RECLAMATION OF MINERAL INSULATING OIL

Experience of EOS
Recycling Used Mineral Insulating Oils

- Challenging Environment
- EOS - Who we are
- Operating Environment
  - UK Power Transmission System
- History
- Regulations
- Definitions & Standards
- Closed-Loop Business Model
- Developments & Trends
- In-situ treatment option
- The Future
- Conclusions
Utilities are under increasing pressure to meet regulatory targets for both environment (2020) and cost efficient energy supply.

Legal and other environmental requirements such as ISO 14001 and Waste Hierarchy obligations now necessitate waste management and the options of recycling used oil responsibly or treating insulating oils to extend use.

Based on the continued focus on environmental awareness, increased regulations, cost restraints and effectiveness in managing key assets it is important to review the options available to asset managers.

Increased need to manage renewable sources of generation in the network.

A key factor in recent years has been transformer life extension and the various options to effectively manage insulating oil in a responsible manner.

Reclaiming transformer oil is a well-established proven and trusted method in the UK to meet all these objectives.
EOS: Who we are

- Leading supplier of insulating oils and services in the UK
- 60 year history/experience
- 20,000mt/a static reclamation plant at Stanlow
- Collect and reclaim up to 15,000mt/a of UTO
- Manufacture RTO to BS148 STD
- Recondition and regenerate oil-in-service on-site (in-situ)
- Provide sample analysis and technical support in transformer oil management
Central Location

- Collection, storage, reclamation and distribution of transformer/insulating oils.
- Dedicated Transformer Oil Reclamation Plant
- 60 Storage tanks. (15,000m³)
- PCB-Removal Plant
- Base for 4 x Reconditioning units, 2 x Mobile Regeneration units & 1 x Hybrid(Regen & Recondition)
Key Activities

- **Processes**
  - Transformer Oils reclamation through
    - Bauxite Clay Column Percolation
  - PCB Removal
  - Degassing
  - Drum Receipt and Filling

- Good level of investment and maintenance to meet Operating License conditions.
- Excellent SHE performance and QA management required
UK Power Transmission System

Simplified UK Electrical Power Transmission system
Electricity Supply Network

- 38 Major power producers (85GW)
- 3 Transmission Operators (275kV and 400kV transmission)
  - National Grid (England & Wales)
  - Scottish Power (Southern Scotland)
  - Scottish Hydro (Northern Scotland)
- 14 Licensed DNOs (132kV down to 11kV and 240V in homes)
Electricity consumption increased by ~150% between the post war nationalisation of the industry in 1948 and 1965.

During the 1940s some 90% of the generating capacity was fired by coal, with oil providing most of the remainder.

The United Kingdom started to develop a nuclear generating capacity in the 1950s with 26% of the nation's electricity generated from nuclear power at its peak in 1997.

Starting in 1993, a combination of factors led to a so-called Dash for Gas, during which the use of coal was scaled back in favour of gas-fuelled generation due to the availability of cheap gas from the North Sea. In 1990 just 1.09% of all gas consumed in the country was used in electricity generation; by 2004 the figure was 30.25%.

From the mid-1990s new renewable energy sources began to contribute to the electricity generated.

In 2014, total electricity production stood at 335 TWh (down from a peak of 385 TWh in 2005), generated from the following sources:

- Gas: 30.2% (0.05% in 1990)  
  Coal: 29.1% (67% in 1990)
- Nuclear: 19.0% (19% in 1990)  
  Wind: 9.4% (0% in 1990)
- Bio-Energy: 6.8% (0% in 1990)  
  Hydroelectric: 1.8% (2.6% in 1990)
- Solar: 1.2% (0% in 1990)  
  Oil and other: 2.5% (12% in 1990)

The United Kingdom is planning to reform its electricity market. It plans to introduce a capacity mechanism and contracts for difference to encourage the building of new generation.
Regulations, Directives & Targets

- **The Renewable Energy Directive 2009/28/EC:**
  - European Union directive which mandates levels of renewable energy use within the European Union. Sets a target for the UK to achieve 15% of its energy consumption from renewable sources by 2020. This compares to only 1.5% in 2005 and 8.3% in 2015.

- **OFGEM:**
  - Sets price, efficiency, investment and environmental controls for ESI

- **Waste Management:**
  - The Waste(England and Wales) Regulations 2012; Ensure waste undergoes recovery operations on technical, environmental & economic basis.

