Specac Application Note

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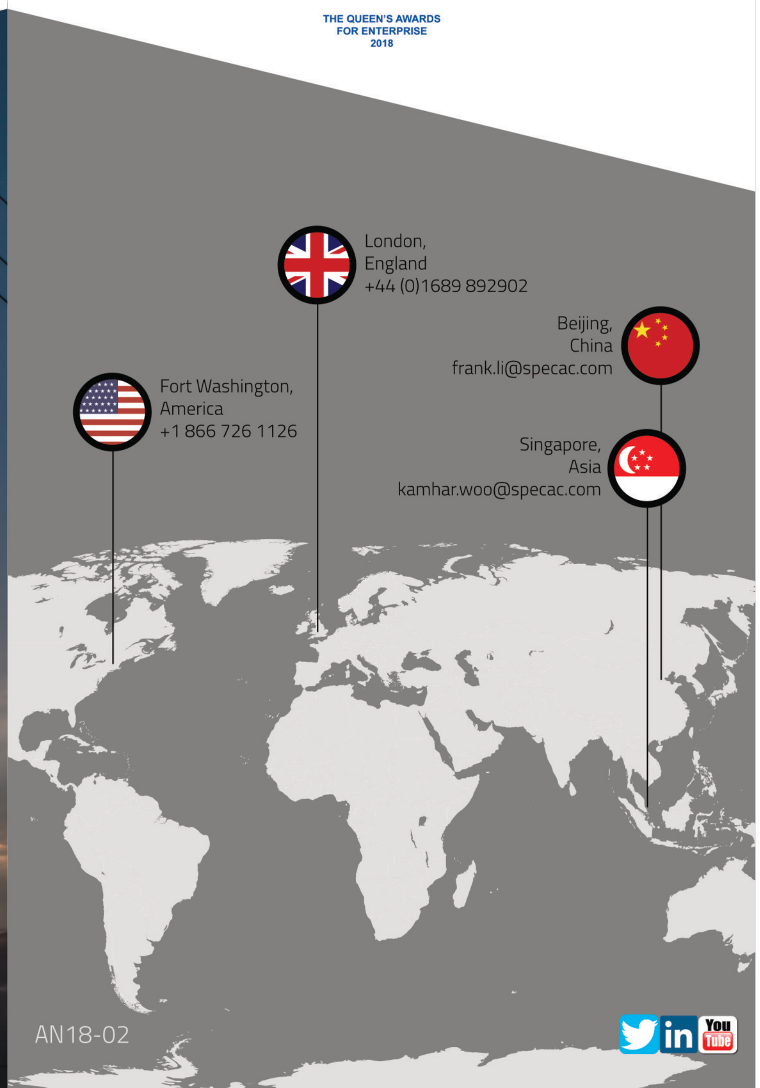
Analyzing the Breakdown of Mineral Oil Under Thermal Stress Using the Pearl™



Viscous substances such as transformer oils are sampled easily with the Pearl™. A consistent pathlength is achieved every time.

Mineral oils are employed as thermal and electrical insulators in many power transformers. Thermal and electrical stress over the lifetime of the transformer results in the chemical breakdown of the oil, which can be monitored using FTIR spectroscopy and principal component analysis (PCA).

These chemical changes are accompanied by changes in physical properties such as viscosity, making consistent and reliable sampling of the oils a challenge. In particular, achieving a consistent pathlength for FTIR analysis becomes challenging. Here the Pearl™ liquid transmission accessory, fitted with an Oyster Cell™, is advantageous as a consistent pathlength can be easily achieved even for the most viscous of oil samples.

Specac's Liquid Transmission Accessory, The Pearl™

Acknowledgement

Graeme Smith, AMRSC, a Ph.D. Student at Glasgow Caledonian University has provided the data, figures, and text forming the basis of this application note

Experimental

Mineral oil was purchased from Eden Transformer Oil and various samples were prepared to mimic the conditions found in transformers, where the oil is in contact with Kraft paper and copper. The samples were then subjected to thermal stress by placing them in a heat block at 120°C for 80 days. Samples were taken periodically, and the FTIR spectrum recorded to monitor the breakdown of the mineral oil using the Pearl™ in a commercially available spectrometer.

Oils in a liquid state are pipetted into the cell, while more viscous samples are spread onto the cell's CaF_2 window using a spatula. Closing the cell door ensures a consistent 100 µm pathlength.

Figure 1 shows the FTIR spectra obtained for various oil samples (with and without Kraft paper and/or copper) studied when the oil was kept at ambient temperature (Fig 1a) and at 120°C (Fig 1b). The samples kept in ambient conditions show very little change in their FTIR spectra. However, the peaks in the carbonyl (~1735 cm^{-1}) and aldehyde (~2723 cm^{-1}) regions were observed to increase over time when the samples were stored at 120°C. Spectra are normalised to the C=C stretch at 1600 cm^{-1} prior to statistical analysis.

