Consideration of Ester-Based Oils as Replacements for Transformer Mineral Oil

Portland State University
Maseeh College of Engineering & Computer Science
Department of Electrical & Computer Engineering

Authors:
Nicole Zimmerman
Robert Bass, Ph.D.
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1 Introduction

Within this report, we compare the technical, environmental and cost merits of using natural and synthetic ester oils as replacements for mineral oil in distribution transformers, with the goal of assisting Portland General Electric (PGE) to make informed decisions regarding the use and adoption of ester oils throughout its service area.

Ester oils offer several advantages, including biodegradability, higher flash point, higher thermal conductivity, lower calorific value and higher temperature stability.[1] Consequently, ester-based oils offer better benefit-to-cost ratios than mineral oil. Within this study, we weigh these benefits against costs such that PGE can make informed decisions regarding the types of dielectric oils it chooses to use in its transformers and in which scenarios the use of ester oils makes the most sense.

Ester dielectric oils are completely miscible with mineral oils and most standard transformers require no mechanical modifications[2] in order to be retrofilled with the fluids, so retrofilling existing assets is a viable option. Ester oils promote extended asset lifetime through the slowing of the aging rate of cellulose paper within new and retrofilled transformers. Our analysis indicates there would be a cost benefit for PGE if they were to retrofill existing mineral oil transformers with ester oils during routine servicing, and purchase new distribution-sized transformers filled with the fluid. During our investigation we made contact with representatives from Cooper Power Systems and Cargill, both of whom offer comprehensive support to customers who are adopting these products. Several utilities, particularly Sacramento Municipal Utility District (SMUD) and Pacific Gas and Electric Company (PG&E), have successful track records with ester transformer oils.

There are several motivations for using dielectric fluids made from natural or synthetic esters as a replacement for mineral oil in transformers. Ester oils feature higher thermal conductivity than mineral oil and are therefore better suited for

[1] Esters are a class of chemical compounds derived from the condensation of an inorganic or organic acid with an alcohol. Creation of esters involves the replacement of at least one hydroxyl (-OH) group from the acid by an alkoxy (-O-alkyl) group. For example, naturally occurring oils are esters of organic fatty acids and glycerol.

[2] As stated by Cargill representative.

regulating transformer temperature. Flash points and fire points are both significantly higher for esters than mineral oils. Fire Safety Class, another measure of fire point, for esters are K class while that for mineral oil is O. Natural esters therefore can mitigate fire safety and insurance concerns, particularly in situations where fire clearances are constrained. Esters have a lower calorific value than mineral oil, so in the event of a fire they provide less energy per unit weight than mineral oil. In addition, the combustion of esters does not produce toxic or environmentally persistent by-products.

Esters, natural and synthetic, have higher temperature stability than mineral oil, meaning esters can be exposed to a higher temperature for longer periods with less degradation than would be expected when using mineral oil. Use of esters has been demonstrated to extend transformer asset life, particularly those with cellulose-based insulation. This is largely due to the greater solubility of water in ester oils, which draws moisture out of the cellulose insulation thereby reducing the cellulose aging rate.

Natural esters are ultimately biodegradable and synthetic esters are readily biodegradable. As such they may be preferred for use in transformers near environmentally sensitive areas. Also, transformers manufactured prior to 1979 often used PCB-containing dielectric fluids. However, because mineral oil and PCB are highly miscible, transformers from that period currently in use could still contain PCB contaminants. Replacing PCB-contaminated mineral oil with ester oils offer an environmentally conscience option as a replacement dielectric fluid when servicing these older transformers.

2 Ester-based Dielectric Oils

Ester oils are dielectric coolants designed for use in distribution and power class transformers. They may be natural or synthetic in origin, deriving from commodity seed oils or inorganic feedstocks. While the specific formulations are proprietary, these dielectric fluids are biodegradable compounds combined with a small percentage of biodegradable additives for performance enhancement.

2.1 Ester Fluid Properties

Due to its low cost and effective dielectric capabilities, mineral oil as a cooling fluid for use in transformers has been an industry standard for decades. Ester oils can be utilized as a replacement for mineral oil in distribution and power class transformers. Its safety, environmental and performance capabilities, in comparison to mineral oil, are examined below.

