Oil Analysis
Key Points

- Increase your understanding of Oil Analysis.

- Oil analysis is a Proactive maintenance tool that can Trend Critical Assets Conditions.

- We can provide a Fast Turnaround time on urgent samples.
Content

- Introduction
- What is Oil Analysis?
- The Laboratory
- The Report
- How to Take a Sample
- Case Study
Who we are

- Employ 40 people
- Operate the following laboratories
  - Fuel Analysis
  - Environmental Analysis
  - Machine Care Oil Analysis
  - Transformer Oil Analysis
  - Chemical Manufacturing
  - Marker Dyes
  - Chlorination
  - R&D Section
    - 8 European funded FP7 project
    - 1 Horizon 2020 funded project
Customers

- Transport
  - Road
  - Rail
  - Shipping
  - Air
- Breweries
- Mining
- Construction
- Power Generation
- Injection Moulding

- Engines
- Transmission
- Gearboxes
- Turbines
  - Wind
  - Gas
  - Stream
  - Hydro
Benefits

- What are the benefits?
  - Reduced downtime 50–80%*
  - Reduced maintenance costs 50–80%*
  - Increased machine life 20–40%*
  - Productivity increased 20–30%*
  - Profit increased 25–60%*

- Extended Warranties

Overview of Service

- We test approx 300 samples per week

- We have an expertise in mechanical maintenance and lubrication has been built up across various industries in manufacturing & maintenance

- Extensive training has been undertaken by our engineers and laboratory technicians

- Training Courses offered – International Qualification
Welcome to the website of the International Council for Machinery Lubrication.

ICML is a global non-profit organization dedicated to helping lubrication practitioners succeed in their professional careers. ICML certification exams are in accordance with ISO 18436 and are available worldwide, in multiple languages.

**Search ICML:**

Google Custom Search

**ICML Exam Session Calendar**

(Notes: search for the city, or country name, or for the U.S. two-letter state abbreviation.)

**Search Exam Location:**

Find Show all

To apply for an exam, choose the exam session below to get started:

- **Dallas, TX** (8:00 - 11:00 AM)
  - Embassy Suites Dallas-Frisco - 7600 John Q
  - Hammonds Dr. - Frisco, TX
  - Sponsor: NAPA
  - Apply
  - 1/30/2015

- **Louisville, KY** (8:00 - 11:00 AM)
  - Holiday Inn Louisville Eastgate - 1325 S.
  - Hurstbourne Parkway - Louisville, KY
  - Sponsor: NAPA
  - Apply
  - 2/20/2015

- **Knoxville, TN** (6:00 to 9:00 PM)
  - Knoxville Convention Center - 701 Henley St. -
  - Knoxville, TN
  - Sponsor: MARCOM
  - Apply
  - 2/24/2015

- **Yokohama, Japan** (4:00 - 7:00 PM)
  - Takeda Industrial Estate - Yokohama, Co. Ltd.
  - Sponsor: T.E. Laboratories Ltd.
  - Apply
  - 2/24/2015

- **Tokyo, Japan** (8:00 - 11:00 AM)

**What's Happening**

- Can't travel to take an ICML exam?
  - How about sitting it in your hometown? ICML may be able to offer an examination session on-site or locally - even for small groups or individuals. If you would like to arrange for an exam or would like more information, please contact registrations@lubecouncil.org.

