Oil Analysis Overview

NWHA 2015 Technical Seminar
Oil Analysis Process

• Oil analysis is like a blood test
  – Sample is taken
  – Sample internally documented
  – Sample is delivered to a lab
  – Sample is analyzed
  – Results are interpreted
  – Diagnostic report is issued
  – Follow up!
Oil Analysis Objectives

• Fluid Management
  – Serviceability
  – Contamination
  – Drain intervals

• Predictive Maintenance
  – Abnormal machine wear behavior
  – Maintenance planning
  – Elimination of repetitive problems

• Reliability
  – Ferrographic failure predictive capability
  – Root cause analysis
What Oil Analysis Looks At

• Machine Wear Behavior
  – Identify problems in the initial stage of development
  – Pinpoint component source of wear

• Contaminants
  – Early detection of
    • Dirt
    • Water
    • Coolant
    • Fuel Dilution
    • Soot
    • Wrong oil

• Lubricant Serviceability
  – Lube suitability for further service time
  – Lube requires off-line purification
  – Reservoir needs sweetening or changed
Sampling
FLUID SAMPLING BASICS

• Be safe
• Warmed-up machine
• Clean process
• Properly documented
• Send immediately to lab

good input supports good output
SAFETY RISK ASSESSMENT

• High temperatures
• Moving parts
• High pressures
• Chemicals
• Heights

ALS recommends a Job Safety Analysis to establish Safe Sampling Procedures
• Representative means it is typical of the fluid as it is in use - a snapshot of the in-service lubricant and machine wear behavior

• **Best way**, take while running
• If not running, start and run until operating temp is reached, then take the sample

• If you must shut down to sample, do so within 30 minutes of shut down
• Use same correct procedure
• Use same correct location each sample
• Consistency for trend
WHAT YOU CAN’T SEE WILL HURT YOU!

Almost everything we test for in the lab is **INVISIBLE** to the naked eye.
PARTICLE SIZE

- **HUMAN HAIR, 80 MICRONS**
- **FINE FLOOR DUST, 40 MICRONS**
- **TALCUM POWDER, 10 MICRONS**
- **RED BLOOD CELL, 5 MICRONS**
- **WHITE BLOOD CELL, 20 MICRONS**
- **BACTERIA, 3 MICRONS**

**HUMAN VISIBILITY RANGE**
10 IMPORTANT SAMPLING RULES

1. Sample upstream of the filter

2. Sample downstream of the work area

3. Return lines are good

4. With valves/ports *always flush* 2-3x sample volume

5. Needle probe used one time only – throw away
10 IMPORTANT SAMPLING RULES

6. Plastic tubing use one time only – throw away

7. In reservoirs, aim for the mid-point of tank

8. Do not sample off the bottom (over concentrated)

9. Do not sample from top (under concentrated)

10. Do not sample when machine is cold
Routine Test Methods
Viscosity – ASTM D445

- Fluid’s resistance to flow, which relates to oil thickness
- Measured in time it takes to flow a certain distance in a capillary tube
- Reported in centistokes (cSt)
- *Most important physical property of oil*
- Measured at 40°C for industrial oils and 100°C for engine oils
**Viscosity**

• Increase in engine oil viscosity results in increased operating temperature.

• A Change in viscosity may also be result from the following:
  
  a) Oxidation of oil/Thermal degradation.
  
  b) Topping up with wrong oil
  
  c) Shearing of oil
  
  d) Depletion of the light ends of base stock
  
  e) Contamination from water, Fuel or Glycol
Base Number, Acid Number

• Acid Number and Base Number tests are standard for monitoring the suitability of the lubricant for continued service.

• For Base Number & Acid Number, you must know the value for the new (unused) oil in order to measure changes.
Base Number, Acid Number

• For Base Number & Acid Number, you must know the baseline value for the new (unused) oil in order to measure change from that reference point

• BN values decrease – monitoring alkaline reserve
  – Should also be specified by test method (ASTM D4739 – used oils, or ASTM D2896 – new oils)

• AN values increase – monitoring oil degradation
  – Significant variation in baseline values of new oil depending on type of product (ASTM D664/D974)
Acid Number – ASTM D664

• Measures total concentration of both strong and weak acids

• Sample titrated with potassium hydroxide (KOH) and results expressed as milligrams of KOH per gram (mg/KOH/g)

• All new oils have an initial AN that can be measured as a baseline

• Since oxidation produces acids use of AN is indicator of oil oxidation

• An increase of 2-3X the baseline AN in new oil indicates degree of oxidation
Fourier Transform
Infrared Analysis - FTIR

• Identifies organic functional groups by measuring infrared absorption at various wavelengths

• Expressed as absorbance/centimeter

• Tests used to qualify
  – Water
  – Oxidation
  – Nitration
  – Glycol
  – Phenol Additives
  – Sulfur Compounds
  – Soot
  – Other organic contaminants
Why Is Oxidation Important?