2.1.1 Safety Factors

Ester fluids offer an excellent fire safety record through ten years and more than 45,000 installations.[1] They have a flash point as defined by ISO 2719 of 330°C and fire point defined by ISO 2592 of 360°C versus 160-180°C typically for mineral oil. As such, they meet the US National Electric Code (NEC) definition of ”improved fire safety” for dielectric fluids, and are listed as such by both FM Global and Underwriters Laboratories (UL). They are also classified as K fire hazard class dielectric insulating fluids per the IEC standard 61100.[2]

Ester fluids will not sustain a flame absent a high-energy source of ignition. Because of this, clearances are reduced and the need for fire mitigation and deluge systems is lessened. The byproducts of ester fluid combustion are water, carbon dioxide and carbon monoxide which are less toxic than the carbon, nitrogen and sulfer oxides produced by a mineral oil fire.

Ester fluids are miscible and compatible with mineral oil-filled transformers. Therefore, retrofilling existing mineral oil transformers with ester coolants is an option. Mixing ester fluid with conventional mineral transformer oil will lower the flash point and the fire point of the ester fluid. If the fire point (ASTM D92) of the ester/mineral oil mixture is less than 300°C, the transformer will not meet the requirements of Article 450-23 of the NEC.[3] Also, in the case of retrofilling where mineral oil is present within the transformer, the utility is liable for the performance of the combined fluids.

2.1.2 Environmental Benefits

Ester fluids contain no petrochemicals, siloxanes or halogens. Seed-based, or "natural," esters derive from renewable agricultural seed crops, such as soybean, rapeseed, sunflower, canola and corn.

Natural ester oils are oral and aquatic non-toxic and classified as non-carcinogenic in California.[4] Natural esters are ultimately biodegradable with prolonged exposure to the environment while synthetic esters are readily biodegradable, as defined by OECD 301.[5] EPA OPPTS 835.3100 tests prove complete biodegradation in 28 days. This process may be more rapid depending on temperature, food sources or the presence of water. If necessary, this time to biodegradation can also be reduced by the addition of enzymes. This means that spill mitigation and clean-up procedures are less costly compared to mineral oil spills. However, it does not change reporting and cleanup requirements for spills in waterways.

2.1.3 Transformer Performance

The cellulose paper used to insulate windings in fluid-filled transformers degrades significantly more slowly in the presence of ester dielectric fluids than in conventional mineral transformer oil.[6] This is measured in terms of tensile strength and degree of polymerization derived from accelerated aging tests.[7] Paper aged at 170°C in ester fluids takes 5 to 8 times longer to reach standard end of life points, as defined by C57.100, than paper aged in standard mineral oil.[8] Paper aged at 150°C in mineral oil reached standard end of life points. However, paper aged at 150°C in esters does not reach end of life. It is estimated that the time to end of life for a transformer with paper submersed in ester oil at 110°C is at least 2.5 times that of transformer with paper submersed in mineral oil.[3][9][10] This extension of the paper insulation thermal life leads to fewer failures over time and improved service reliability.

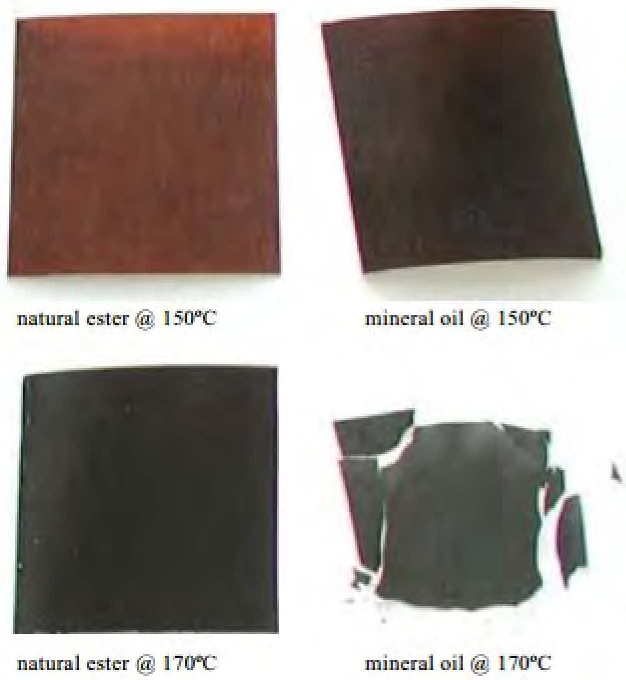

Figure 1: Relative accelerated aging study of new thermally upgraded cellulose paper.[9]

