Presentation to:
Western Mining Electric Association
• World’s Largest Database of Test Records
  • 4,000,000 Customer Transformer Test Records.

• World’s Leading Reclaimer of Transformer Oil
  • Over 1 Billion Gallons Processed.

• Wrote the Book on Transformer Maintenance
  • The Transformer Maintenance Guide.

• Oil Testing Diagnostics – Unequaled
  • Over 300,000 Samples Annually.
Our Services

- Analytical Services
- Substation Services (SDMI International)
- Engineered Products (SDMI International)
- SDMI Solutions
- PCB Disposal Services – (SDMI International)
Analytical Services

- On-Line Transformer Testing & Software
- In-Service Insulating Liquid and Solid Insulation Analysis
- Electronic Data Management
- Services for Sampling, Testing, Analysis, Interpretation and Recommendations

SDMI Facts:

World’s Largest Database of Test Records

SDMI Facts:

Unequaled Oil Testing Diagnostics
Engineered Products (International)

- Oil Reclamation Systems
- Transformer Dry-Out Systems
- Vacuum Oil Purifiers
- PCB Process Solutions
SDMI Solutions

- University & TMI
  - Seminars
  - Transformer Maintenance Guide
  - e-training

- Consulting Services
  - Transformer Assessments
  - Management & Operational Services
  - Oil Processing Specifications
  - Onsite Supervision for Field Service and Transformer Manufacturing
Craig Schley
Corporate and International B.D.
TLES Services
What Keeps Your Transformers Humming?

- Transformer Insulating System
- Oil
- Paper
OIL!

- Acts as a Coolant
- Provides Dielectric Strength
- Protects the Paper
- Used as Diagnostic Tool
Stages of Oil Oxidation
PAPER!

PROVIDES...

- Mechanical Strength
- Dielectric Strength
- Dielectric Spacing
Properties of Kraft Paper

- Mechanical strength 117,000 kPa (17,000 psi)
- Dielectric strength 1000 volts/mil (1600 volts/mil when oil impregnated)
- Cost Effective
“Death” of Kraft Paper

End of Life Equals . . .

• 75% loss of tensile strength

• 200 degree of polymerization
Solid Insulation

• The life of the insulation is the life of the transformer.
• Insulation is the weakest link in the transformer.
• Insulation system is the most important part of the transformer to maintain.
• Requires early and prompt attention.
<table>
<thead>
<tr>
<th></th>
<th>DP</th>
<th>Tensile (kPA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New paper</td>
<td>1,200</td>
<td>117,000</td>
</tr>
<tr>
<td>New paper in a new transformer</td>
<td>1,000</td>
<td>105,000</td>
</tr>
<tr>
<td>End of reliable life</td>
<td>200</td>
<td>30,000</td>
</tr>
</tbody>
</table>

Relationship: DP to Tensile Strength
Paper weakens as it ages

- What causes cellulose molecules to depolymerize?
  - Heat
  - Oxygen
  - Water
  - Oil oxidation by-products
WHAT HAPPENS?

- Untreated, your oil will attack the paper and drastically cut short the life of your transformer.

- Oil tests reveal the condition of the oil, paper and therefore the transformer.
0.05 ACID 750x MAGNIFICATION
0.10 ACID 750x MAGNIFICATION
0.15 ACID 750x MAGNIFICATION
Liquid Screen Test: Acid
Curve Showing Absorption Effect of Paper on Acid

**Oil Without Copper Wire**
Oil, when aged alone shows a low level of decay products.

**Oil + Copper Wire without Paper Insulation**
When copper is placed into the oil, as in a transformer, it acts as a catalyst and the oil aging rate is greatly increased.

**Oil + Paper Wrapped Copper Wire**
When paper is wrapped around the copper, as is in a transformer, the aging still occurs, but the decay products go into the paper insulation.
Can We Solve the Problem by Changing the Oil?
Immediately After Changing The Oil . . .
0.30 ACID 750x MAGNIFICATION
THE SOLUTION...

- Remove the sludge, water, etc... from the oil and the PAPER.

- Extend the useful life of the transformer.

- Perform the work while energized.

- Minimize unplanned downtime.
OIL RECLAMATION
1. Filter oil through 0.5 micron filter.
2. Heat oil up to 200 F - turning it into solvent.
3. Filter with Regenerative Fullers Earth (FLUI DEX) to remove oxidation by-products.
4. Apply vacuum to remove moisture and gases.
NEW OIL 750x MAGNIFICATION
HOW IT WORKS...

