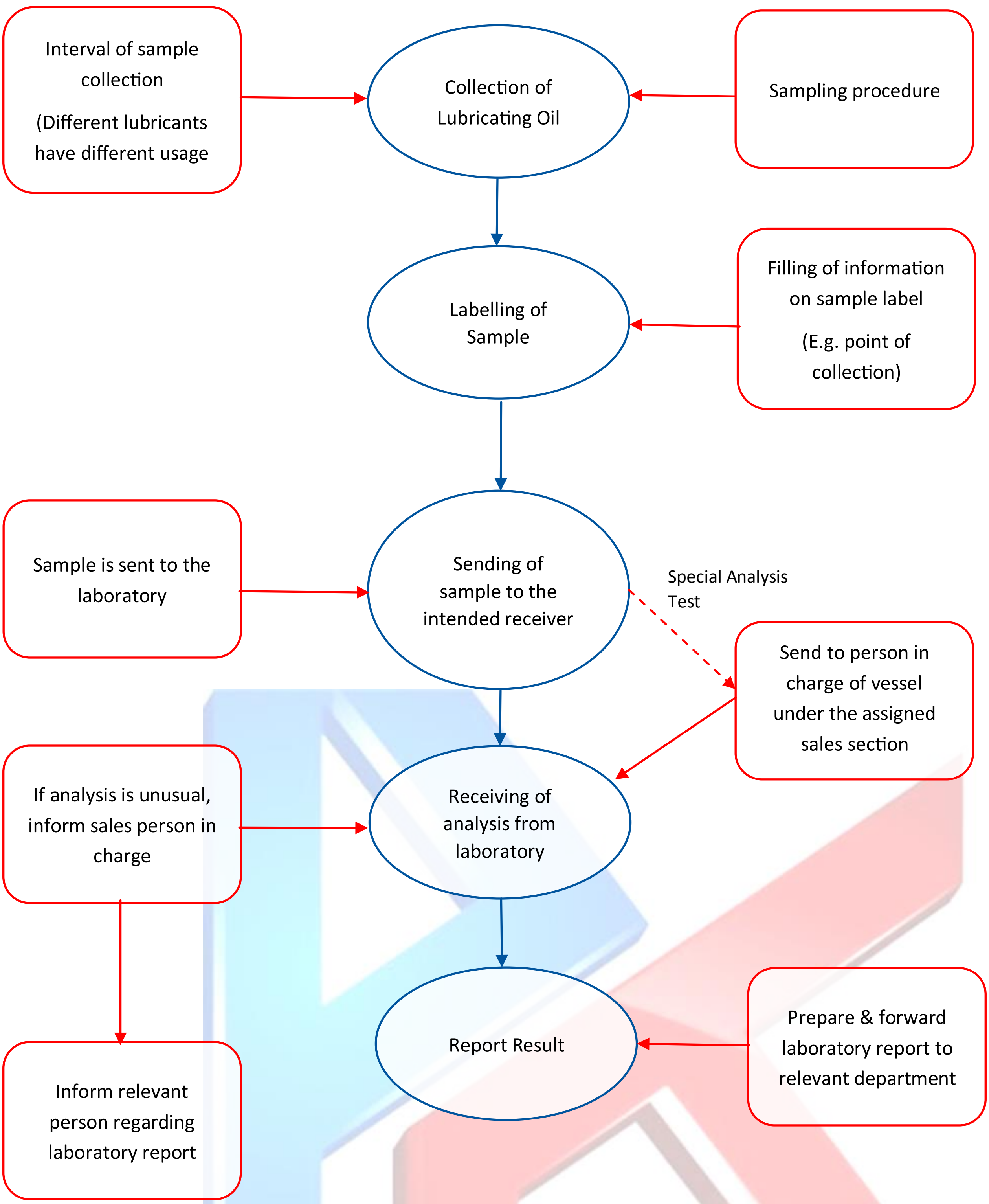
What Oil Analysis Can Tell You?

