Moisture Tolerance and Asset Life Extension

Moisture Tolerance

MIDEL eN 1215 has a very high moisture tolerance. This means it can absorb far greater amounts of water than mineral oil and silicone liquid without compromising its dielectric properties. MIDEL eN 1215 can also consume water which may slow down cellulose ageing. In the case of mineral oil, there is a danger that this water will be released as condensation.

Why Moisture Tolerance is Important in Transformers:

- Dielectric strength - reduces as moisture content increases
- Rate of paper ageing - increases with higher moisture content
- Condensation during cool down - risk of release of free water from mineral oil

Dielectric Strength

Figure 1 shows the breakdown voltage at ambient temperature of MIDEL eN 1215, mineral oil and silicone liquid with increasing moisture levels. It clearly illustrates that even a small amount of water in mineral oil and silicone liquid cause a rapid deterioration in breakdown voltage. In contrast, MIDEL eN 1215 maintains a high breakdown voltage even when moisture levels exceed 300ppm.

Paper Ageing and Asset Life

The rate of paper ageing is directly related to water content. Various studies have shown that the lifetime of paper reduces by as much as a factor of ten for each extra 1% of water content in the cellulose. As the cellulose ages it releases water, thus accelerating the ageing process. Therefore it is vital that cellulose is kept as dry as possible.

Evidence from a number of studies with natural ester has demonstrated that this type of fluid keeps the paper drier and can enhance lifetime. The findings are summarized in Annex B of IEEE C57.154, published in 2012. This includes a unit life prediction for thermally upgraded paper immersed in natural ester, in comparison to mineral oil, as shown in figure 2.

By using the information in this standard, users can either extend the lifetime of transformers, or alternatively run at a higher temperature while maintaining the same life. With thermally upgraded paper the increase in temperature can be as much as 20°C, which in turn allows more compact transformer designs. Another way to use this benefit is to allow overloading of the transformer by up to 20%.

Figure 1 - **Breakdown voltage vs. moisture content at 20°C (IEC 60156 2.5mm)**

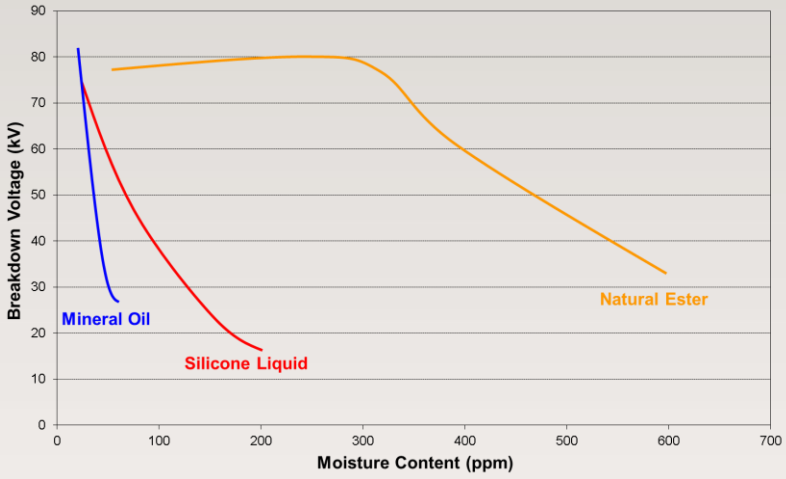
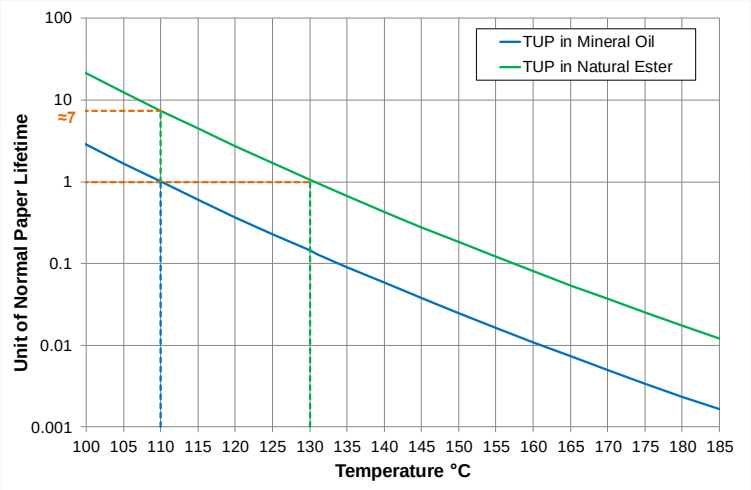


Figure 2 - **TUP Unit Life vs Temperature IEEE C57.154 Annex B**



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Condensation During Cool Down

With mineral oil there is a potential for water to be released when a transformer cools from operating temperature to ambient. This is because mineral oil has a low moisture saturation limit, which reduces as the temperature drops. MIDEL eN 1215 has a much higher saturation limit, which means that it is far more difficult to reach the saturation point.

For example if a transformer with mineral oil and a paper water content of 1.5% was running at 90°C the water content of the mineral oil would be 65ppm. If the transformer then shut down, the water would tend to stay in the mineral oil. At 20°C the saturation limit of mineral oil is 55ppm, so the mineral oil would be 118% saturated, releasing free water into the transformer. The breakdown voltage of the mineral oil will also be very low, increasing risk of failure when restarting.

Using the same example for MIDEL eN 1215 at 90°C the water content would be around 300ppm. The saturation limit for MIDEL eN 1215 at 20°C is 1100ppm, so even if all the water stays in the MIDEL eN 1215 it will only be 27% saturated. This means there would be no free water and still an excellent breakdown voltage.

Table 1 - **Standards for moisture content in equipment at ≤69kV**

Standard	Moisture Content
IEEE C57.147 – Natural Ester	max. 300ppm
IEEE C57.106 – Mineral Oil	max. 35ppm

Moisture Content Testing

Natural esters, such as MIDEL eN 1215 have a much higher affinity for water than mineral oil and this is reflected in the moisture content limits for the fluids. A comparison of the standard values relating to moisture content for new fluids are shown in Table 1. New MIDEL eN 1215, as delivered, is manufactured to very high standards with a typical moisture content of 50ppm.

The different water behavior of esters has practical implications for the interpretation of moisture level analysis between MIDEL eN 1215 and mineral oil in service. Users should be careful to apply the correct limits from guides such as IEEE C57.147. Also, if moisture-monitoring equipment is integrated within a transformer, it should be calibrated for natural ester and tolerance settings should be adjusted accordingly.

Moisture Removal

Should the moisture content rise above the maximum recommended in-service limit, the same methods and equipment that are used for removing moisture from mineral oil can also be used to remove moisture from MIDEL eN 1215. Dissolved water can be efficiently removed by the use of vacuum dehydration equipment, or by the use of molecular sieves.

For further advice on the moisture tolerance and asset life extension benefits of MIDEL eN 1215 please contact the MIDEL technical team on: mideltech@mimaterials.com.