

SC D1 – Materials and Emerging Test Techniques PS 3 - Testing, Monitoring and Diagnostics



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Methanol As a Paper Ageing Indicator for Oil/Paper Insulation Systems with Alternative Insulating Liquids

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Transformer Solid Insulation

- Cellulose based paper is used as conductor insulation due to their high abundance and sufficient mechanical strength
- Irreversible nature of paper-ageing makes paper insulation one of the main life-time deciding factors for the transformer
- Ageing state of paper can be measured through tensile strength or degree of polymerisation (DP)
- DP is a measurement of the average number of monomer units in the polymer
- DP of new paper can be about 1000 1200





T. A. Prevost and T. V. Oommen, "Cellulose insulation in oil-filled power transformers: Part I - history and development," *Electrical Insulation Magazine, IEEE*, vol. 22, no. 1, pp. 28-35, 2006.



Paper Ageing Indicators





Research Methodology

- Investigations were conducted on the ability to use methanol as an ageing indicator for insulation systems with alternative insulating liquids
 - Non thermally upgraded kraft paper test object
 - Gas-to-liquid (GTL) oil test object
 - It is an iso-parafinic hydrocarbon oil manufactured from natural gas (methane)
 - The oil has a higher flash point and much lower impurities than conventional mineral oil
 - Synthetic esters test object
 - It is a liquid manufactured synthetically by reacting alcohols and acids
 - Synthetic esters are bio-degradable and has a higher flash point than mineral oil
 - Mineral oil for reference
- Methanol in transformer oil was measured through an in-house method developed based on gas chromatography and mass spectrometry technique
- Experiments conducted include,
 - Oil-paper ageing experiments
 - Oil-only ageing experiments
 - Partitioning experiments



Methanol Measurement Technique



*youtube.com



Laboratory Ageing Experiment – Gas-to-liquid Oil

Background | Methodology |

Experiments

- DP of paper aged in the GTL oil reduced similar to that aged in the mineral oil
- Methanol in both GTL oil and the mineral oil varied in a similar manner





Variation of Methanol and 2-FAL in GTL Oil

- Variation of methanol and 2-FAL in the GTL oil against the DP of paper is similar to that in the mineral oil
- Methanol can be used as an early ageing indicator for paper ageing in GTL oil





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Laboratory Ageing Experiments – Synthetic Ester

- DP of the paper aged in the synthetic ester was similar/lower than to that of mineral oil
- However, methanol in the synthetic ester was higher than that in the mineral oil



Variation of DP of paper

Variation of methanol in liquid



Variation of Methanol and 2-FAL in Synthetic Ester

- 2-FAL in synthetic ester varied similar to that in mineral oil
- However, for similar paper ageing methanol in synthetic ester • was higher than in mineral oil



Variation of methanol and 2-FAL against DP of paper



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The University of Manchester

Partitioning of Methanol between Oil and Paper

- New oil prepared with ~5mg/kg of methanol was mixed with paper and left at room temperature to allow methanol to partition between oil and paper
- In mineral oil and GTL oil, only about 5% of methanol remained in oil, while in synthetic ester about 40% of methanol remained in oil
- Experiment was repeated at 60 °C and a significant increase in the remaining amount of methanol in oil was observed in the mineral oil and GTL oil





Methanol Generation From Oil

- Methanol production from oil was investigated through oil-only ageing experiments at 120 °C
- All the three oil types produced methanol during the ageing process
- However, the amount produced from oil was much lower than that produced from oil-paper ageing experiment conducted under same conditions





Methanol Generation due to Severe Oil Ageing

- A laboratory ageing experiment was conducted at 130 °C with an intermittent air supply to obtain severely aged oil samples
- An increase in the methanol production was observed at high acidity levels



Variation of methanol produced from oil against acidity in oil



Summary

It was confirmed that methanol can be used as an early ageing indicator for insulation systems with the gas-to-liquid oil and the synthetic ester

Variation of methanol in the gas-to-liquid (GTL) oil was similar to that in the mineral oil

For similar paper ageing level, methanol in the synthetic ester was higher than in the mineral oil due to a difference in the partitioning between oil and paper

It was found that the temperature plays a main role in the partitioning of methanol in the mineral oil and the GTL oil than in the synthetic ester

Apart from paper, oil can also generate methanol. The production of methanol from oil could depend on oil type, temperature and the ageing condition



Contributions

- CIGRE/ IEC Working Groups
 - CIGRE JWG A2/D1.46 Field experience with transformer solid insulating ageing markers
 - IEC 63025-1 Quantitative determination of methanol and other light alcohols in insulating liquids
- Journal and Conference papers (2 Journal papers and 6 conference papers)
 - S. Y. Matharage, Q. Liu, Z. D. Wang, G. Wilson and Ch. Krause "Aging Assessment of Synthetic Ester Impregnated Thermally Non-upgraded Kraft Paper through Chemical Markers in Oil," IEEE Trans. Dielectr. Electr. Insul., [In Press], 2018
 - S. Y. Matharage, Q. Liu and Z. D. Wang, "Ageing Assessment of Kraft Paper Insulation through Methanol in Oil Measurement," IEEE Trans. Dielectr. Electr. Insul., vol. 23, pp. 1589-1596, June 2016.



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