- Do not let your ICML credential expire!
  - Your certification is valid for three years from the date you sat your exam and needs to be extended every three years by re-certification. ICML has a system of re-certification by points available. When needed points can come from your continued employment in the field - it's an easy process, but we need to hear from you in order to ensure your certified status is preserved. Email edevelopment@lubecouncil.org for more information.
Section Two

What is Oil Analysis?
Functions of a lubricant

- Creates a boundary layer reducing friction
- Dissipates heat from surfaces
- Transports contaminants to filters
- Protects from oxidisation & corrosion
- Power transmission
Tribology & Mechanics

- Tribology – the science of interacting surfaces in relative motion.
Surface finishes are in fact rough on a microscopic scale—Series of troughs (asperities) and peaks

The lubricating fluid boundary layer will ideally separate the asperities thus reducing wear

Minimum film thickness

Shear mixed layer ~ 1um thick for steel
Regimes of Lubrication

**LOW LOAD**
- Hydrodynamic Lubrication
  - Laminar Flow
  - Film thickness several times greater than surface roughness

**HIGH LOAD**
- Mixed Lubrication
  - Laminar Flow of oil disturbed
  - Film thickness same order as Surface roughness

**VERY HIGH LOAD**
- Boundary Lubrication
  - Boundary Films
  - Viscous oil properties ineffective
Wear Particle Progression to Failure

Wear Particle Size in µm (micrometers)

Wear Particle Concentration (WPC)

0.1
1
10
100
1,000

Benign Wear
Onset of Severe Wear Mode
Advanced Failure Mode
Catastrophic Failure
Section Three

The Laboratory
The Report

Split into Four sections:

1. Elemental Analysis
   Wear Metals
   Contaminants
   Additives Elementals
2. Kinematic Viscosity
3. Chemical properties
4. Particle count results
   Laser Net Fines
   Ferrography
Spectrooil M (RDE–OES)

- Analyses 21 parameters simultaneously
- 30 second run time
- Measures metals, additive levels, contaminants and silica/dirt within the oil sample
## Wear Metals

<table>
<thead>
<tr>
<th>Metal</th>
<th>Gears</th>
<th>Hydraulics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron (Fe)</td>
<td>Gears, Bearings, Shaft, Housing</td>
<td>Rods, Cylinders, Gears</td>
</tr>
<tr>
<td>Chromium (Cr)</td>
<td>Roller Bearings</td>
<td>Shaft</td>
</tr>
<tr>
<td>Aluminum (Al)</td>
<td>Pumps, Thrust Washers</td>
<td>Bearings, Thrust Plates</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>Steel Alloy from Roller Bearings and Shaft</td>
<td></td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>Bushings, Thrust Plates</td>
<td>Bushings, Thrust Plates, Lube Coolers</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>Bushings (Bronze Alloy), Grease Contamination</td>
<td>Bushings (Bronze Alloy)</td>
</tr>
<tr>
<td>Tin (Sn)</td>
<td>Bearing Cage Metal, Lube Additive</td>
<td></td>
</tr>
<tr>
<td>Molybdenum (Mo)</td>
<td>Ring Plating, Lube Additive, Coolant Inhibitor</td>
<td>Lube Additive, Coolant Inhibitor</td>
</tr>
</tbody>
</table>
## Contaminants

<table>
<thead>
<tr>
<th>Metal</th>
<th>Gears</th>
<th>Hydraulics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon (Si)</td>
<td>Dirt, Seals and Sealants, Coolant Inhibitor, Lube Additive (15 ppm or less)</td>
<td>Dirt, Seals and Sealants, Coolant Inhibitor, Lube Additive (15 ppm or less)</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>Lube Additive, Salt Water Contamination, Airborne Contaminate</td>
<td>Lube Additive, Coolant Inhibitor, Salt Water Contamination, Airborne Contaminate</td>
</tr>
</tbody>
</table>
## Additives

<table>
<thead>
<tr>
<th>Metal</th>
<th>Gears</th>
<th>Hydraulics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnesium (Mg)</td>
<td>Detergent Dispersant Additive, Airborne Contaminant at some sites</td>
<td>Detergent Dispersant Additive, Airborne Contaminant at some sites</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>Detergent Dispersant Additive, Airborne Contaminant at some sites, Contaminant from Water</td>
<td>Detergent Dispersant Additive, Airborne Contaminant at some sites, Contaminant from Water</td>
</tr>
<tr>
<td>Barium (Ba)</td>
<td>Usually an Additive from Synthetic Lubricants</td>
<td>Usually an Additive from Synthetic Lubricants</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>Anti wear/ Extra pressure</td>
<td>Anti wear/Extra pressure</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>Anti wear</td>
<td>Anti wear</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>High Temp Lubrication</td>
<td>High Temp Lubrication</td>
</tr>
</tbody>
</table>
## Multiple Source Metals

