



TRANSFORMERS • SERVICE • TRAINING • COMPONENTS

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**WAUKESHA ELECTRIC SYSTEMS'
POSITION ON DE-RATING EXISTING TRANSFORMERS RETROFILLED WITH
ENVIROTEMP™ FR3™ FLUID**

History

As of the date of this writing, dozens of existing medium and large power transformers, initially designed and tested with mineral oil, have been field retrofilled with FR3 fluid. The largest unit to date is 200 MVA and the highest voltage is 230 kV. Applications have been at generation plants, transmission inter-tie substations, distribution substations and industrial plants. Typically these transformers have not required de-rating after retrofilling.

The cooling characteristics of FR3 fluid are somewhat different than mineral oil. The primary difference is the viscosity of FR3 fluid is higher than mineral oil so it does not flow as fast and therefore does not conduct heat away from the windings as quickly as mineral oil. Therefore a transformer designed for mineral oil and filled with FR3 fluid will typically operate at a somewhat higher temperature rise.

Typical temperature rise calculation programs use a database of existing designs correlated with heat run test data. Multiple linear regression equations are derived from this database and reasonable estimates of temperature rise can be made as long as the new design has all of the same characteristics as the units in the database. If you change something fundamental such as the cooling medium, then the existing data is no longer useful for calculating the temperature rise of a new design with a fluid other than what was included in the transformers in the database. Waukesha Electric developed a temperature rise calculation program that starts with the basic fundamentals of thermodynamics and heat transfer. The fluid characteristics can be changed to those of FR3 fluid and temperature rise calculations can be made more accurately for transformers filled with FR3 fluid.

Waukesha Electric examined 25 existing designs that have been built and temperature rise tests were performed. The temperature rise calculation program was modified for the FR3 fluid characteristics and the temperature rise calculations were redone. The lowest temperature rise was less than 3°C higher than with mineral oil and the highest was less than 19°C higher than with mineral oil. Combing the calculations for all of the LV and HV windings, 86% of the hottest spot winding temperature rises were less than 15°C higher with FR3 fluid than with mineral oil.

Waukesha Electric Position

If the transformer operates at a higher temperature rise, shouldn't you de-rate it? Not necessarily. Cooper Power Systems has conducted accelerated life testing based on IEEE C57.100 for insulation systems, and developed the A and B factors for FR3 fluid and thermally upgraded paper. Based on these factors, the aging rate of cellulose paper insulation in FR3 fluid is dramatically reduced when compared with mineral oil. Furthermore, cellulose can operate in FR3 fluid as high as 21°C hotter and maintain the same aging rate as mineral oil systems. So, if a transformer is retrofilled with FR3 fluid and operates 5-10°C higher, the cellulose is still likely to age at a slower rate than when it operates in conventional mineral oil. For these reasons, Waukesha does not de-rate transformers after retrofilling them with FR3 fluid.

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