Multiple passes of transformer oil through heat, vacuum and fullers earth returning the oil to near virgin condition and cleaning the paper.
WHEN TO RECLAIM . . .

• Before the oxidation inhibitors are depleted.
• While the oil is still in good condition.
• WHY? The oil is filtered through the paper, removing contaminants. While the oil still appears clean, the paper is actually gathering sludge and deteriorating.
Inhibitor Content Test

Life of New Oil as Relates to Inhibitor Depletion

- Acid x 1000
- IFT x 10
- DBPC x 1

Hours of Oxidation

A  B  C  D
How do we get started?
Testing Insulating Liquids

- Nameplate Information
- Visual Inspection and Representative Sample
- Laboratory Analysis
- Interpretation of Results
- Review and Clear, Understandable Recommendations
- Maintenance Acceptance Report
- Project Management
What oil testing is done?

- Testing new oil.
- Testing oil in newly installed transformers.
- Testing of in-service oil.
  - Routine and non-routine
  - Monitoring
  - Diagnostic
Testing new oil.

- Qualifying new suppliers.
- Buying oil for especially large, expensive, or critical units.
- Acceptance testing.
Testing oil in new equipment.

- Confirm quality of oil used.
- Confirm proper processing and installation of oil.
- Confirm internal cleanliness of electrical equipment.
- Confirm proper operation for first hours, days, weeks of service.
Testing in-service oil.

• First routine interval.
• Purposes of routine testing:
  – Oil aging and oxidation
  – Contamination
  – Routine monitoring or operation
  – Evaluate condition of solid insulation
• How well is the oil continuing to fulfill its functions?
• Non routine testing.
Four Functions of Insulating Liquids:

- Protect the Paper Insulation
- Provide Dielectric Strength
- Provide Heat Transfer (Cooling)
- Testing Serves as a Diagnostic Tool for the Condition of the Equipment
Routine Oil Testing
(in-service)

- Liquid Screen Tests
- Liquid Power Factor @25 and 100C
- Oxidation Inhibitor
- Moisture Content
- Dissolved Gas Analysis
Liquid Screen Tests

• Neutralization Number
• Interfacial Tension (IFT)
• Specific Gravity
• Color and Appearance
• Dielectric Breakdown Strength
Liquid Screen Tests (Monitoring tests)

- Neutralization Number and IFT measure oil aging and oxidation.
- Specific Gravity and dielectric primarily look for contamination by materials other than moisture.
- Color and Appearance tests are done mostly to identify unusual conditions.
Liquid Power Factor
(Monitoring test)

- Run at 25 °C and 100 °C.
- Good clean, dry insulating liquid has a low liquid power factor.
- Oil aging and oxidation, moisture, and contamination all increase liquid power factor.
- Observing the trend of the values at two temperatures aids determination of the cause of elevated liquid power factor.
Oxidation Inhibitor Content (Monitoring test)

- Almost all new mineral oil is inhibited.
- Uninhibited oil has inhibitor content less than 0.08%.
- Canada standard is 0.4% inhibitor; rest of North America is 0.3%.
- Under normal circumstance, active inhibitor content will prevent the start of oil oxidation.
Moisture Content
(Monitoring test)

- Modern transformer operate at very low moisture levels.
- Free-breathing transformers typically use desiccant breathers.
- Low ppm content are advisable, but this information alone is not adequate for maintenance.
- Use oil temperature data at time of sampling to calculate % saturation and % moisture by dry weight.
Moisture Content Calculations

- % Saturation
  How much moisture is in the oil compared to how much moisture it can hold.
- % Saturation is a measure of the risk of dielectric failure due to formation of free water in the transformer.
Moisture Content Calculations

- % Moisture by Dry Weight
  Calculated water content of the solid insulation.
  Correlates well to insulation power factor electrical tests.
  % M/ DW affects insulation life.
  Double the moisture content doubles the aging rate.
  Higher % M/ DW also indicate much more difficult task to dry out unit.
Dissolved Gas Analysis
(Diagnostic test)

- Abnormal operation of transformers cause combustible fault gases to form and to dissolve in the oil.
- Dissolved gas analysis extracts and analyses these gases.
- Qualitative and quantitative tools are used to interpret the results.
- A complete DGA includes a diagnosis and a recommendation for the next appropriate action.
Non-Routine Diagnostic Testing

- Furan Analysis
- Dissolved Metals
- PCB Analysis
- Corrosive Sulfur
- Particle Count Distribution
- Particles and Filming Compounds
Special testing:

- Corrosive sulfur
- Particle count distribution analysis
- Particles and filming compounds analysis
- Others
Results Master