	Root Cause Detection	Initial Fault Detection	Problem Diagnosis	Failure Prediction	Post Review
What Oil Analysis can tell the User	When something is occurring that can lead to failure	When an early-stage fault exists that may be unnoticed. For e.g. abnormal wear	• What is the nature? • Where is it ? • How severe? • Can it be rectify?	When a machine is worn out and needs to be repaired or replaced	• What is the cause of failure? • Could it be avoided?
What the User Monitor	Particles, moisture, viscosity, temperature additives, oxidation, TAN/TBN, soot, glycol, FTIR, RPVOT	Wear debris density, temperature, particle count, moisture, elemental analysis, viscosity, analytical ferrography	Wear debris, elemental analysis, moisture, particle count, temperature, viscosity, analytical ferrography, vibration analysis	Elemental analysis, analytical ferrography, vibration analysis, temperature	Analytical ferrography, ferrous density, elemental analysis
Maintenance Mode	Proactive	Predictive	Predictive	Run-to Failure	Run-to Failure

Three Categories of Oil Analysis

Categories / Tests	1. Fluid Properties Physical and Chemical properties of used oil	2. Contamination Lubricants and Equipment contaminants	3. Wear Content Presence and identification of wear particles
Particle	Not Significant	Very Significant	Significant
Viscosity analysis	Very Significant	Significant	Not Significant
Moisture analysis	Not Significant	Very Significant	Not Significant
Wear debris density	Not Significant	Not Significant	Very Significant
TBN	Very Significant	Significant	Significant
Analytical ferrography	Not Significant	Significant	Very Significant
Flash point	Significant	Very Significant	Not Significant
Fourier Transform Infrared (FTIR)	Very Significant	Significant	Not Significant
Patch test	Not Significant	Very Significant	Significant
Elemental analysis	Very Significant	Significant	Very Significant

Oil Sampling Flow Diagram



Standard Sampling Sequences

<table>
<tr><th></th><th>(1) Main Diesel Engine</th><th>(2) Generating Diesel Engine</th><th>(3) Hydraulic Equipment</th><th>(4) Others</th></tr>
<tr><td>1st Sampling</td><td>When tank is filled with new oil (Use the same oil after flashing)</td><td>When tank is filled with new oil (Use the same oil after flashing)</td><td>When tank is filled with new oil (Use the same oil after flashing)</td><td>When tank is filled with new oil</td></tr>
<tr><td>2nd Sampling</td><td>After official sea trial</td><td>After official sea trial</td><td></td><td>Appropriate</td></tr>
<tr><td>3rd Sampling</td><td>After maiden voyage</td><td>Some samples should be taken after approximately every 500 hours of operation to determine appropriate time to change oil</td><td rowspan="3">Samples should be taken approximately every 6 months or so. However it is convenient to take samples when ship is docked for intermediate or regular inspections</td><td rowspan="3">Sampling times and intervals for lubricants in other equipment should be determined or followed according to the equipment manual or advice from the technical service engineer</td></tr>
<tr><td>4th Sampling</td><td>After approximately 1,500 hours of engine operation</td><td>After determining the oil change period, samples should be taken at intervals of given operation time</td></tr>
<tr><td>5th Sampling</td><td>After every 1,500 ~ 2,000 hours of engine operation</td><td></td></tr>
</table>

Sampling Procedure

When collecting the samples

- Ensure that the typical used oil is collected
- Ensure the following precautions and methods are follow:

