Traditional Transformer Oil vs. Today's Alternative Fluids

by **Mark Stone**

Today, most transformers are filled with mineral oil. This has been the case since the late 19th century, when chemist Elihu Thomson, whose company later merged to form General Electric, patented the use of mineral oil in transformers to help disperse heat from the core of a transformer in order to prolong its life. Presently, alternative fluids are becoming more and more popular as we look for options that further prolong transformer life, lower environmental risks, and save money.

What makes these new natural and synthetic fluids so popular?

There are a small handful of companies that make natural and synthetic esters, including Cargill, ABB, M&I Materials and GE Prolec, to name a few. By far, one of the most popular alternative fluids in today's market is Cargill's FR3. One of the biggest drivers behind the popularity of FR3 and other natural and synthetic esters is the fluid's high flash point (330°C) and fire point (360°C). This is more than double what mineral oil filled transformers can stand, making them great fluids for both indoor and outdoor transformer placement.

Another factor driving popularity is their biodegradability. Biodegradable fluids are more suitable for sensitive areas like dams and any property close to water. By choosing these fluids, you will avoid investing large sums of money on containment structures to hold 110% of nameplate gallons. Environmentally speaking, because these fluids are biodegradable, leaks or failures of units will have a much lower environmental impact than what we see with traditional transformer fluid. FR3, for example, contains no petroleum, halogens, silicones, or sulfurs, making the cleanup easier and less expensive than that of typical transformer mineral oils. As a result, this type of fluid is very desirable to insurance companies. For example, companies like FM Global are offering incentives and encouraging some industrial manufacturers to retrofill or replace all their oil filled units with these high fire point, less flammable, natural or synthetic ester fluids.

What about reliability?

Reliability is very important in today's electrical energy industry. Natural and synthetic esters are very stable fluids and have a greater cooling capacity than the high-molecular-weight silicone fluids and hydrocarbon dielectric fluids, adding to their desirability. Transformers with thermally upgraded paper and FR3 take about eight times longer to reach end of life criteria than a mineral oil filled transformer.

Oil testing process

The testing of FR3 is similar to the way mineral oil is tested – by pulling a good representative sample from the bottom valve of the transformer. The difference is more about the interpretation of the results than the tests themselves. To maximize the life of natural and synthetic ester fluid transformers, the units need to be maintained at low oxygen levels and low moisture levels, just like mineral oil filled transformers.

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Gassing

During the first few years, natural esters will generate small amounts of ethane (C_2H_6; around 200 to 300 ppm), which is caused by the stray gassing that naturally occurs with these natural ester fluids. This is not an indicator of a localized hot spot in the transformer. The C_2H_6 emissions should level off after a few years.

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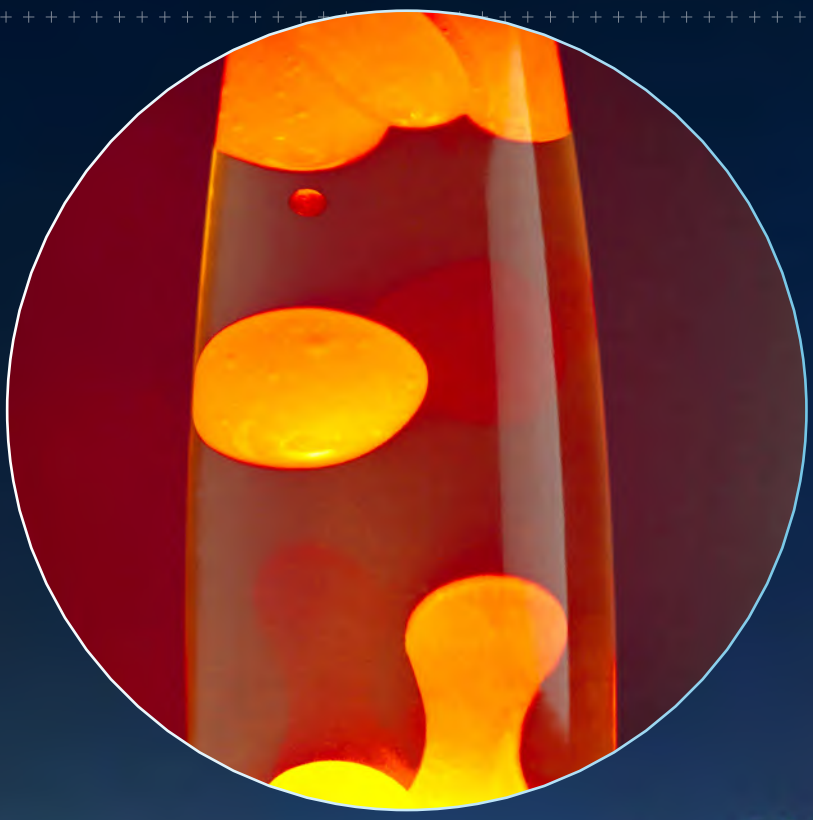
Moisture content