Statistical Analysis

To further analyse the spectral data principal component analysis (PCA) was performed. PCA is a powerful statistical method that can reduce large data sets into a smaller number of components to allow for a better understanding of the factors affecting changes in the spectra. Figure 2 shows the principal component analysis score plot for the first two principal components.

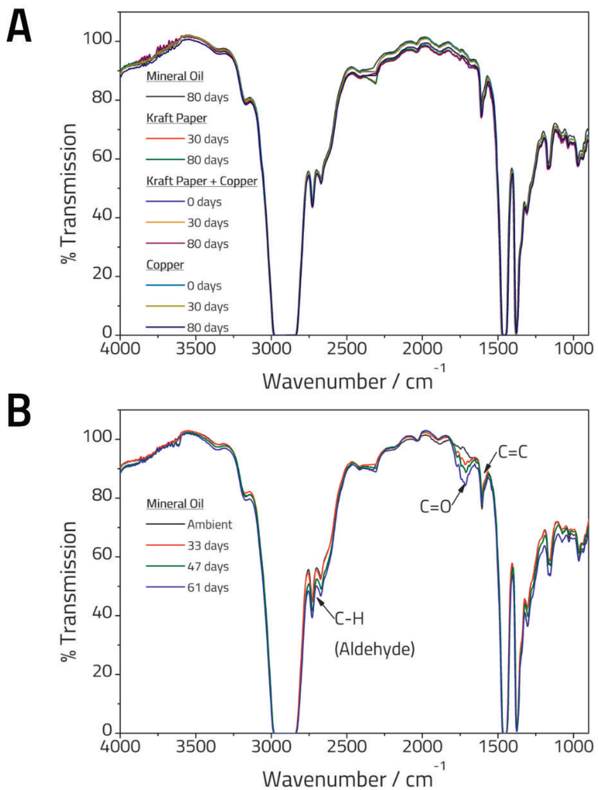


Figure 1 FTIR spectra of Mineral Oil over time (A) stored at ambient temperature (B) kept at 120°C

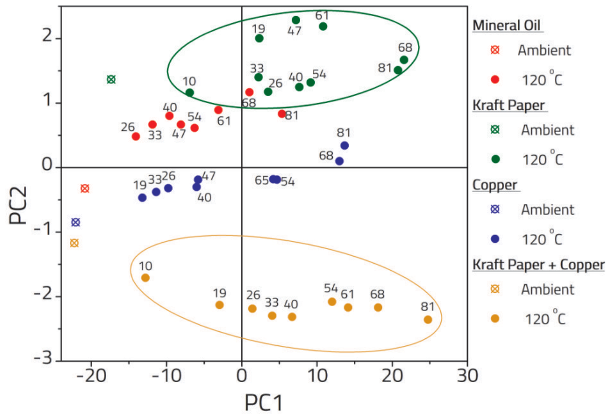


Figure 2: PCA scores plot of PC2 versus PC1 for the mineral oil samples C=O region.

Clear groupings of the data are obtained, highlighted in the figure. The first component is associated with the growth of the carboxylate acid group over time; the second component separates out the samples that have been exposed to different conditions. Samples containing Kraft paper (green circle) have a consistently higher value for PC2, which may be an indication of the cellulose components in Kraft paper dissolving into and reacting with the mineral oil. The samples containing both Kraft paper and copper (grey circle) have a negative value for PC2 which would suggest that copper acts as a catalyst.

Conclusion

The Pearl™ system is invaluable when attempting to record spectra of challenging samples such as mineral oils, whose viscosity increases over time and with greater amounts of thermal stress. The procedure of loading the sample and cleaning is easy and fast compared to traditional cells. Obtaining reliable spectra is essential for statistical analysis, whereby PCA was performed to aid with the identification of both time of exposure of the mineral oil to thermal stress and exposure to other materials within high voltage transformers.

References

[1] D. M. Hepburn, F. Waite, and I. J. Kemp, "Effect of metal and paper inclusions on mineral oil degradation," Conference Record of the 2004 IEEE International Symposium on Electrical Insulation, pp. 241-244, 2004.

[2] R. Blue and D. Uttamchandani, "Infrared Detection of Transformer Insulation Degradation Due to Accelerated Thermal Aging," IEEE Transactions on Dielectrics and Electrical Insulation, vol. 5, no. 2, pp. 165-168, 1998..

[3] P. Verma, M. Roy, R. K. Tiwari, and S. Chandra, "Generation of furanic compounds in transformer oil under accelerated thermal and electrical stress," Proceedings - Electrical Insulation Conference and Electrical Manufacturing Expo, vol. 2005, pp. 112–116, 2005.