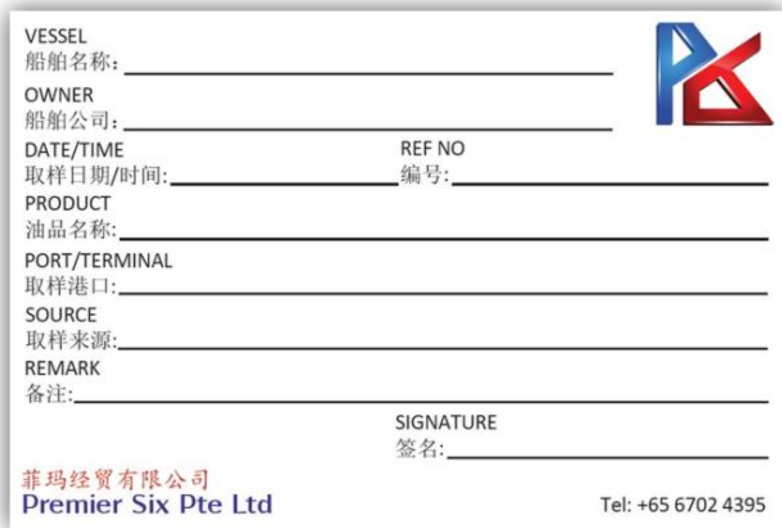
1) Sample container used must be suitable for the oil.
2) Sample containers must not have any foreign matters such as water, dust or other types of oil. Inner walls of used container should be thoroughly washed and dried before performing the sampling procedure.
3) To collect the sample, ensure that foreign matters adhering to cocks and valves at sampling places are removed and oil remaining in piping must be completely flushed away.
4) It is best to obtain samples during the operation when the lubricant is at the regular operating temperature if it is to represent all the lubricants. However, if samples cannot be taken during the operation, the samples should be obtained immediately after operation has ceased.
5) Samples for lubricant control should be taken from a given location at all times and a minimum of half a litre is required. Samples for trouble shooting purposes should be taken at appropriate locations.
6) Samples from machines that have not been used for a long time should be taken from two locations, both at the top and bottom of the oil tank.
7) Container should be sealed immediately after collecting sample to prevent contamination by any foreign matter. The types of samples collected should be clearly indicated on the container.

Sending Out Samples

Sample containers sent for analysis tests should be properly labelled with clear indication of the type of lubricant in it as well as the following details listed below. This is to facilitate better identification of the samples to avoid any confusion or loss of samples.

(1) Sample Container Label

Following details should be indicated on the sample container's label as shown.


VESSEL
船舶名称: ________

OWNER
船舶公司: ________

DATE/TIME
取样日期/时间: ________ REF NO 编号: ________

PRODUCT
油品名称: ________

PORT/TERMINAL
取样港口: ________

SOURCE
取样来源: ________

REMARK
备注: ________

SIGNATURE
签名: ________

菲玛经贸有限公司
Premier Six Pte Ltd
Tel: +65 6702 4395

Label should be clearly indicated with a ball-point pen that will not be easily smudged by oil or water. Label should only be placed on the filled sample container after any oil or water on the surface of the container is removed. The objective of the analysis, sample number and other remarks should be written in the "remarks" column.

Testing

Various tests and analysis will be carried out at testing laboratory on the received samples such as:

- Basic Quality Control Tests

- Special Analysis Tests as requested

Basic Quality Control Tests

Depending on the type of the oil, equipment and operating conditions, properties of lubricating oil varies greatly during usage. To investigate the changes in the oil properties, usage conditions and selection of the appropriate tests must be taken into account.

The following tests are performed on lubricating oil samples taken for regular inspection for quality control purpose.

Special Analysis Tests

In any event that special testing is required, the following special tests can be consider:

(1) Demulsibility Test

(2) Foaming Test

(3) Rust Prevention Characteristics Test

(4) Load Carrying Capacity Test

(5) Oxidation Stability Test

(6) Metal Analysis Test

(7) Component Analysis Test

(8) Others

Items of Quality Control Test

Types of Test \ Types of oil	Marine Cylinder Oil	Marine System Oil	Marine TPEO	Hydraulic Oil (Inc. Turbine Oil)	Gear Oil	Testing Methods
Appearance	✓	✓	✓	✓	✓	Visual
Density @ 15°C, kg/l	✓	✓	✓	✓	✓	ASTM D4052
Kinematic Viscosity @ 40°C, mm^2/s (cSt)	✓	✓	✓	✓	✓	ASTM D445
Kinematic Viscosity @ 100°C mm^2/s (cSt)	✓	✓	✓	✓	✓	ASTM D445
Viscosity Index	✓	✓	✓	✓	✓	ASTM D2270
Total Base Number, mg KOH/g	✓	✓	✓			ASTM D2896
Flash Point (open),°C	✓	✓	✓	✓	✓	ASTM D92
Pour Point, °C	✓✓	✓✓	✓✓	✓✓	✓✓	ASTM D97
Water Content, ppm / Vol %	✓	✓	✓	✓	✓	ASTM D6304 / D95
Copper Corrosion, (100°c, 3h)	✓✓			✓✓	✓✓	ASTM D130
Rust Preventive				✓✓	✓✓	ASTM D665
Foaming Characteristics		✓		✓	✓	ASTM D892
Demulsibility Characteristics, (40-37-3), 54°c		✓		✓	✓	ASTM D1401

✓ - **Denote Basic Quality Control Test**

✓✓ - **Denote Special Analysis Test**

If any special analysis is required to investigate the cause of operational problems in equipment, please approach our Marine Oil Customer Service Department in Singapore at +65 6702 4395.

Significance of Each Test

1. Color (Visual)

Determine the color of lubricant product by assessing the appearance of transmitted light—appearance and intensity, as compare with a standard.

Color alone is not an indicative of purity or formulation. It may be associated with uniformity in lubricant or presence of contaminants. In used oils, it is very useful to develop colorimeters to identify oxidative or thermal oil degradation.

2. Density (ASTM D4052)

Determine the density or relative density of petroleum and its products is necessary for the conversion of measured volumes to volumes at the standard temperature of 15°C.

Density does not indicate the quality of lubricating oil but is a measure or indicator for lubricant deterioration due to combustion residue and other insolubles in the oil such as oxidized insolubles. Presence of water and other types of oil also change the density. Since the type of ring dam used in the purifier is determined according to density, it is always necessary to know the density of the oil being used.

3. Kinematic Viscosity (ASTM D445)

Determine whether the viscosity of the oil used is appropriate. Viscosity of system oil used in diesel engine increases when oxidized matter or combustion residues mixes into the oil and viscosity of system oil will decrease when fuel dilution takes place.

Generally, lubricating oil used in turbine engines show little change in kinematic viscosity during usage. And when there is a significant change of kinematic viscosity, it is usually due to entry of a different oil type.

4. Viscosity Index (ASTM D974)

The viscosity index is a widely used and accepted measure of the variation in kinematic viscosity due to changes in the temperature of a petroleum product between 40 and 100°C. A higher viscosity index indicates a smaller decrease in kinematic viscosity with increasing temperature of the lubricant. The viscosity index is used in practice as a single number indicating temperature dependence of kinematic viscosity.

Viscosity Index is sometimes used to characterize base oils for purposes of establishing engine testing requirements for engine oil performance categories.

5. Total Base Number (ASTM D2896)

Determine the alkaline (base) characteristics of a lubricant using Potentiometric Perchloric Acid Titration.

The Base Number measures the level of reserve alkaline. For in service lubricant it trends the depletion of detergent and anticorrosive additives.

6. Flash point (ASTM D92)

Determine the temperature at which oil vaporizes sufficiently to sustain momentary ignition when exposed to a flame.

Flash Point measure the volatility of the lubricant. It is an important property when selecting lubricants for high temperature applications. Decreasing flash point in used oil is mot often caused by fuel or chemical dilution.

7. Pour Point (ASTM D97)

Determine the lowest temperature at which an oil will flow under the influence of gravity.

Pour Point relates to a lubricant ability to flow in cold start-up conditions.

