Ferrographic & Oil Analysis
At Vibe Institute
Piedmont Chapter
May 2008
Setting Up A Program

- Set Goals
- Equipment Survey
- Set Up Equipment Specific Analysis Programs
- Train Personnel in Sampling Techniques & Report Interpretation
- Monitor Results & Progress
When it comes to your machinery's life, don't guess.

**Problems Identified**

- Imbalance
- Misalignment
- Bearings (BAD / COCKED)
- Bent shaft
- Looseness
- Out-of-round Journal
- Gear Problems
- Impeller Blade Problems
- Magnetic Noise
- Electrical Noise

*PREDICT*
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>Indicates condition severity &amp; wear mechanism</td>
</tr>
<tr>
<td>Shape</td>
<td>Indicates wear mechanism</td>
</tr>
<tr>
<td>Composition</td>
<td>Indicates source of wear debris</td>
</tr>
<tr>
<td>Concentration</td>
<td>Indicates condition severity, rate of particle generation and wear mechanism.</td>
</tr>
<tr>
<td>Morphology</td>
<td>Indicates wear mechanisms</td>
</tr>
</tbody>
</table>
Wear Mechanisms

Adhesive

Plastic zone

Adhesive transfer

Wear fragments

When it comes to your machinery's life, don't guess
Selecting the correct technique to meet maintenance goals is critical. Overemphasizing the value of screening or basic elemental analysis techniques routinely results in missed expectations and increased costs.
Wear debris particles vary in size, composition, type, morphology and concentration depending on many factors:

- Loading
- Materials
- Wear Mechanism

No two particles are the same and no single monitoring techniques is capable of analyzing all particles.

A world class program incorporates specific techniques applicable to the application.

The true value and ultimate success of a monitoring program is proper design; applicability to system being monitored, utilizing correct techniques and knowledgeable personnel.
When it comes to your machinery's life, don't guess.

Sampling Point Selection

COMPONENT

FILTER

CIRCULATING LUBRICANT

SAMPLING VALVE

SAMPLE BOTTLE

PUMP

RESERVOIR

When it comes to your machinery's life, don't guess.
Lubricant Sampling Objectives

1. Determine wear condition of lubricated surfaces
2. Determine contaminant levels:
   - Particulates
   - Water and other fluids
3. Determine lubricant condition
4. Propose accurate maintenance recommendations
Effective lubricant condition programs begin with a representative sample.

A -¼”NPT
B -1.52” (38.64mm)
C - 0.63” (16mm)
Hex 0.67” (17mm)
Length of Extender: 12”, 20”, 30”
Tube 3/16” OD

Consistent sampling logistics maximize the quality of the analysis and promotes accurate condition trending.

Internal check valve opens only when the appropriate fitting with the sample tubing is attached, eliminating leakage.

When it comes to your machinery’s life, don’t guess.
When it comes to your machinery’s life, don’t guess

Taking a Sample

- From valves in return line
  - Place valve as close to pipe as possible
  - Use as small diameter pipe as possible
  - Calculate dead volume & flush 2X amount into waste can
  - Clean valve spigot before taking sample
  - Take sample before closing valve & fill bottle only 3/4 full
  - Send out same day -- don’t wait!
When it comes to your machinery's life, don't guess.

Outboard Bearing

Inboard Bearing

Sample Taps
When it comes to your machinery’s life, don’t guess

Sampling Habits

- Label Sample Point Locations
- Mark Sample Bottles Prior to Sampling
- Clean Surfaces Prior to Sampling
- Drain Stagnant Oil From Valve
- Use New, Clean, Plastic Bottles
- Use New Sample Tubing
- Ship Samples Immediately
When it comes to your machinery's life, don't guess.

Size Comparison Chart

<table>
<thead>
<tr>
<th>Inches</th>
<th>Microns</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>.001</td>
<td>10</td>
<td>Fog</td>
</tr>
<tr>
<td>.002</td>
<td>20</td>
<td>Visibility Limit (cannot be seen by the naked eye)</td>
</tr>
<tr>
<td>.003</td>
<td>30</td>
<td>Pollen</td>
</tr>
<tr>
<td>.004</td>
<td>40</td>
<td>200 Mesh Screen</td>
</tr>
<tr>
<td>.005</td>
<td>50</td>
<td>Table Salt</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>Industrial Haze</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>Diameter of Human Hair</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>Red Blood Cells</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>Talcum Powder</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>White Blood Cells</td>
</tr>
<tr>
<td></td>
<td>110</td>
<td>Bacteria</td>
</tr>
<tr>
<td></td>
<td>120</td>
<td></td>
</tr>
<tr>
<td></td>
<td>130</td>
<td></td>
</tr>
</tbody>
</table>