Relative to mineral oil, ester fluids are highly water absorbent and remove moisture from the paper insulation used in transformers.[11][3] Moisture is generated in transformers as the cellulose insulation ages at elevated temperatures. As the moisture content of the insulation system increases, dielectric strength drops. Since ester fluid can absorb moisture to a greater extent than mineral oil, moisture migrates from cellulose into ester fluids. Multiple accelerated life tests have demonstrated that the aging rate of cellulose insulation can be significantly slowed when impregnated with ester fluid compared to mineral oil.[12]

As such, retrofilling a service-aged mineral oil transformer with ester fluid will remove water from the insulation. Dry insulation is preferred because it slows the

[3]Esters have a limited ability to participate in hydrogen bonding, doing so only as hydrogen-bond acceptors. As such they offer some water solubility.

aging rate of cellulose, improves the electrical characteristics of the transformer and extends the life of the asset. Ester fluid in a new transformer enables the insulation system to be self-drying.

Dielectric fluid within a transformer must have adequate oxidation stability to efficiently cool and maintain desirable electrical characteristics for the life of the transformer. The by-products of mineral oil oxidation can precipitate as sludge and eventually reduce transformer cooling capacity and electrical characteristic. As shown in Figure 2, ester fluids oxidize differently than mineral oil and have shown, through accelerated aging methods, that they do not form sludge precipitates.[13]

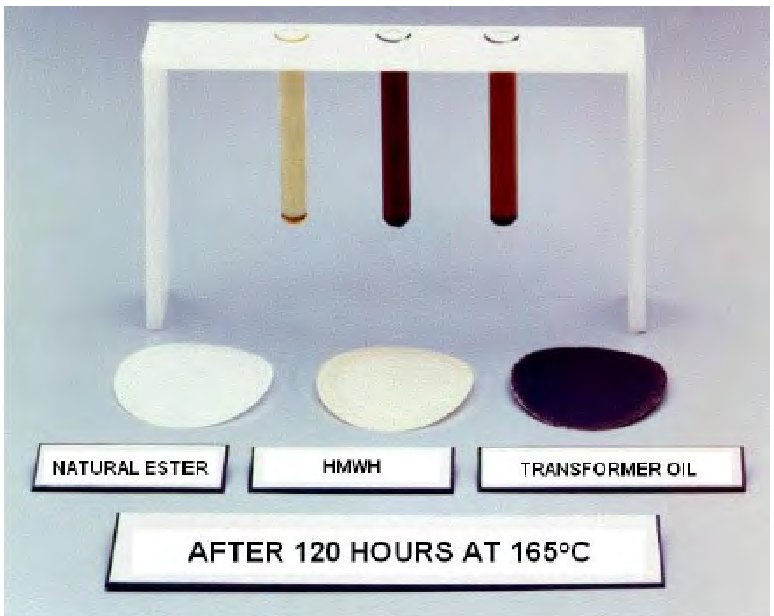

Figure 2: Natural ester fluid, high molecular weight hydrocarbon and mineral oil after oven aging. Filterable particulate oxidization products shown on filter papers.

Transformers can be installed with reduced ratings where natural ester dielectric fluid is supplied. In other words, where a 50 kVA unit would historically have been required, a 37.5 kVA unit can now be installed.[14][4] Greater nameplate ratings when transformers are filled with natural ester fluids, allowing transformers to

[4]This IEEE practice is a guide that outlines the fundamental considerations and review of elements to be considered when applying specific cases.

be rated and operated at higher temperatures when filled with the ester fluid, are recognized by IEEE C57.154.[15] This allows ester fluids to meet the conservation of energy standards for liquid-immersed, distribution transformers as set forth by the Department of Energy in 78 FR 23335 by enabling the transformers to be operated at higher temperatures without decreasing their useful lifespan.[16] For example, a fully loaded transformer filled with conventional dielectric fluid is required to have a top oil temperature that is not more than 65°C above ambient. If filled with natural ester fluid, IEEE C57.154 allows the same transformer design to be more heavily loaded, such that the top oil temperature is 75°C above ambient.[15] The nameplate rating of the transformer would increase in accordance with the higher temperature rise.[14]

2.2 Ester Fluid Considerations

2.2.1 Compatibility

Natural ester fluids are miscible with conventional mineral oil fluids. Natural ester fluids can be mixed with conventional mineral oil dielectric where the mineral oil concentrations are up to 8% without significant degradation of their most significant dielectric and fire point properties. However, after mixing with mineral oil, the compound fluid can no longer be considered biodegradable. With higher ratios of mineral oil, the characteristics of the mixture asymptotically degrades to the performance levels of the mineral oil. Retrofills of transformers that were previously filled with silicone-based dielectric is not recommended due to unpredictable dielectric behavior.