8. Water Content (ASTM D6304/D95)

Determines the amount of water content which has entered the oil.

Increase in the water content will deteriorate the quality. And, when chlorine or substances with strong acid properties are also present, corrosion and rusting of lubricating systems are also accelerated and emulsification will take place when using HD type oil. To determine type of water, i.e. brine or fresh water, the amount of chlorine must be measured.

9. Copper Corrosion (ASTM D130)

Evaluate the degree to which a lubricant will corrode copper-containing materials (i.e. Bronze).

This test helps to determine the suitability of a lubricant for use in equipment containing copper-based components. It may also be used with silver bearing metals (found in some engine components). Cutting fluids used in the machining of non-ferrous materials should be non-corrosive.

10. Rust Preventive (ASTM D665)

Determine the rust preventive properties of turbine oils and other industrial lubricants.

A Pass result in this test, means the lubricant will not typically produce significant rust formation in the equipment under moisture conditions.

11. Foaming Characteristics (ASTM D892)

Determine a lubricant ability to dissipate foam quickly.

The foam volume at the end of the blowing period is a measure of the foaming tendency of the oil, while the foam volume of the end of the settling period (which is usually zero) is a measure of the stability of the foam.

12. Demulsibility Test (ASTM D1401)

Determine the water separation characteristics of the lubricant subject to water contamination and turbulence. It is used for specification of new oils and monitoring of in-service oils.

This test method provides a guide for determining the water separation characteristics for oils. This test was developed specifically for steam turbine oils having viscosities of 32 cSt to 150 cSt at 40°C.

13. Oxidation Stability Test (ASTM D943)

Determine the time required to achieve a specified degree of oxidation under accelerated test conditions.

The greater the time in hours reported, the higher the oil resistance to oxidation. Oxidation stability is of special importance in turbine oils, gear oils, hydraulic fluids and electric transformer oils. There is not good correlation between oxidation test results and filed experience.

14. Rotating Pressure Vessel Oxidation Test RPVOT* (ASTM D2272)

Determine the lubricant resistance to oxidation and sludge formation using accelerated test conditions that involve high temperature, high pressure oxygen the presence of water and active metal catalysts.

This test is up to 1,000 times faster than D943 method, making it practical for use as a product quality measure and to measure the remaining useful life of in-service oils. The higher the RPVOT* value, the higher its relative oxidation stability.

14. Panel Coker Test

Determine the relative thermal stability of industrial lubricants in contact with hot metal surfaces.

Weight gain and the amount of oil consumed during the test are an indication of the lubricant performance under the conditions where lubricants contact hot surfaces. Lower weight gain by the panel and the cleaner the pane indicates better hot surface thermal stability.

15. Four-Ball EP Test (ASTM D2596)

Evaluate the performance of a lubricant under high loads.

Load Wear Index (LWI) - Is a measure of the ability to prevent wear at applied loads. For each run, the applied weight, multiplied by the lever arm, is divided by the average of 6 scar measurements. The resulting quotient is corrected for the elastic deformation of the ball surfaces due to static loading. This yields the correct load.

Welding Point (WP) - Is the lowest applied load at which either the rotating ball seizes and the welds the three other stationary balls. Or at which extreme scoring of the three stationary balls results.

16. Four-Ball Wear Test (ASTM D2266)

Determine a lubricant relative wear-prevention properties under boundary lubricant conditions.

The lower the Scar Diameter, the higher the protection of this lubricant under sliding conditions. In comparing the capabilities of various lubricants, the results of both the EP and Wear Test should be considered. Lubricants that have good extreme pressure properties, may not be equally effective in reducing wear rate at less severe loads and conversely.

17. FZG Test

Understand the performance of a gear lube to resist wear and scuffing with actual gear contact and operating conditions.

Evaluates scuffing load capacity of oils used to lubricate spur and helical gear units. The higher the lubricants pass stage the more its resistance to scuffing.