<table>
<thead>
<tr>
<th>Metal</th>
<th>Gears</th>
<th>Hydraulics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molybdenum (Mo)</td>
<td>Lube Additive, Coolant Inhibitor, Grease Additive</td>
<td>Lube Additive, Coolant Inhibitor</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>Wear metal</td>
<td>Wear metal</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>Coolant contamination</td>
<td>Coolant contamination</td>
</tr>
</tbody>
</table>
Viscometer

- 4 tube automated viscometer (40 – 100°C)
- All samples measured at 40°C
- Samples can be measured above 40°C depending on machine operating temperature
- Measures kinematic viscosity in cSt
Kinematic Viscosity

- Foremost indication of the health of the oil & equipment
- A change in viscosity can alter the boundary layer of lubrication between the moving surfaces causing wear
- Water ingress & additive depletion (forming sludge) appear the two issues affecting viscosity for wind turbines
Viscosity Effect

- **High Viscosity**
  - Increased op costs
  - Engine overheating
  - Restricted oil flow
  - Accelerated wear
  - Oil–filter by–passed
  - Harmful deposits/sludge

- **Low Viscosity**
  - Engine overheating
  - Poor lubrication
  - Metal to Metal contact
  - Increased operating costs
Fluid Scan (IR)

- 75 second run time
- Measures chemical properties of the oil
- Uses infrared light passed through the oil sample to quantify the results
Chemical properties

- **FTIR Fluid Scan**
  - TAN (Total Acid Number) – Acid Content
    - Gearboxes
    - Hydraulic System
    - Increases over time.
  - TBN (Total Base Number) – Alkaline Additives
    - Engines. Decreases over time. (Indicates oil change interval)
- Glycol
- Fuel Dilution
- Soot
- Water content
- Oxidation, Nitration levels
Virgin Samples

- Virgin oil samples give the maintenance technician invaluable information
  - Baseline additive values
  - Cleanliness code
  - Baseline chemical properties, water & TAN

- It is imperative to obtain adequately clean virgin oils and monitor with reference to that cleanliness thereafter
Laser Net Fines – Particle Counting and Classification

- Measures particles from 1–100µm using laser & camera technology
- Gives total particle count for that sample & ISO 4406/99 code
- Classifies particles in different wear modes
  - Cutting, sliding, fatigue, non–metallic, fibers
Particle Count Results
Laser Net Fines

- ISO Code 4406/99 contains three number that are in a logarithmic scale representing particles per ml of sample.
- The first number is in the range $\geq 4\mu$, the second $\geq 6\mu$ and the third $\geq 14\mu$.
- Software has the ability to calculate limits and statistical info like $\sigma$ values.
Ferrography (Root Cause Analysis)
Typical surface finish

Benign Wear & Normal Wear

Cutting wear particle

“Hard” Surface

“Soft” Surface

Hard abrasive

Cutting Wear
Severe Sliding Wear Particles – Major Dimension to Thickness Ratio of ~ 10:1 & Striations

Fatigue Chunks – Thick With Smooth Surfaces and Irregular Edges
Section Four

The Report
Stage one – Gathering information
- OEM Recommendations
- Oil Spec Data Sheets
- Virgin oil sample – Baseline
- Similar equipment data

Stage Two – Developing Trends – Proactive
- Trending results – Major changes
- Statistical analysis on historical data
- Wear particles – Ferrography
Establish Baseline to Trend From

- Large Particles
- Severe Wear (exponential rise)

Concentration

Equilibrium

Screen using other techniques
LNF

Large Particles
Severe Wear
(exponential rise)