1 Micron = 0.001mm = 0.000039 Inches

From Schroeder Industries
When it comes to your machinery’s life, don’t guess

**UOA/WPA Analysis**

**Used Oil Analysis**: Determines the **condition** of the **OIL**.

**Wear Particle Analysis**: determines the **condition** of the **MACHINE**.

This is the critical difference between the two technologies. Many confuse the two and will generically refer to it as oil analysis. The difference always needs to be clarified in the mind of the user in order to create Value.
When it comes to your machinery’s life, don’t guess
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Wear Particle Analysis Using Ferrography, PQ, Tribometrics, RPD, X-Ray Fluoresce, Spectrometer, Contamalert, Lasernet, Oilanalyser & Particle Counter
When it comes to your machinery's life, don't guess.
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Rotary Particle Depositor

PQ Oil Analyzer

ContamAlert

Particle Counter

X-Ray Fluorescence
Ablasive Wear

Ablasive Wear Effects
- Dimensional changes
- Leakage
- Lower efficiency
- Particles = More particles

When it comes to your machinery's life, don't guess.

Chip/Grit
- Too large to enter clearance

Silt (clearance size)
- Interacts w/surfaces
- Causes abrasive wear

Ultrafines
- Too small to interact with surfaces

From Leugner, 1989
Due to foreign particles in the oil.
The harder dirt particle imbeds itself in a softer metal and gouges the metal away from the rotating metal separated by the lubricant film.
Three Body Abrasive Wear

When it comes to your machinery's life, don't guess
Wear Particle Analysis
A Three Step Process

1. TRENDING
   Wear Particle Concentrations to Identify Onset of Abnormal Wear

2. PARTICLE IDENTIFICATION
   Microscopic & Analytical Analysis to Determine Origin & Severity

3. INTERPRETATION
   Analysis of All Data & Recommendations

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Wear Particle Analysis Instruments

Quantitative Analysis

- DR Ferrograph
When it comes to your machinery’s life, don’t guess.
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Ferrography

Direct Reading Ferrograph

- Produces two numbers DL and DS
- Trends data to identify the onset of abnormal wear
- Sensitive to ferrous particles only

\[ WPC = DL + DS \]
When it comes to your machinery’s life, don’t guess.

**WEAR PARTICLE CONCEN. ACCEPTANCE LIMITS**

<table>
<thead>
<tr>
<th>Machine Type</th>
<th>WPC Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuum Pumps</td>
<td>WPC = 1-5</td>
</tr>
<tr>
<td>Boiler Feed Pumps</td>
<td>WPC = 1-100</td>
</tr>
<tr>
<td>Gas Compressors</td>
<td>WPC = 1-20</td>
</tr>
<tr>
<td>Turbines</td>
<td>WPC = 1-20</td>
</tr>
<tr>
<td>Fans</td>
<td>WPC = 1-20</td>
</tr>
<tr>
<td>Journal Bearings</td>
<td>WPC = 1-20</td>
</tr>
<tr>
<td>Roller Bearings</td>
<td>WPC = 5-100</td>
</tr>
<tr>
<td>Engines</td>
<td>WPC = 10-150</td>
</tr>
<tr>
<td>Transmissions</td>
<td>WPC = 10-150</td>
</tr>
<tr>
<td>Extruder Gearboxes</td>
<td>WPC = 100-600</td>
</tr>
<tr>
<td>Dragline Gearboxes</td>
<td>WPC = 1,000-50,000</td>
</tr>
<tr>
<td>Hoist Gearboxes</td>
<td>WPC = 1,000-50,000</td>
</tr>
</tbody>
</table>

**DR General Acceptance Limits**
When it comes to your machinery’s life, don’t guess
When it comes to your machinery's life, don't guess
Wear Particle Analysis Instruments

**Qualitative Analysis**
- FM Ferrograph

*When it comes to your machinery's life, don't guess*
Wear Particle Analysis Testing

Ferrogram Maker

0.3x60mm Glass Substrate

< 0.5mm Ferrous Particles

-5mm | +5mm Ferrous Particles

Non-Ferrous Debris

EXIT END

Non-Wetting Barrier

Distance in mm

Flux Lines w/Debris

N Magnet Pole

Non-Magnetic Barrier, 2.5mm

S Magnet Pole

ENTRY POINT

When it comes to your machinery’s life, don’t guess
Wear Particle Analysis Instruments

Qualitative Analysis

- Ferroscope V

When it comes to your machinery's life, don't guess
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**Wear Particle Analysis System & Software**

- **Passport System V**

*Images of a laboratory setting with various equipment and a person working on a computer.*
When it comes to your machinery's life, don’t guess.