- Liquid Screen
- Liquid Power Factor
- Karl Fischer
- Gas in Oil
- Metals in Oil
- Inhibitor
- Furan
- PCB
# Transformer Moisture Content

**Karl Fischer Testing**

**Moisture Content in PPM**

<table>
<thead>
<tr>
<th>Date</th>
<th>Temp (C)</th>
<th>PPM</th>
<th>PCT.</th>
<th>MOIST./DRY WGT.</th>
<th>GRADE</th>
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<tbody>
<tr>
<td>03/07/1999</td>
<td>29</td>
<td>36</td>
<td>45</td>
<td>3.78</td>
<td>D</td>
</tr>
<tr>
<td>03/07/2000</td>
<td>29</td>
<td>36</td>
<td>45</td>
<td>3.78</td>
<td>D</td>
</tr>
<tr>
<td>03/07/2001</td>
<td>31</td>
<td>12</td>
<td>14</td>
<td>1.14</td>
<td>A</td>
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<tr>
<td>03/07/2002</td>
<td>31</td>
<td>12</td>
<td>14</td>
<td>1.14</td>
<td>A</td>
</tr>
<tr>
<td>03/07/2003</td>
<td>31</td>
<td>12</td>
<td>14</td>
<td>1.14</td>
<td>A</td>
</tr>
</tbody>
</table>

**Furan Analysis**

**Expression in PPM**

<table>
<thead>
<tr>
<th>Date</th>
<th>(SHF2)</th>
<th>2FOH</th>
<th>2FAL</th>
<th>2ACF</th>
<th>5M2F</th>
<th>TOTAL</th>
</tr>
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<tbody>
<tr>
<td>03/07/1999</td>
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<tr>
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<tr>
<td>03/07/2001</td>
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<tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
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</tbody>
</table>

**Recommendation**

- Calculated DP: 800
- Est. Life Remaining: 100%

**Gas-in-Oil Analysis**

**Gas Chromatography Expression in PPM**

<table>
<thead>
<tr>
<th>Date</th>
<th>Hydrogen</th>
<th>Oxygen</th>
<th>Nitrogen</th>
<th>Methane</th>
<th>Carbon Monoxide</th>
<th>Carbon Dioxide</th>
<th>Ethane</th>
<th>Ethylene</th>
<th>Acetylene</th>
<th>Total Combustible Gas</th>
<th>Total Gas</th>
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</thead>
<tbody>
<tr>
<td>03/07/1999</td>
<td>48.3</td>
<td>10.0</td>
<td>4.5</td>
<td>7.4</td>
<td>2.1</td>
<td>6.2</td>
<td>2.3</td>
<td>1.1</td>
<td>1.2</td>
<td>66.1</td>
<td>77.4</td>
</tr>
<tr>
<td>03/07/2000</td>
<td>48.3</td>
<td>10.0</td>
<td>4.5</td>
<td>7.4</td>
<td>2.1</td>
<td>6.2</td>
<td>2.3</td>
<td>1.1</td>
<td>1.2</td>
<td>66.1</td>
<td>77.4</td>
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<td>03/07/2001</td>
<td>48.3</td>
<td>10.0</td>
<td>4.5</td>
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<td>77.4</td>
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<tr>
<td>03/07/2002</td>
<td>48.3</td>
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<td>1.2</td>
<td>66.1</td>
<td>77.4</td>
</tr>
</tbody>
</table>

**Recommendation**

- Retest in 1 year
- No significant increase in the combustible gas volume.

**Inhibitor Content**

**Liquid Screen Test Data**

<table>
<thead>
<tr>
<th>Date</th>
<th>Service</th>
<th>Acid</th>
<th>IFT</th>
<th>DIOL 077</th>
<th>DIOL 1016</th>
<th>COLOR</th>
<th>SP. G.</th>
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<tbody>
<tr>
<td>03/07/1999</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
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<tr>
<td>03/08/2000</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
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<tr>
<td>03/09/2001</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
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<tr>
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</tbody>
</table>

**ICP Metals-in-Oil Expression in PPM**

<table>
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<tr>
<th>Date</th>
<th>Al</th>
<th>Fe</th>
<th>Ni</th>
<th>Cu</th>
<th>Other</th>
<th>Total</th>
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**PCB Content Expression in PPM**

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<td>0.05</td>
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</tbody>
</table>

**Recommendation**

No PCB detected.

**Key to Abbreviations:**
- AC: Acceptable
- QU: Questionable
- UN: Unacceptable
Any Questions?