Break In

Oil Change

Wear Out

Operating Time in Hours
Spectrotrack Database
Customer Page

Wind Power Customer - Home

Oil Analysis Course for 2015
Condition Based Monitoring - Oil Analysis Course
March & September 2015 Courses

Condition Based Monitoring - Wind Turbine Training
Course Overview - hosted by Irish Wind Energy Association

ISO 9001:2008
EN ISO 9001:2008 has been granted to TelLab Ltd by NSAI

Ferrography
New Ferrography Service Available

Demo Customer
If you would like a username and password to view Demo Customer please e-mail sales@tellab.ie with your contact details.
Trending
Trending Graphs
Wind Power Customer
Location: Gearbox Samples
Unit ID: Turbine 11 Gearbox 54807
Model: Moventas - PLH-400-211
Machine Type: Turbine, Wind

Wear appears satisfactory. No significant signs of contamination. Advice: Monitor at the next sampling period.

Padraig Kelly, 13 Jun 2014

<table>
<thead>
<tr>
<th>Oil</th>
<th>Texaco Motorex 320</th>
<th>Sample ID</th>
<th>39438D (N5844)</th>
<th>307914 (M11096)</th>
<th>229D05 (L12377)</th>
<th>182F7D (L5641)</th>
<th>12AA12 (K0476)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>9000</td>
<td>4000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Metal</th>
<th>ppm</th>
<th>ppm</th>
<th>ppm</th>
<th>ppm</th>
<th>ppm</th>
<th>ppm</th>
<th>ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>9</td>
<td>5</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Chrome</td>
<td>&lt;1</td>
<td></td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Nickel</td>
<td>&lt;1</td>
<td></td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>&lt;1</td>
<td></td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Aluminum</td>
<td>&lt;1</td>
<td></td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Lead</td>
<td>&lt;1</td>
<td></td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Copper</td>
<td>&lt;1</td>
<td></td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Tin</td>
<td>&lt;1</td>
<td></td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Silver</td>
<td>&lt;1</td>
<td></td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Titanium</td>
<td>&lt;1</td>
<td></td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Silicon</td>
<td>1</td>
<td></td>
<td>&lt;1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sodium</td>
<td>&lt;1</td>
<td></td>
<td>2</td>
<td>17</td>
<td>16</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Vanadium</td>
<td>&lt;1</td>
<td></td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Calcium</td>
<td>&lt;1</td>
<td></td>
<td>&lt;1</td>
<td>31</td>
<td>32</td>
<td>34</td>
<td>36</td>
</tr>
</tbody>
</table>

ASTM D6595-08 WEAR METALS
ASTM D6595-08 CONTAMINANTS
Logging samples on-line

Machine: Turbine 1 Gearbox
Wind Power Customer Gearbox Samples

ID: 3E431C:Tellabs Date: 10/15/2014
Oil: Texaco Meropa 320 Oil: ........... h Eqpt.: ........... h Top Up ..... 1
Analysis: LNF FS AES V40
Sample submission

- Customers can log samples onto the Spectrotrack database from the customer side and trace the progress from that point.
- Self logged samples will be given priority upon arriving at the laboratory ahead of any possible back log during busy periods.
- This will give faster turn around times for the samples.
Section Five

How to Take a Sample
Sampling Techniques

- Thief pump reduces chances of contamination from outside sources
- Sample bottle screws directly onto pump
- One pull of the handle creates the vacuum to fill the bottle
- Tubing can be cut to the specific length from the 100m roll and discarded after use
Importance of Proper Sampling

- Take sample within 15 minutes of shutdown.
- Sample must be taken before the filter in the system.
- Sampling should be treated with extreme diligence & care to prevent contamination.
- Cut tubing to desired length.
- Pull handle to create vacuum and the bottle will fill.
- Once filled unscrew from pump and screw on lid, making sure sample is not contaminated from the environment.
- Wipe bottle, attach label and send to the laboratory.
Sample Location