Synthetic ester oil-based fluids are liquid dielectric coolants that possess similar improved fire safety, biodegradability and performance properties as their natural counterparts, but are typically more expensive. These formulations are augmented with proprietary additives which give them very low freezing and melting points, making them most suitable in applications that demand thermal stability where extreme temperature variations exist. They also offer oxidation stability and so should be used in free-breathing transformers in order to avoid the thin film of polymerization that is formed on hot surfaces exposed to air.

2.2.2 Storage & Handling

When the location and style of permanent ester-fluid storage tanks is not yet determined for a given transformer yard, direct transfer from the delivering bulk containers to the transformers might not be possible. It may be necessary to transfer the fluids into smaller storage tanks in order to move it to locations within the working area that are convenient for the filling of equipment. Purchase of the fluid in drums or totes could be more practical during the initial stages of a new project.

Figure 3: Example of 330 gallon tanks that ester fluid is delivered in.

In order to utilize the product in this fashion a pumping system would need to be used to transport fluid to working areas. Since the viscosity of natural ester fluids is generally higher than ordinary transformer oil, care must be taken in selecting a pump with proper horsepower and capacity ratings. First, the maximum flow rate required must be determined and then a pump and motor selected that will handle the requisite flow rate at the lowest temperature (highest fluid viscosity) to be encountered. The most commonly recommended pump for ester fluids is the positive displacement gear pump. A standard iron pump with either mechanical seal or stuffing box is also satisfactory. An example of a portable pump system that SMUD uses is shown in Figure 4. For reference, steps for retrofilling mineral oil tanks with FR3™ fluid, as recommended by the manufacturer, are included in the appendix.

Figure 4: Example of a portable pumping system used by SMUD to move the FR3™ fluid around the transformer shop.

Polymerization of ester fluid spills on transformer components occurs within a few days, forming a thin film when exposed to air. Any spills should be wiped away as they occur. Ester fluid contamination can be difficult to clean, compared to mineral oil, after polymerization occurs. Removal of the polymerized fluid is labor intensive. An example of this is shown in Figure 5.

Figure 5: Polymerized ester fluid on the outside of a transformer tank.

SMUD tested several methods for removing this thin film from the exterior of tanks and bushings. They tried soap and water, vinegar, window cleaner, chlorine bleach, Simple Green, ammonia, petroleum-derived thinners (toluene, methanol, acetone), contact cleaner, Brakleen, and potassium bitartrate with acetic acid. Based on results, as shown in Figure 6, and the fact that neither product is a volatile organic compound, a vinegar & cream of tartar combination was identified as the preferred method for removing polymerized fluid from the outer surfaces of the transformers.

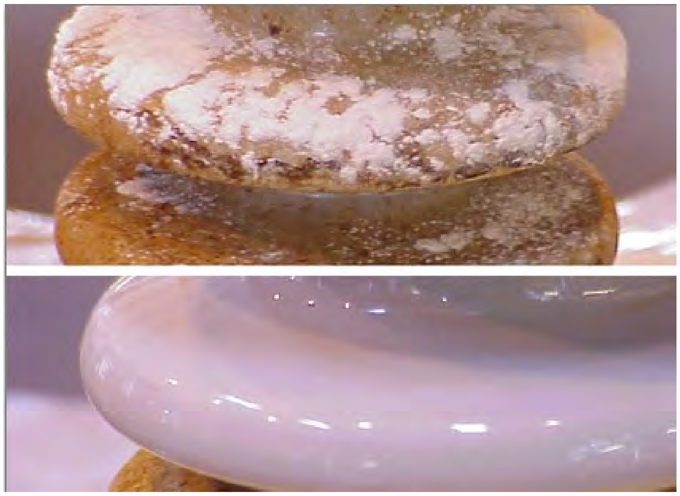

Figure 6: A bushing covered in polymerized ester fluid at top. The same bushing after cleaning with vinegar and cream of tartar.

