

Potential benefits of Envirotemp™ FR3™ fluid filled transformers increasing load capability in distribution transformers.

Knowing or estimating customer demand for distribution transformers, especially in residential areas, can be quite challenging. Renewable power sources are growing in the market, making power flow even harder to predict. Since the cost to replace a transformer is many times higher than the actual transformer cost, an engineer often times needs to use a larger rated capacity to plan for future growth.

Using a larger transformer increases the initial cost and may lead to higher operational costs due to increase of no-load losses associated with the larger transformer size.

Conversely, the increased capability enabled by the lower degradation rate of the paper immersed in FR3 fluid may allow a relevant value of extra effective capacity without reducing the expected lifespan.

Rated Capacity versus Capability

The nameplate rated capacity does not indicate the actual capability of a transformer. Standardization, efficiency mandates, safety margins, etc., may lead to a “reserve of capacity” often higher than 10%. Envirotemp FR3 chemistry “wicks” water away from insulating paper thus protecting the paper from further aging/thermal degradation.

This expanded thermal capability can:

- Reach a capability as high as +50% without additional life reduction (continuously loaded);
- As much as 2x more capacity, with limited additional paper degradation, but not damaging the insulation.

Excluding cases where the required rated capacity is defined by voltage drop, this can lead to economic savings.

Loading Guides

The loading guides IEEE C57.91 and IEC 60076-7 have incorporated (from even their very early versions) additional limits for loading distribution transformers above nameplate rating; allowing up to 300% loading (for less than ½h), with top-oil as high as 120°C and a hotspot up to 200°C.

When using FR3 filled units, the only modification is an increase of the temperature limit for the top-oil, (or “top-liquid”). All other limits remain the same.

Increasing the top-liquid value to 140°C using FR3 fluid instead of 120°C with mineral oil is a great benefit, as it allows higher loading along with lower loss of paper life (paper degradation) by being immersed in FR3 fluid.

Table 1 – Time durations for operating above rate hottest-spot temperature for different loss of life values assuming a thermal class of 140 for thermally upgraded kraft paper immersed in FR3 fluid not crossing the indicated loss of life.

Hot Spot temp	F _{AA} (aging acceleration factor)	Percent loss of life for operating at the hotspot temperature during the indicated hours ^a						
		0.0133 ^b	0.02	0.05	0.1	0.2	0.3	0.4
130°C	0.94 x	25.4 h	-	-	-	-	-	-
140°C	2.32 x	10.3 h	15.5 h	-	-	-	-	-
150°C	5.48 x	4.4 h	6.6 h	16.4 h	-	-	-	-
160°C	12.4 x	1.9 h	2.9 h	7.2 h	14.5 h	-	-	-
170°C	27.2 x	53 min	1.3 h	3.3 h	6.6 h	13.2 h	19.9 h	-
180°C	57.4 x	25 min	38 min	1.6 h	3.1 h	6.3 h	9.4 h	12.5 h
190°C	117.4 x	12.3 min	18.4 min	46 min	1.5 h	3.1 h	4.6 h	6.1 h
200°C	232.9 x	6.2 min	9.3 min	23.2 min	46.4 min	1.6 h	2.3 h	3.1 h

^aBased on a normal life of 180,000 h. Time durations not shown are in excess of 24 h.

^bThis column of time durations for 0.0133% loss of life gives the hours of continuous operation above the basis-of-rating hottest-spot temperature (130.6°C) for one equivalent day of operation at 130.6°C. (verify that 0.0133% = 24th/180,000h = nominal life consumption rate)

Paper life

The available Arrhenius curve for thermally upgraded kraft (TUK) paper immersed in FR3™ fluid (informative Annex B of IEEE C57.154:2012 and Annex C of IEC 60076-14) allows the development of the “loss of life” tables and “percent loss of life” chart widely used from IEEE C57.91 (for TUK paper in mineral oil). Both the table and the chart are presented in this document.

The most relevant result is the ability of handling larger values of overloading for longer periods of time. It means the limits for planned loading above nameplate or even the emergency overloading will lead to a much smaller sacrifice of transformer life expectation as seen in Table 1 and Figure 1.

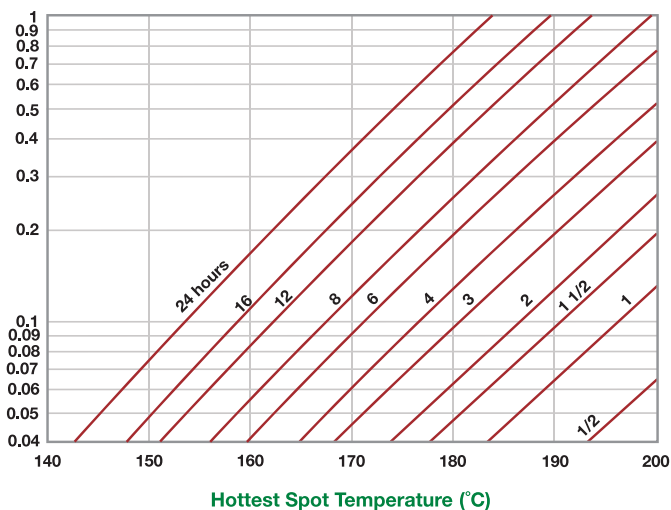


Figure 1 - Percent loss of life expectancy for time at temperature (based on a normal life of 180,000 h) for TUK paper immersed in FR3™ fluid, having thermal class 140.

Continuous drying of insulated paper

In a mineral oil filled unit, the moisture content in paper gradually increases with years of operation, even in perfectly sealed units. This process occurs because moisture is both a byproduct and a catalyst of paper degradation. This “self-

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induced” reaction does not occur with the paper in FR3 fluid. The moisture generated by paper degradation migrates to the FR3 fluid and then gets consumed by a hydrolysis reaction.

The moisture content of the insulating paper in FR3 starts at a typical value of 0.5% in a new transformer and remains fairly stable throughout the transformer life.

Additional benefits of this include:

- Dielectric withstand capacity of the insulation system is preserved throughout life.
- Risk of failure by “Bubbling,” which is driven by the moisture content in paper, is mitigated.
- Increasing the average assets utilization level may improve the overall system efficiency.

Utilities benefits

- New transformers purchase savings. Although price per rated kVA is higher, the price for effective kVA will be lower. The total investment will be reduced, since buying less “rated kVAs.”
- Peace of mind for handling large load fluctuations due to the amplified capacity for overloading
- Resilient grid, due to the expanded capability
- Higher reliability, as paper is continuously dried
- Increase asset utilization, as the average loading factor will be increased
- Fire safety, ZERO fires reported in FR3™ fluid filled units
- Environmentally friendly, bringing benefits in sustainability, carbon footprint, renewability, and safety in the case of spills

Cargill’s technical team is ready to help your company estimate the TCF of your transformers.