

Material Compatibility

This section discusses the important subject of material compatibility between transformer materials that have continuous or intermittent contact with the dielectric coolant.

Within this section, the following documents are found:

- **Reference Guide:** A listing of all 87 typical transformer materials tested
Conclusion: In all cases, tested materials that are compatible with mineral oil are compatible with FR3 fluid.
 1. **Elastomers:** In general, elastomers and oils react when in contact. However, FR3 fluid, like mineral oil, is compatible with nitrile gasket materials. Gaskets immersed in FR3 fluid tend to shrink about 5% versus swell 5% in mineral oil. The results vary with the different compound formulations found in nitrile gasket manufacturers, and sometimes from lot to lot from the same manufacturer; these volume changes are acceptable for static, flat gasket seals.
 2. **Insulating Paper** had a significant reduced degradation rate aged in FR3 fluid.
- **CPS Test Report:** Transformer Fluid Compatibility Testing of EPDM rubber.
Conclusion: FR3 fluid is significantly less aggressive than mineral oil in contact with both semi-conductive and non-conductive EPDM jacket material. For example, the percent volume change was 5% to 7% compared to 162% to 202% respectively.
- **Comem Letter of Approval:** Comem S.p.A. accessories are compatible with Envirotemp FR3 fluid.
- **CPS Bulletin:** Insulating Paper Aging Comparison. This bulletin contains several photos of aging test specimens. Testing was performed per IEEE C57.100 Normative Annex.
Conclusion: The visual difference after aging is striking, and is relative to the measured resulting tensile strength.
- **CPS Reference Information:** Cellulose Interaction with Envirotemp FR3 Fluid. This technical bulletin offers theory and confirming test results on the molecular level processes that reduce the aging rate of immersed insulating paper by a factor of 5 to 8 times when tested per the IEEE method.
Conclusion: The study provided scientific evidence that the paper is chemically enhanced due to hydrolysis of FR3 fluid and transesterification of the cellulose from by-products of the hydrolysis.
- **IEEE/PES 1999 T&D Conference Paper:** Fire Resistant Natural Ester Dielectric Fluid and Novel Insulation System for Its Use. This paper reported the results of accelerated life test per IEEE C57.100 main method, a.k.a. the Lockie Method. **Conclusion:** The FR3 fluid filled transformers exceed the minimum life

requirements by an average 400%, indicating dramatic reduction of insulating paper aging rate and improved maintenance of dielectric properties.

- **IEEE/PES 2001 T&D Conference Paper:** Aging of Paper Insulation in Natural Ester Dielectric Fluid. This paper reported the results of the relative rate of insulating paper aging test per IEEE C57.100 Normative Annex method, a.k.a. the Sealed Tube Aging Method.

Conclusion: Using this method, paper aged in FR3 fluid aged at a rate 5 to 8 times slower than in mineral oil. A hypothesis on why the aging rate was so reduced also appeared in this paper.

- **IEEE ICDL Conference Paper:** Aging of Kraft Paper in Natural Ester Dielectric Fluid. This paper reported the results of the testing non-thermally upgraded Kraft paper, the type typically used in IEC standard transformers, per IEEE C57.100 Normative Annex Method.

Conclusion: Non-thermally upgraded Kraft insulating paper, which is typically limited to 55°C rise designs, showed at least a magnitude longer to reach IEEE end-of-life conditions in natural ester than in conventional mineral oil.

- **Additional IEEE conference technical papers on insulating paper aging rate reduction, including:**
 - Test on cotton/Kraft blend paper
 - Impact of retrofilling insulating paper aged in mineral oil with FR3 fluid
 - Additional details on the interaction mechanisms
 - Effect of FR3 on insulating paper water content
 - Comparisons of test results: Tensile Strength vs. Degree of Polymerization