- **Health & Safety**
  - Responsible Care
  - OHSAS 18001

- **Environmental & Energy**
  - ISO 14001 Standard to prove “GREEN” credentials
  - Environmental Protection Act
  - Duty of Care Regulations
Site Regulations

Health & Safety
- Structured safety management system
- Responsible Care
- OHSAS 18001

Environmental & Energy
- Consent to discharge trade effluent via United Utilities
- Environmental Permit under IPPC
- ISO 14001
- ISO 50001 will be implemented in 2016

Quality assurance
- ISO 9001
Definitions and Standards in the UK

- **Recycling**: Generally refers to reconditioning, reclaiming or re-refining
  - Reconditioning: Oil that is filtered, dehydrated and degassed. Usually on-site where a processing unit is connected to the transformer.
  - **Reclaiming**: Oil that has been dehydrated, degassed and filtered with bauxite or clay to remove polar contaminants. This process can be done on-site or remote from the transformer at a static plant after collection.
  - Re-refining: Oil that has been collected and subjected to some refining processes e.g. hydro treating at a remote location.

- **Standards**:
  - **BS148:2009** – Standard for reclaimed mineral insulating oils
  - **IEC 60296** – Standard for unused mineral insulating oils
  - **IEC 60422** – Mineral insulating oils in electrical equipment — Supervision and maintenance guidance
Closed-Loop Business Model (1)

Basic Principle: Collect all Used Transformer Oil (UTO) from customer sites (drums & bulk), transport to Stanlow, reclaim to BS148:2009 standard and deliver back as required.

- **Road Transport**
  - UTO and reclaimed product are transported to and from Stanlow Manufacturing Centre via drums or road tanker (40:60).
  - When the tankers collect UTO from customers, it is classed as hazardous waste and requires a hazardous waste consignment note.
  - Transport companies require a hazardous waste carrier licence.
  - Collect and reclaim up to 15,000mt/a of UTO
  - 20,000mt/a static *reclamation* plant at Stanlow
Closed-Loop Business Model (2)

Stanlow Manufacturing Centre

- **Percolation and Degassing**
  - UTO is passed through bauxite columns (aluminium oxide) to remove impurities.
  - The next process stage, passes the clean oil through degassing units to remove CH gases, at which point the oil is classed as finished product.

- **Regeneration**
  - The bauxite columns need regular reactivation. Heat and air are passed through the oil soaked bauxite. The air absorbs the contaminated materials within the column, is emitted at the bottom of the columns and then cooled before being discharged via a stack.

- **Final Product to BS148:2009** only after meeting oxidation stability tests
Closed-Loop Business Model (3)

Quality Controls
- Dedicated lines & tanks
- On site testing & analysis of all UTO received due to waste management regulations
- End of waste testing
- Finished products are tested after processing and again at loading to guarantee all products meet specifications at the time of shipment.
UTO Feedstock QC

- The QC selection for UTO is based on:
  - Colour: If visibly poor or highly carbonated then we would segregate to waste or base oil feedstock
  - Metals: Any oil with metals content >10ppm is rejected to other process stream i.e. Base oil
  - Silicon: Any oil with content >10ppm is rejected to other process stream i.e. Base oil
  - PCB: Oil >10ppm PCB is rejected; borderline oil may be used for base oil. Oils above this would be segregated and removed from site to oil treatment facilities or, if >49ppm transfer to an incinerator.

- Segregation required to maintain good quality UTO pool and prevent damage to Bauxite columns
UTO Feedstock properties

- **Acidity**
  - Switchgear oil accounts for 60% of UTO pool
  - Most other oil from failed transformers or closure of power plants
  - Ranges from 0.03-0.009 mg KOH/g
  - Averages 0.06 mg KOH/g

- Not highly oxidised
- Good level of natural inhibitor retained
# RTO TO BS148:2009 Standard