18. Timken Extreme Pressure Test (ASTM D2509)

Determine the Extreme Pressure protection characteristics of a lubricant

The higher the Timken OK Load, the higher the protection a lubricant has to protect machinery under Extreme Pressure. ASTM D2509 is for Lubricating Greases and ASTM D2782 is for Lubricating Fluids.

19. Denison High Pressure Pump Wear Test (T6C and P46)

T6C Rotary Vane Pump: A 100-hour hydraulic vane pump wear test run at 2,500 psi and 2,400 rpm. Cam ring and vane wear is evaluated.

Evaluates ability of a hydraulic fluid to prevent wear in a vane pump.

P46 Axial Piston Pump: A 100-hour hydraulic piston pump wear test run at 5000 psi and 240rpm. Piston shoes, swash plate and port plate are all visually rated.

Evaluates ability of a hydraulic fluid to prevent wear in a piston pump.

20. Vickers Test

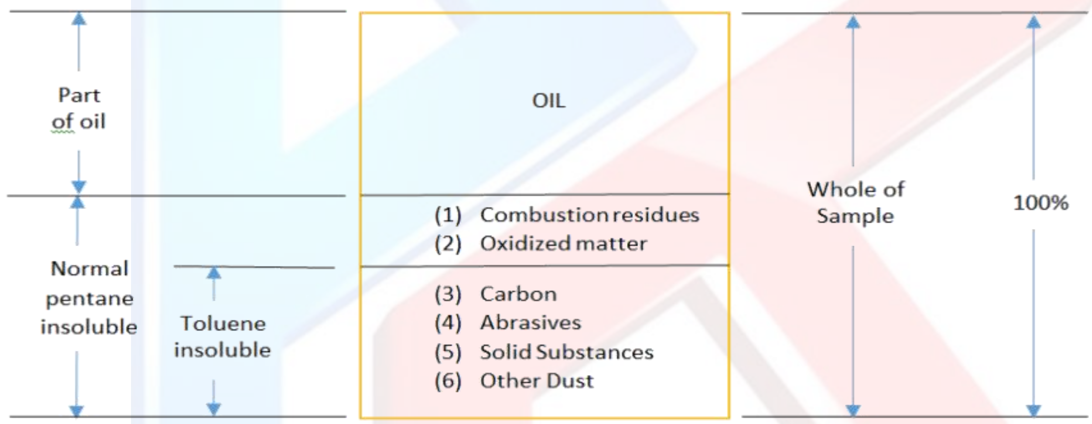
Measure the oil ability to provide optimum performance in vane pumps operating at maximum rated pressure and speed.

The unacceptable weight loss, signifies wear protection. The results may be reported as pass/no -pass. A pass means the lubricant is performing within the acceptable limits.

21. Solvent Insolubles

Solvent insolubles generally implies to normal pentane insoluble and toluence insolubles. The test results are also a measure of oil contamination and degradation. The difference between the two insolubles, known as resin quantity, indicates whether the contamination of oil is due to degradation of oil itself or due to entry of foreign matter. Substances other than lubricating oil, such as combustion residues, oxidized matters formed by the oil itself, carbon, abrasives and solid substances entering the oil are all detected as normal pentane insolubles. Toluence insolubles detect inorganic matters like carbon, abrasives and solid substances entering the oil.

The two insolubes obtained implies as follows:



Interpretation of Used Oil Analysis Results

Changes in the properties of lubricating oils depend on the type of oil as well as the lubricating and operating conditions of the various machinery and equipment used.

For more effective lubrication control, it is advisable to find the cause for change in the oil properties through examination of the analysis test results in order to determine appropriate countermeasures.