2.2.3 Cold Start Recommendations & Procedures

When a transformer filled with natural ester fluid has been de-energized in temperatures at or below -20°C for periods of a few hours or longer the fluid will begin to thicken and, with time, form a gel. Natural ester insulating fluids for transformers are made from vegetable oils, which are a combination of different triglyceride compounds. As the temperature of the fluid decreases, the individual compounds eventually reach their freezing point and crystallize. The increasing number of crystals increases the viscosity of the fluid because, as the crystals grow, they form larger networks until they impede the flow so much that the pour point of the fluid is reached. However, it should be noted that, unlike mineral oil, natural ester fluids maintain their dielectric strength and continue to work even when the pour point is reached. Freezing and thawing of natural ester fluids has no effect on their physical, chemical, or electrical properties.[17] It has been found that the same cold start up procedure that is used for transformers filled with mineral oil can be used for transformers filled with natural ester fluids rated up to 240 MVA.[18]

Cooper Power System's cold start recommendations for distribution class transformers include:

1. Recommendation for energizing natural ester fluid-filled transformers having no movable components immersed in fluid: Units should be energized using normal start up procedures, regardless of ambient or fluid temperature.

2. Recommendation for energizing natural ester fluid-filled transformers containing liquid immersed movable components: If the transformer has been exposed to temperatures continuously below -20°C for longer than seven days, or the fluid temperature is below -25°C, warm the unit until the fluid temperature reaches -10°C, then energize using normal start up procedures. For less severe temperature conditions, energize using normal start up procedures.[19]

Standard operating practices can be used with ester-oil filled distribution transformers even in the coldest temperatures available within PGE's service area.

3 Cost Benefit Analysis

3.1 Life Cycle Cost Comparisons

The use of both natural and synthetic ester-based dielectric fluids results in longer transformer life. As a conservative estimate, it is anticipated that new transformers would experience a life extension of 33% if filled with ester-based dielectric fluids. Based upon this assumption, an economic analysis has been performed to quantify the potential benefit of filling new transformers with natural ester-based fluids. The analysis refers to the three most commonly utilized single-phase and three-phase pole-type and pad-mounted distribution transformers used by PGE, rated at 15 kVA, 25 kVA and 50 kVA. The analysis incorporates the initial and replacement cost of each transformer utilizing current prices and labor estimates, as provided by PGE. A unit filled with conventional dielectric fluid is assumed to require replacement in 30 years, while an identical unit filled with ester-based dielectric fluid is assumed to require replacement in 40 years. This lifetime estimate is based on an assessment made by SMUD of their distribution system transformers and it should be noted that the average operating temperature within SMUD's service area is significantly higher than that of PGE's. This implies that the average years that a transformer operates within the PGE service area and the potential savings of lifetime extension could be higher than as calculated in this analysis. Salvage credits for remaining transformer life are incorporated for each scenario at the end of the forty-year study period, assuming 10% of the asset's straight-line depreciation value. A PGE discount rate[5] of 7.59% from 2007 and an inflation rate of 1.7% current as of September, 17th, 2014, are used.

The total ownership cost (TOC), excluding losses, is assessed and compared for conventional and ester-based dielectric fluid-filled transformers. The difference in these costs constitutes a value that can be assigned to prolonged transformer life associated with filling transformers with the ester-based fluids. This value is also

[5] A discount rate is the interest rate used in discounted cash flow analysis to determine the present value of future cash flows. The greater the uncertainty of future cash flows, the higher the discount rate.

presented as a percentage of the present base price of each transformer in Table 7 below. Spreadsheets for these calculations are included in the appendix.

Transformer Description	Purchase Price	PV TOC with Mineral Oil Dielectric (30-year life)	PV TOC with Natural Oil Dielectric (40-year life)	PV TOC Difference	Present Value Benefit over Purchase Price
15kVA	$660	$2,145	$2,001	$144	22%
25kVA	$865	$2,375	$2,215	$160	19%
50kVA	$1,110	$2,721	$2,536	$184	17%

Figure 7: Life cycle cost comparison of three most common sizes of PGE distribution transformers.

