DuPont™ Nomex® 910 Engineered Cellulose Insulation Thermal Aging Analysis

Summary

As previously announced, DuPont has been conducting long-term thermal aging studies of new Nomex® 910 engineered cellulose insulation. These studies are based on the recently revised IEEE C57.100™-2011, the “IEEE Standard Test Procedure for Thermal Evaluation of Insulation Systems for Liquid Immersed Power and Distribution Transformers.” After more than 10 months of aging work, DuPont has established that the thermal performance of new Nomex® 910 insulation is at least 10°C better than the industry standard thermally upgraded kraft paper (TUK) in mineral oil systems. These studies also indicate that new Nomex® 910 insulation may provide an additional 10°C performance enhancement in natural ester liquids. Based on Table 1 of IEEE C57.154™-2012, this performance enhancement translates to a system Thermal Class of 130 in mineral oil and 140 in natural ester liquids.

Background

Researchers at DuPont have developed a unique technology that combines Nomex® aramid ingredients with cellulose, using the superior thermal capability of Nomex® to improve the thermal capability of the combined product. Because the majority of the insulation is made from cellulose, the thermal improvement comes at a small increase in the price of the insulation, providing users with an attractive cost/performance ratio.

The introduction and final issuance of the two IEEE standards noted above have helped lead the way to a new portfolio of insulation materials for the liquid transformer industry. Nomex® 910 insulation is the first of those to be introduced by DuPont.

In what may be the first published report of aging results based on IEEE C57.100™-2011, an extensive evaluation was conducted of the industry standard system and new candidate systems using Nomex® 910 insulation. These reported results are based on sealed tube aging of more than 100 aging cells, involving at least six different system combinations, including systems with mineral oil and biodegradable liquids.

DuPont conducted aging tests at seven different temperatures vs. the minimum three temperatures required by the standard.

Sealed tube aging of the industry standard system of TUK and mineral oil at three temperatures resulted in an end-of-life target of approximately 16.3% of the original tensile strength. Under this version of IEEE C57.100™-2011, the end of life is now 180,000 hours, compared to the original value of 50% tensile retention at 65,000 hours. This system has an industry-accepted thermal index of 110°C when projected to 180,000 hours and a thermal class of 120.

Using this base point, the individual cell combinations were aged from four to six timeframes, with failure points beyond the base point. The data were then interpolated for each system temperature to arrive at the end-of-life times at the 16.3% target. Once these data were obtained, the life (Arrhenius) curve was then plotted with end-of-life vs. temperature. These curves were then projected to 180,000 hours to arrive at the thermal index of each system.

Conclusions

The Arrhenius curve for the Nomex® 910 insulation and mineral oil system is shown in Figure 1. The curve projects to a thermal index of 120°C at 180,000 hours for a thermal class of 130.

A comparison of these results to those for the industry-proven system (control) are shown in Figure 1.

![Figure 1](image-url)
This initial study was based on the distribution system material ratios found in Table B.1 of IEEE C57.100™-2011. A 7-mil (0.18-mm) thickness of Nomex® 910 insulation was used in this study because this thickness is representative of a common layer insulation used in the distribution industry.

Despite the fact that more solid material is in the same volume of liquid, the aging results with the 3-mil thickness of Nomex® 910 insulation were at least as good as those of the 7-mil (0.18-mm) thickness of Nomex® 910 insulation paper previously tested in the distribution transformer ratio. The interpolated time to 16.3% tensile strength at 180°C was nearly 50% higher (611 vs. 414 hours) in this aging experiment (see Figure 2). Based on these results, DuPont believes this shows at least equivalent performance.

Future Studies

Additional thermal aging analysis of Nomex® 910 insulation in several biodegradable liquids is in progress. Due to the superior thermal capability of Nomex® 910 insulation and the enhancement of the liquids over mineral oil, the end-of-life of these systems has far exceeded DuPont projections when the aging studies began. As a result, more testing at higher temperatures will be required to determine the thermal index in a reasonable amount of time.

Sealed tube materials ratios

<table>
<thead>
<tr>
<th>Material</th>
<th>Transformer Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulating Liquid</td>
<td>Power</td>
</tr>
<tr>
<td>0.05 to 0.10 mm</td>
<td>6.4 cm³</td>
</tr>
<tr>
<td>0.13 to 0.38 mm</td>
<td>11.2 cm³</td>
</tr>
<tr>
<td>1.00 to 3.00 mm</td>
<td>1.2 cm³</td>
</tr>
<tr>
<td>2.00 to 8.00 mm</td>
<td>16.4 cm³</td>
</tr>
<tr>
<td>Ratio—liquid to solid</td>
<td>8.8 to 1</td>
</tr>
</tbody>
</table>

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