Tests	Causes	
	Decreased Value	Increased Value
Specific Gravity	1. Oil of lower specific gravity being supplied/introduced 2. Fuel diluted by light fuel	1. Contamination by insoluble matters (e.g. Metal powder, Fuel residues and Carbon) 2. Deterioration of oil 3. Oil of higher specific gravity being supplied/introduced
Flash Point	1. Fuel dilution (lighter fuel has more pronounced effect) 2. Oil of lower viscosity being supplied/introduced	1. Oil of higher viscosity being supplied/introduced
Kinematic Viscosity	1. Oil of lower viscosity being supplied/introduced 2. Diluted by lighter fuel	1. Oil of higher viscosity being supplied/introduced (e.g. Trunk type diesel engine increase in kinematic viscosity is usually caused by entry of cylinder oil) 2. Contamination by insoluble matter 3. Deterioration of oil 4. Emulsification due to water

Tests	Causes	
	Decreased Value	**Increased Value**
Total Base Number	1. Consumption of additives (ability to act as detergent, disperse and neutralize acid	1. New or "made-up" oil is added 2. Entry of cylinder oil 3. Residue of chemical purification liquid
Solvent Insoluble and Contamination	1. Supply of new oil 2. Effect of purification Renewal of filters 3. Precipitation in lubrication system 4. Inappropriate sampling method	1. Extreme amount of combustion residues entering oil 2. Heavy corrosion and wear 3. Bad environmental conditions (sand & dirt entering into oil during machine operation) 4. Oil filter is plugged 5. Deterioration of oil
Water Content	1. Water evaporation 2. Inappropriate sampling method	1. Cooling water temperature too low 2. Water leakage from cooling system 3. Severe blow (by gas) especially in trunk type diesel engine 4. Inappropriate water injection method in detergent action 5. Decrease of oil anti-emulsification property
Colour	1. Supply of new oil 2. Oil of paler colour is supplied/ introduced	1. Combustion residues (especially carbon particles) and entry of foreign substances into oil 2. Deterioration of oil (formation of sludge)

Quality Control Standard of Used Oil

Even though lubrication control is performed and appropriate treatment is administered according to the condition of the oil, the time will come when the oil will not be satisfactory even after the purification. As such, the oil will have to be changed.

No definite standards can be established as condition of use and an operational condition varies. However, the following can be used as a guide for oil management.

It is important to make an overall decision rather than an individual decision from each analysis.

System cylinder oil for small trunk piston type diesel engine

Product Names		Shieldguard 3008	Shieldguard 4015	Shieldguard 4030
Test Items	Fuel Oil	Heavy Fuel & Light Fuel		
Flash Point	(PM) °C	Over 180	Over 180	Over 180
Kinematic Viscosity	(40°C) cSt	-15% ~ +30%	-15% ~ +30%	-15% ~ +30%
Total Base Number (Perchloric Acid Method)	mg KOH/g	Over 3.0	Over 8.0	Over 20.0
Water Content	Vol %	Less than 0.3	Less than 0.3	Less than 0.3
N-pentane insoluble	Wt %	Less than 2.5	Less than 2.5	Less than 2.5

System oil for Intermediate Speed Diesel Engine

Test Items	Product Name	Shieldguard 4030
Flash Point	(PM) °C	Over 180
Kinematic Viscosity	(40°C) cSt	-15% ~ +30%
Total Base Number (Perchloric Acid Method)	mg KOH/g	Over 15.0
Water Content	Vol %	Less than 0.3
N-pentane insoluble	Wt %	Less than 2.0

System cylinder oil for small trunk piston type diesel engine

	Fuel Oil	Turbine Oil	Hydraulic Oil	Gear Oil
Kinematic Viscosity	(40°C) cSt	-10% ~ +10%	-10% ~ +10%	-10% ~ +10%
Total Base Number (Perchloric Acid Method)	mg KOH/g	New Oil +3.0	New Oil +0.5	New Oil +2.0
Water Content	Vol %	Less than 0.1	Less than 0.1	Less than 0.1
Insoluble by Membrane Filter Method	(0.8u)	Less than 2.5	Less than 2.5	Less than 2.5