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>UNIT</th>
<th>TEST METHOD</th>
<th>SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. PHYSICAL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appearance</td>
<td></td>
<td>IEC 296</td>
<td>Clear, no sediment</td>
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<tr>
<td>Viscosity @ -15°C</td>
<td>cSt</td>
<td>ISO 3675</td>
<td>800</td>
</tr>
<tr>
<td>Viscosity @ 40°C</td>
<td>cSt</td>
<td>ISO 3675</td>
<td>13</td>
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<tr>
<td>Closed Flash Point</td>
<td>ºC</td>
<td>EN 22719</td>
<td>135</td>
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<tr>
<td>Pour Point</td>
<td>ºC</td>
<td>BS 2000.15</td>
<td>-30</td>
</tr>
<tr>
<td>Density @ 20°C</td>
<td>Kg/dm3</td>
<td>ISO 12185</td>
<td>0.895</td>
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<tr>
<td><strong>2. CHEMICAL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutralisation value</td>
<td>Mg KOH/g</td>
<td>BS EN 6021-1</td>
<td>0.03</td>
</tr>
<tr>
<td>Corrosive Sulphur</td>
<td></td>
<td>BS EN 62535</td>
<td>Non corrosive</td>
</tr>
<tr>
<td>Polycyclic Aromatics mass</td>
<td>%</td>
<td>BS2000</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Part 346</td>
<td></td>
</tr>
<tr>
<td>PCB content</td>
<td>mg/kg</td>
<td>BS EN 61619</td>
<td>10</td>
</tr>
<tr>
<td>Water cont. Bulk Drums</td>
<td>mg/kg</td>
<td>BS EN 60814</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Oxidation stability at 120ºC</td>
<td>mgKOH/g wt %</td>
<td>BS EN 61125 C</td>
<td>1.2 0.8</td>
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<tr>
<td>164h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acidity after Oxidation Sludge</td>
<td></td>
<td>BS EN 61125 C</td>
<td>1.2 0.8</td>
</tr>
<tr>
<td><strong>3. ELECTRICAL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dielectric Dissipation Factor @ 90ºC</td>
<td></td>
<td>BS EN 60247</td>
<td>0.005</td>
</tr>
<tr>
<td>Breakdown Voltage</td>
<td>kV</td>
<td>BS EN 60156</td>
<td>30</td>
</tr>
</tbody>
</table>
Reclamation Developments

- **Changing Market environment:**
  - IEC 62701 was issued in March 2014 as a standard for Recycled mineral insulating oil but was retracted in 2015
  - Closure of Group 1 base oil plants created increased interest in naphthenic oils due to solvency requirements
  - Increased financial restraints-focus on cost reduction

- **Environmental Pressures to reduce PCB content:**
  - Duty of Care obligations
  - Operating Permit Conditions at Stanlow
  - Need to show movement from reduction of PCB to total elimination
  - Waste Hierarchy/ISO 14001
  - Health and Safety obligations under ISO 18001
New PCB Removal Facility

- Integrate Sea Marconi CDP dehalogenation process with EOS reclamation infrastructure
- Chemical elimination of PCB and potential reactive sulphurs
- Fully operational and producing a PCB-free transformer oil and/or base oils to requirements
- The reclaimed High Grade RTO meets all the properties as those required by unused oil as per IEC 60296
- Alternative insulating oil for all maintenance requirements in switchgear, tap changers and distribution transformers
# New High Grade Reclaimed Insulating Oil

<table>
<thead>
<tr>
<th>Property</th>
<th>BS148:2009</th>
<th>RTO (High Grade)</th>
<th>IEC60296:2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kinematic viscosity mm$^2$/s</td>
<td>ppm</td>
<td>≤ 13</td>
<td>≤ 12</td>
</tr>
<tr>
<td>40 °C*</td>
<td></td>
<td>≤ 800</td>
<td></td>
</tr>
<tr>
<td>−15 °C</td>
<td></td>
<td></td>
<td>≥ 135</td>
</tr>
<tr>
<td>−30 °C</td>
<td></td>
<td></td>
<td>≤ −40</td>
</tr>
<tr>
<td>Flash point, °C</td>
<td>ppm</td>
<td>≥ 135</td>
<td>≥ 135</td>
</tr>
<tr>
<td>Pour point, °C</td>
<td>ppm</td>
<td>≤ −30</td>
<td>≤ −40</td>
</tr>
<tr>
<td>Appearance</td>
<td></td>
<td>Clear, free from sediment and suspended matter</td>
<td>Non-corrosive</td>
</tr>
<tr>
<td>Density</td>
<td>kg/dm$^3$ at 20°C</td>
<td>≤ 0.895</td>
<td>≤ 0.895</td>
</tr>
<tr>
<td>Neutralization value</td>
<td>mg KOH per g of oil</td>
<td>≤ 0.03</td>
<td>≤ 0.01</td>
</tr>
<tr>
<td>Potentially/Corrosive sulfur DBDS</td>
<td></td>
<td>Non-corrosive</td>
<td>Not corrosive</td>
</tr>
<tr>
<td>Passivator content</td>
<td></td>
<td>Not detectable</td>
<td></td>
</tr>
<tr>
<td>Anti-oxidant additives</td>
<td></td>
<td>Not detectable</td>
<td></td>
</tr>
<tr>
<td>Water content, mg/kg</td>
<td>ppm</td>
<td>≤ 20</td>
<td>≤ 30 (&lt;10ppm typical)</td>
</tr>
<tr>
<td>bulk delivery</td>
<td></td>
<td>≤ 30</td>
<td>≤ 40 (&lt;10ppm typical)</td>
</tr>
<tr>
<td>drum delivery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxidation stability</td>
<td>ppm</td>
<td>≤ 1.2</td>
<td>≤ 1.2</td>
</tr>
<tr>
<td>-total acidity</td>
<td>mg KOH per g of oil</td>
<td>≤ 0.8</td>
<td>≤ 0.8</td>
</tr>
<tr>
<td>-sludge</td>
<td>% by mass</td>
<td>≤ 0.8</td>
<td>Max. 0,500</td>
</tr>
<tr>
<td>Breakdown voltage</td>
<td></td>
<td>Min. 30kV (typical 60kV+)</td>
<td>Min. 30 kV (typical 60kV+)</td>
</tr>
<tr>
<td>as delivered, kV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dielectric dissipation factor at 90 °C and 40 Hz to 62 Hz</td>
<td>ppm</td>
<td>≤ 0.005</td>
<td>≤ 0.005</td>
</tr>
<tr>
<td>Total PCB content</td>
<td>ppm</td>
<td>≤10ppm</td>
<td>Not detectable (&lt;2 mg/kg)</td>
</tr>
<tr>
<td>Total furans</td>
<td>ppm</td>
<td></td>
<td>Not detectable (&lt;0.05 mg/kg) for each individual compound</td>
</tr>
</tbody>
</table>
Advantages of High Grade RTO