• Oxidation may lead to...
  – Viscosity increase
  – Varnish
  – Sludge & sediment
  – Additive depletion
  – Base oil breakdown
  – Filter plugging
  – Loss of foam properties
  – Acids
  – Corrosion
  – Wear
Water

- Second most destructive contaminant
- Measured by use of crackle test for quick qualitative evaluation \( \approx 500-1000 \text{ ppm} \)
  - Used as a screen, PASS/FAIL
- Karl Fischer titration test used for accurate, precision testing; measures total water present
  - Dissolved
  - Emulsified
  - Free
Karl Fischer Titration - ASTM E203 / D6304

• Method for precise determination of water content
  – ASTM E 203 (Volumetric)
    • Preferred for moisture concentrations between 0.1% to 100%
  – ASTM D6304 (Coulometric)
    • Preferred for moisture concentrations between .001% to ~2.0%

• As iodine and water react through electrolysis, the measured reaction is proportional to the quantity of water

• The reagent is added until an electrometric end point is reached

• Water concentration in PPM or percent is calculated from the amount of reagent used to reach the end point
Water Contamination

Various degrees of water contamination in a clear petroleum product.
Spectrochemical Elemental Analysis

Primary Tests
Spectroscopic Elemental Analysis

• **All Systems**
  – Wear metals
  – Contaminants
  – Lubricants, metallic additives

• **Particle Count (ISO Cleanliness Code)**
  – Filtered systems- hydraulics, turbines, compressors, industrial circulating oils
Elemental Analysis

<table>
<thead>
<tr>
<th>Wear Metals</th>
<th>Contaminants</th>
<th>Lubricant Additives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron (Fe)</td>
<td>Chromium (Cr)</td>
<td>Nickel (Ni)</td>
</tr>
<tr>
<td>Aluminum (Al)</td>
<td>Copper (Cu)</td>
<td>Lead (Pb)</td>
</tr>
<tr>
<td>Tin (Sn)</td>
<td>Silver (Ag)</td>
<td>Silicon (Si)</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>Potassium (K)</td>
<td>Molybdenum (Mo)</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>Magnesium (Mg)</td>
<td>Calcium (Ca)</td>
</tr>
<tr>
<td>Barium (Ba)</td>
<td>Phosphorus (P)</td>
<td>Zinc (Zn)</td>
</tr>
</tbody>
</table>

Reported in concentrations of parts per million - PPM
Spectrochemical Elemental Analysis

- Abnormal Component Wear
  - Identify likely component source of metals

- Contaminants
  - Abrasive dirt
  - Coolant additive trace elements

- Lube Additive Levels
  - Correct Lubricant
  - Lube mixing - wrong makeup oil added
  - Dilution
  - Leakage from transmission/hydraulic compartment
Particle Count

- Particle Count
  - determines number of solid particulate in various size ranges: test used for hydraulics, turbines and many compressors

- Contaminant Classification, Reporting
  - ISO 4406:1999 Cleanliness Code (per 1 ml)
  - NAS 1638 Class (per 100 mls)
  - SAE 749D Class (per 100 mls)
# Particle Count ISO 4406:1999

Expressed as $x/y/z$

$X$ is always more than $Y$ is always more than $Z$

19/14/11

19---$\geq 4\mu m[c]$

14---$\geq 6\mu m[c]$

11---$\geq 14\mu m[c]$

Note: each incremental increase in ISO Code indicates **TWICE** the number of particles.

Old ISO Code:

$>2\mu m$, $>5\mu m$, $>15\mu m$

Older Code:

$>5\mu m$, $>15\mu m$
Advanced Test Methods
Water Separability

Demulsibility Bath

Water Separation Result
• ASTM D6971/D6810

• Remaining Useful Life Evaluation Routine

• Quantifies the hindered phenol and aromatic amine additive levels in turbine oils by linear sweep voltammetry

• The antioxidant additive levels of the in-service fluid is compared to a reference sample of the new (unused) product
Foaming Tendency - ASTM D892

- The tendency of oils to foam can become a serious problem in some systems.
- The results of excessive foaming may lead to inadequate lubrication, cavitation, and overflow loss of oil, all of which may cause mechanical failure.
- This is a 3-part test: Sequence I, Sequence II and Sequence III
Varnish Potential Report

- Special test slate for predicting varnish potential
- After correlating all of the test results, the data analyst communicates the Varnish Potential in a report to the customer
- Levels reported are:
  - LOW
  - MODERATE
  - ELEVATED
  - HIGH
Thank you!