Photos courtesy of Ecopower
Fixed Position sample points
<table>
<thead>
<tr>
<th>Equipment</th>
<th>Normal Use</th>
<th>Intermittent Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel Engine</td>
<td>Monthly, 500 Hours</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Gas Turbine</td>
<td>Monthly, 500 Hours</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Steam Turbine</td>
<td>Bi-monthly</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Gas &amp; Air Comp</td>
<td>Monthly, 500 Hours</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Refrigeration Comp</td>
<td>Beginning, Midpoint &amp; End of Season</td>
<td></td>
</tr>
<tr>
<td>Gears, Bearings</td>
<td>Bi-monthly</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Hydraulic</td>
<td>Bi-monthly</td>
<td>Quarterly</td>
</tr>
</tbody>
</table>
Section Six

Case Study – Ferrography
Ferrography

Report
- Large Sliding Wear
- Severe Copper & White Metal Particles
- Moderate Amount of dark-metal oxides
- Red oxides present
- Silica
- Fatigue chunks

Context
- 2600 Fleet
- Locomotive Engine
- Cork Depot
- Initial report showed signs of abnormal wear
- Engineer concern

Findings
- Water Ingress
- Lubricant Starvation

Result
- Engine Teardown
There is some benign rubbing wear together with a number of large sliding wear steel particles and some dark metallo-oxides present. This is indicative of a transition from normal to severe sliding wear and likely due to insufficient lubrication.

There are a few cutting wear particles due to the presence of non-metallic crystalline particles in the form of silica. There are a number of severe copper alloy fatigue chunks and a few overheated tin/lead alloy fatigue chunks indicating severe bearing wear.

There are moderate amounts of red oxides present indicating water ingress at some stage.

The presence of a large amount of submicroscopic particles at the exit end is indicative of corrosive wear.

There is a moderate amount of insect and plant matter indicating seals and filters may be compromised or sampling technique may not be adequate.

Advice: Check bearings for signs of wear. Change oil and check filters and seals. Resample after 10 hours.
<table>
<thead>
<tr>
<th>Types of Particles</th>
<th>None</th>
<th>Few</th>
<th>Moderate</th>
<th>Heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bubbling Wear Particles</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severe Wear Particles</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Abrasive Wear Particles</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Chunks</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Renewed (Laminar) Particles</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Spheres</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Dark Metallo-Oxide Particles</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Fod Oxide Particles</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Corrosive Wear Debris</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Nonferous Metal Particles</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonmetallic Crystalline Particles</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Nonmetallic Amorphous Particles</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Friction Polymers</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Fibers</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Other (Specify)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Considered Judgment of Wear Situation:</th>
<th>Normal</th>
<th>Caution</th>
<th>Critical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comments:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Sample 2610 Ferrogram Images

Entry view (step 1/2 x100)
Moderate to heavy amount of severe wear particles, with copper and white metal particles.

Step 3 x500
Moderate amount of Dark-metallo-oxides indicative of lubricant starvation and abnormal wear & red oxides indicating water ingress.
Sample 2610 Ferrogram Images

Step 3 x1000
Large abnormal sliding wear particles >20um

Step 3 x500 – non ferrous examination
Copper Chunk >20um
Sample 2610 Ferrogram Images

Step 6 x500
Non-Metallic Crystalline particles
silica and rust
Sample 2610 – Heat Treatment 330 DegC

**Step 3 x500**
Copper chunks

**Step 7 x500**
Non-metallic crystalline debris (silica some rust)
Sample 2610 – Heat Treatment 330DegC

Step 9 x500
Fatigue Particle

Step 9 x500 – After Heat
Low Alloy steel fatigue particle
Sample 2610 - Heat Treatment 330DegC

Step 9 x500 After Heat
Cast Iron fatigue chunk possibly from case hardened gear pitch line
Photographs of Disassembled Bearing
Visible Chunks in Sump
Thank you for your time.