This economic analysis establishes a significant value associated with obtaining distribution transformers filled with ester-based dielectric fluids, resulting in equipment life extension. To derive economic benefit, this value must be greater than the additional cost associated with supplying such fluids. Transformer manufacturers have indicated that units filled with ester dielectric fluid would price at a 5%-10% more, dependent on design and quantity. This suggests a potential economic benefit to PGE, dependent on exact pricing.

3.2 Other Cost-Saving Considerations

This study is not sufficient to quantify the value of environmental performance or fire hazard reduction that could be associated with ester-based fluid-filled distribution transformers. These benefits can be best quantified where a clear risk can be shown to exist. Also, because industry standards have not addressed the re-rating of transformers filled with ester dielectric fluids the potential cost benefits derived from this practice have not been calculated.

In areas where the distribution system is lightly loaded, smaller-sized transformers with overload ratings could be installed. For example, in lieu of buying a traditional thermally upgraded cellulose paper transformer rated for 65°C average winding rise (AWR), esters enable the same unit to continuously operate at 20°C higher temperature without degradation to insulation life.[20] A transformer with a smaller rating that is run at a higher average operating temperature could be installed in this case. This allows initial asset investment to be lower and total operating costs to be lower while still reaping the benefits of life extension and more thermal capability. These savings can be quantified based on the number of locations identified as viable for this option.

4 Ester Fluid Suppliers and Adopters

4.1 Ester Fluid Product Suppliers

There are two principal brands of high fire-point natural ester insulating fluids for transformers. Cargill makes Envirotemp™ FR3™ fluid and ABB makes BIOTEMP. The FR3™ fluid produced by Cargill is the most common ester oil available in the market today. There are several suppliers from which FR3™ fluid and new FR3™ fluid-filled products can be purchased. These include General Electric (GE), Cooper Power Systems and SPX Waukesha.

4.2 Utilities

Since June 2003 the SMUD has specified that all distribution transformers, pole-type, padmount, vault-type and network, shall be filled with natural ester dielectric fluid. They received their first shipment of ester fluid-filled transformers in September 2003. To date, they have purchased and installed approximately 7100 transformers containing 350,000 gallons of the natural dielectric. This total represents approximately 8% of their 90,500 distribution-sized units installed within their system. They state that they have experienced no significant issues with the switchover from mineral oil to FR3™ fluid. They have extensive experience and are fervent supporters of the use of the FR3™ dielectric fluid. Contact information for representatives can also be found in the appendix.

Since 2012 PG&E has been purchasing some of their new distribution transformers with the FR3™ fluid. They worked with suppliers in order to create competing bids for both the FR3™ fluid and traditional mineral oil. The FR3™ bids came in as the most cost effective options. Approximately 18,000-20,000 of their distribution transformers out of a total of 1,000,000 are FR3™ units. Currently, they only buy new units filled with the FR3™ fluid and do not retrofill existing mineral oil distribution transformers. The reason cited for this is that they experienced leakage problems when retrofilling mineral oil transformers with the FR3™ fluid in cases where they didn't replace the gasket set. It is more cost effective for them to purchase a whole new asset than to pay for the labor of replacing a gasket set. Within five years the utility will be halting the purchase of new mineral oil distribution transformers completely.

5 Conclusion

Ester-based transformer dielectric cooling fluids offer utilities significant advantages, in terms of both performance and life cycle cost, over traditional mineral oil fluids. Ester fluid-filled transformers are being used by other utilities, particularly SMUD and PG&E. This report presented the technical, environmental and cost merits of using ester oils as replacements for mineral oil in distribution transformers.

Both varieties of ester fluids are free from petroleum, siloxanes and halogens. They are non-toxic, non-carcinogenic and completely biodegradable. Ester dielectric coolants offers flash and fire points that are much higher than that of their mineral oil counterpart, giving them a superior safety record. Even when mixed with mineral oil in concentrations of up to 8% in retrofill applications, ester oils retain these characteristics. These factors make the materials safer, easier to handle and suitable even in the most sensitive areas where transformers are installed.

Transformer performance is greatly improved by the use of ester products compared to mineral oils. The rate at which cellulose paper ages is slowed, thereby extending transformer life and improving service reliability. Analysis of life-cycle costs show that there are significant cost savings to be achieved because of this asset life extension. Increased loading capabilities and absence of problematic oxidization issues also contribute to cost reduction. These savings can offset the higher initial cost of the ester fluid and ester fluid-filled transformers.