One of the biggest enemies to the solid insulation in the transformer is water. Natural and synthetic ester fluids will hold more moisture in the fluid and less moisture in the paper as compared to mineral oil filled transformers, helping to keep the most important part of the transformer, the solid insulation, dry. For instance, at about room temperature, mineral oil will hold approximately 50 ppm, whereas FR3 will hold around 1000 ppm. If you have a high moisture content in your ester fluid filled transformer, the ester fluids will generate acids. These weak, long-chain fatty acids react to form new ester links that put a protective layer over the solid insulation, protecting it from future decay. In oil filled transformers, the oil does not help keep the paper dry. As a matter of fact, the paper can hold hundreds or even thousands of times more moisture than the oil, which results in a very long and drawn out process to dry an oil filled transformer in the field.

Can an oil filled transformer be retro-filled with natural ester fluid?

Extensive lab testing and field work confirmed that transformers filled with mineral oil and high temperature hydrocarbon fluids (R-Temp) can be retrofilled with natural ester fluids. Performing the retrofill can help slow the transformer aging process, lower the environmental risk, and improve the short-term capability to overload the transformer.

Before you begin, there are a few things you should know. The biggest issue with retrofilling an oil filled unit with FR3 is the draining process. You will never get 100% of nameplate gallons out of the transformer because the winding, core, paper, and cardboard inside the transformer have been absorbing some of the oil over time. While your transformer is being drained, confirm enough of the original fluid is removed from the windings, or you may lower the fire point to below 300°C, making the



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transformer unacceptable for indoor use. You should also verify that there are no free breathing capabilities by checking that the conservators and nitrogen systems are working properly, and that atmosphere cannot come in contact with the FR3.

Fluid compatibility

Remember that there are quite a few different types of transformer fluids out there, some of which you can no longer purchase. If you have these types of fluids and your transformer develops a leak, you must be very careful when choosing which type of fluid you are going to use to top off your transformer.

Some of these transformer fluids are not compatible with each other. Take silicone for example. While you can still buy silicone, it does not mix well with other fluids. If you top off an oil filled transformer with silicone, the two fluids will not be miscible; the fluids inside your transformer will look like a lava lamp – unmixed. Again, if you are topping off a transformer with a different fluid, make sure the two fluids are compatible.

Conclusion

Over the years, the transformer industry has seen little change. The shift in fluids is one of the bigger changes we have seen in years, and everyone is extremely interested in learning as much as they possibly can about these natural and synthetic ester fluids.

Today, we have many more codes that dictate which type of fluids we can use depending on where we install our transformers (NEC codes, fire prevention codes, etc.). Mineral oil is still, by far, the most popular fluid for transformers because it is lower in cost and readily available, but is it always going to be available to us? Though the change may not be quick, the natural and synthetic ester fluids market is coming on strong. If you do not have a transformer with one of these fluids, you probably will soon.