- Meets the requirements of unused Insulating Oil to IEC 60296
- Can be use as a direct replacement for all maintenance activities
- Cost effective alternative to other insulating oils
- Fit for purpose for maintenance or refurbishment of oil-in-service replacements
- Looking to the future and the removal of existing/ tightening of standards
- Stable pricing in volatile markets
- Green benefits at a cheaper price
In-situ Regeneration-Oil Change alternative

- Technological advances
- Treats whole insulation system
- 15% of oil is in the paper thus “deep cleaning” effect
- Removes oxidation products and DBDS if present
- No outage required
- Less stress on the paper
- Cheaper and environmentally attractive-less chance of spills with lower Carbon-emissions
- Inhibitor added to extend life
When to Regenerate on-site?

- IEC 60422 suggested limits:
  - Acidity of 0.15 – 0.2
  - DDF of 0.1 - 0.2
  - IFT at 22 – 28
- Regenerate the oil and recondition
- Get oil back to “as new”
Case Study: 66kV Steel Works Transformer

- 10MVA Unit installed in 1959
- Contained 17,000litres of oil
- DP of paper was 420
- Acidity of 0.24mg KOH/g
- IFT of 22
- DDF of 0.23
- No history of faults and
- DGA “normal” for age
Results after in-situ regeneration

Post regeneration:
- Acidity of 0.02mg KOH/g
- IFT of 44
- DDF of 0.04
- Life extended
The Future

- Increased demand for recycling of used transformer oils in UK and EU
- GEIR (European Waste Oil Re-refining Industry Association) proposes:
  - By 2020 that 95% of waste oils be collected and
  - At least 65% be converted to reclaimed or re-refined oils and
  - By 2025 these targets be increased to 100% and 85%
- Proposing that targets be legislated
- Will assist in meeting CO2 Emission and environmental targets
- Reclamation and in-situ regeneration extended in Europe as green options
- The IEC needs to address lack of a standard since IEC 62701 was retracted. The Standards Management Board (SMB) has directed IEC TC 10 to incorporate recycled oil into the current IEC 60296 Standard for Unused oil based on its ability to meet the existing specifications with no reference to the oil source.
- Maintenance Team 38 (MT38) has been formed in IEC to perform the work mandated by SMB.
Legal and environmental requirements such as ISO14001 and Waste Hierarchy obligations necessitate recycling or treating in-service oils to extend transformer life.

Utilities are under increasing cost and regulatory pressure to meet environmental targets (2020) and cost effective energy supply.

Reclaiming the Used Transformer Oil to now “as new” oil meeting the property criteria of established standards such as BS148 and IEC 60296 is a viable alternative to oil changes and maintenance or refurbishment work on oil-filled switchgear, tap changers and distribution transformers.

Reclaimed or recycled transformer oil is a well-established proven, trusted and cost effective method to meet all key life extension objectives.
Thank you