

Extend The Life Of Your Insurance Protection A Financial Perspective on Retrofills

It is commonly accepted that one of the top three causes of power transformer failures is cellulose insulation failure (the others being LTC and bushing failures). Some in fact believe that cellulose insulation is the very heart of the transformer, as aging (degradation) of the cellulose insulation is irreversible (and the other failure modes can be delayed with robust maintenance). Many transformers in service are approaching their end of life because their cellulose insulation has degraded over time and are no longer able to withstand stresses created during normal operation.

In general, replacing the traditional mineral oil dielectric coolant (retrofilling) with Envirotemp FR3 fluid is a cost effective way to upgrade fire safety, lower the environmental risk and actually slow the thermal aging (degradation) of cellulose insulation.

Transformer Insulation Aging Process

The cellulose insulation aging process begins as soon as the transformer is energized, and the rate of aging increases as temperature (loading) and water concentration increases. It is widely accepted that paper insulation drives off moisture during the aging process.

In general, transformer insulation systems (dielectric coolant and cellulose paper) seek equilibrium. Moisture equilibrium is measured as relative saturation, and changes as loading, operating temperature and ambient temperature change. Moisture can generally be found in both the dielectric coolant and in the cellulose. According to the Weidmann Electrical Technology (one of the largest makers of transformer cellulose paper insulation), for new transformers,

more than 99% of the water in the insulation system is in the paper insulation.

The most widely used dielectric coolant is mineral oil. Mineral oil is *hydrophobic* (tending to repel and not absorb water), and saturates at about 70 ppm at room temperature. Additionally, mineral oil's dielectric strength begins to fade at around 30% saturation (approx 20 ppm water). In new transformers, mineral oil is typically kept very dry, usually containing less than 10ppm water. When combined with cellulose insulation, it is only capable of absorbing a very small amount of water, leaving most of the water in the paper. As noted above, if this water stays in the cellulose, it accelerates the degradation of the paper, effectively killing the transformer. If the systems reaches equilibrium and mineral oil reaches 30% saturation, the oil will have to be maintained (dried via vacuum processor). It is not unusual to service mineral oil several times over the life of a transformer.

In contrast, FR3 fluid actually slows the degradation process. Because of its chemical nature, FR3 fluid is *hydroscopic* (meaning able to readily take up and retain water through either absorption or adsorption), and saturates at about 1000 ppm. Tests confirm FR3 fluid maintains its dielectric strength relative to moisture saturation well beyond that of mineral oil (up to around 40% saturation before dielectric strength begins to weaken). As described above, in systems seeking equilibrium, all things being equal, FR3 fluid can absorb about 14x more water than mineral oil at normal ambient temperature (30 °C).

Given that most of the water is in the paper insulation, FR3 fluid is the most effective drying agent for paper. All things equal, a



mineral oil/cellulose paper insulation system will age substantially faster than an FR3 fluid/cellulose insulation system; additionally, mineral oil will have to be serviced more often than FR3 fluid.

Which Transformers Would Be Good Candidate For Refilling With FR3 Fluid

From the oldest to the newest (and including those purchased in the future), ALL transformers are good candidates for (retro)filling with FR3 fluid! For those transformers that are of most concern (usually the oldest), refilling with FR3 fluid will extend the insurance protection by essentially eliminating the potential for a dielectric pool fire during failure mode, while slowing aging rate of what insulation life is left. Additionally, when the transformer does fail, FR3 fluid can be processed and reused in other assets, allowing a continued return on investment.

For those transformers that are less of an immediate concern, refilling with FR3 fluid will extend the life of that cellulose insulation. But, that benefit can be traded for short term overload capacity. Armed with IEEE C57.92, users can now gain short term capacity up to 15% without exceeding the aging rate that is normal for a fully loaded transformer containing mineral oil, thus delivering an additional return on the investment.

For new transformers, OEMs can take advantage of this technology and optimize the transformer for more power (higher temperature rise transformers) while maintaining the insulation aging rate defined by IEEE.

Fiscal Responsibility

FR3 fluid is an emerging technology that in many categories is proving to be a superior dielectric coolant to mineral oil. Water saturation, dielectric strength retention, fire

ignition resistance, environmental profile, life cycle CO2 generation.

Users will see an immediate reduction in risk when refilling transformers with FR3 fluid. For those companies that reserve funds for future liabilities, they may now choose to reserve fewer funds, immediately improving their profitability.

For those firms in need of short term increased capacity, FR3 fluid provides a step function increase in overload-ability without increasing the aging rate of the insulation, while reducing the likelihood of a dielectric pool fire during failure.

FR3 fluid is the most tested alternative dielectric coolant. Field experience is validating the laboratory results. Transformers as old as 1955 have been refilled with FR3 fluid, and are operating normally. FR3 fluid is being used in transformers rated 245kV, with over 10 (manufactured by three OEMs for four customers on two continents) now energized.

The risks are minimal, the financial returns immense. Upgrade your environmental profile, improve fire safety, and gain overload-ability of your existing transformers. Initiate a refill program today, and begin transforming your firm's long term risks into instant profitability.