Particle types

- Normal Rubbing
- Severe Sliding
- Cutting
- Bearing
- Gear
- Sphere
- Black Oxides
- Red Oxides
- Corrosive
- Lube Degradation
- Sand
- Dirt
- Fibers
- Contaminant Spheres
Matching DR Results

WPC=10  WPC=50  WPC=100  WPC=500  WPC=1000

Results may not correspond in the case of massive water contamination

When it comes to your machinery’s life, don’t guess

PREDICT
Analytical Ferrography

Courtesy of Coastal Training
When it comes to your machinery's life, don't guess.

Identify Major Component

- Rubbing Wear
- Normal Wear
- Condition

- Corrosive Wear
- Aged or Oxidized
- Lubricant

- Black Oxides
- Lubricant
- Starvation

Looking for a predominance and an increase from the previous sample in one of these types of debris.

*When it comes to your machinery's life, don't guess.*
When it comes to your machinery's life, don’t guess.

**Particle Identification**

- Normal Rubbing Wear
  - Chains of small particles aligned with magnetic field

- Cutting Wear
  - Long curly strips

- Bearing Wear
  - Platelets with irregular edges

- Gear Wear
  - Scuffing & Scoring
When it comes to your machinery’s life, don’t guess.
Black Oxides

When it comes to your machinery’s life, don’t guess.
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Black Oxides
When it comes to your machinery’s life, don’t guess
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Fatigue Wear

Bearing wear - smooth edges, very thin

Gear wear - jagged edges, thicker

Spheres - fatigue spalling eminent
Red Oxides

When it comes to your machinery’s life, don’t guess
When it comes to your machinery’s life, don’t guess

Spheres

- Spherical Particles
- Usually 5-10 Microns in Size
- Indicative of Bearing Fatigue Prior to a Spalling Condition
- Black Circles with Shiny Centers
When it comes to your machinery’s life, don’t guess.
When it comes to your machinery's life, don't guess

Bearing Wear

Copper Alloy

Steel Prior to Heat Treatment

Low Alloy Steel

Lead/Tin Babbitt Metal

When it comes to your machinery's life, don't guess
Heat Treatment Procedures

- All slides should be heat treated if large or marginal particles are detected
- Monitor temperature of hot plate to ensure temperature of 330°C, + or - 10°C
- Maintain slide on hot plate for at least 90 seconds to ensure saturation of oxide layer growth
When it comes to your machinery’s life, don’t guess

Low Alloy Steel

- Inclusion of small amounts of alloys
- Blue Color
Cast Iron / Medium Alloy Steel @ 330°C

Inclusions on the surface

⇒ Less area for ion formation
• Less oxide growth

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Equipment Condition Report (cont)

DISCUSSION:
This picture shows the large concentration of copper alloy (bronze) severe sliding wear particles detected near the exit end of the Ferrogram. These particles measure up to 160 microns in size and indicate an abnormal sliding contact, possibly originating from a bearing retainer or bushing.

Photographic Support:
- Magnification: 500x
- Light: White reflected and green transmitted
- Location: 50mm from entry end
- Reticle Division: N/A
When it comes to your machinery's life, don't guess.
EMS Products & Services

- Laboratory services
- Refrigerant analysis
- Vibration analysis
- Surveys & assessments
- Sampling ports & kits
- Id tags
- Vibration instruments & accessories
- Collection services
- Oil safe containers
- Thermography
- Ultrasound
- Integrated reporting

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Case Studies
Mullor Gearcase

Industry: Steel Foundry

COMPONENT:
- Mullor Gearcase; Model: #85B

ANALYSIS:
- Critically high wear rate.
- Large quantities of copper alloy & low alloy gear wear particles particles ranging up to 130 microns in size.

RESULT:
- Inspection revealed pinion gear disintegrated.
- Gearbox was replaced.
- $10,000 Savings for replacement.
- Unscheduled downtime was estimated at $50,000 per day.

When it comes to your machinery’s life, don’t guess
**Motor & Pump Assembly**

**Industry: Fossil Power Plant**

**COMPONENT:**
- Condensate Vertical Pump

**ANALYSIS:**
- Unit rated Critical due to fatigue spheres and bearing wear particles composed of high alloy steel
- Inspection of the bearings recommended

**RESULT:**
- All bearings checked and revealed spalling of the inner race and rolling elements.
- Savings of over $80,000 occurred due to timely inspection

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World Class Predictive Maintenance Solutions

That Works for You