A Appendix

A.1 Contact Information

Cargill
Jeff Valmus
Utilities Sales Manager North America
Cargill Industrial Specialties-Dielectric Fluid
949-496-5802
jeff_valmus@cargill.com

Cooper Power Systems
John O'Brien, PE
Senior Sales Engineer
Eaton's Cooper Power Systems Business
541-912-75690
johnaobrien@eaton.com

SPX Waukesha
Tom Pickens
Service Department
800-835-2732
tom.pickens@spx.com

Sacramento Municipal Utility District
Mike Rudek
Supervisor, Standards
916-732-5720
mrudek@smud.org

Sacramento Municipal Utility District (cont.)

Ed Stockman
Principal Electrical Engineer
estockm@smud.org

PG&E

Daniel Mulkey
Sr. Consulting Electrical Engineer, Distribution
415-973-4699
dhm3@pge.com

A.2 15kVA Cost Analysis

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PGE Specification Cost Analysis

NATURAL ESTER DIELECTRIC FLUIDS IN DISTRIBUTION TRANSFORMERS

DESCRIPTION:

This analysis determines the value of life extension associated with the purchase of distribution transformers filled with natural ester-based dielectric fluids vs. conventional mineral oil based fluids. The analysis is based on accelerated test data supplied by manufacturers showing that the life of the paper insulation more than doubles when transformers are filled with ester based fluids. It is assumed a standard industry unit will provide 30 years of trouble free service. It is then conservatively assumed that the life of a transformer will be extended by 33% by utilizing the ester-based oils. Depreciation of the assets is based on the straight line method and 10% of that depriciated value is assumed to be the salvage value of the assets.

ASSUMPTIONS:

ANTICIPATED LIFE OF STD DISTRIBUTION TRANSFORMER:	30	YEARS
Assumed life extension of 33% by use of ester-based dielectric fluid.	10	YEARS
PERCENTAGE OF TRANSFORMERS TO FAIL IN ONE LIFE	100%	
TODAY'S MATERIAL COST TO REPLACE TRANSFORMER	$660	
Loaded LABOR COST W/ OVERHEADS	$1,294	
RATE OF INFLATION	1.70%	PER YEAR
PGE DISCOUNT RATE	7.59%	PER YEAR

DIELECTRIC FLUID			MINERAL OIL FLUID	NATURAL ESTER FLUID
	Escalated Equipment Cost	Escalated Installed Cost	Projected Investment Stream	Projected Investment Stream (Assumes First Cost Equivalent to Mineral Oil)
YEAR				
0	$660	$1,954	$1,954	$1,954
1	$671	$1,987	$0	$0
2	$683	$2,021	$0	$0
3	$694	$2,056	$0	$0
4	$706	$2,091	$0	$0
5	$718	$2,126	$0	$0
6	$730	$2,162	$0	$0
7	$743	$2,199	$0	$0
8	$755	$2,236	$0	$0
9	$768	$2,274	$0	$0
10	$781	$2,313	$0	$0
11	$794	$2,352	$0	$0
12	$808	$2,392	$0	$0
13	$822	$2,433	$0	$0
14	$836	$2,474	$0	$0
15	$850	$2,517	$0	$0
16	$864	$2,559	$0	$0
17	$879	$2,603	$0	$0
18	$894	$2,647	$0	$0
19	$909	$2,692	$0	$0
20	$925	$2,738	$0	$0
21	$940	$2,784	$0	$0
22	$956	$2,832	$0	$0
23	$973	$2,880	$0	$0
24	$989	$2,929	$0	$0
25	$1,006	$2,979	$0	$0
26	$1,023	$3,029	$0	$0
27	$1,040	$3,081	$0	$0
28	$1,058	$3,133	$0	$0
29	$1,076	$3,186	$0	$0
30	$1,094	$3,241	$3,241	$0
31	$1,113	$3,296	$0	$0
32	$1,132	$3,352	$0	$0
33	$1,151	$3,409	$0	$0
34	$1,171	$3,467	$0	$0
35	$1,191	$3,525	$0	$0
36	$1,211	$3,585	$0	$0
37	$1,231	$3,646	$0	$0
38	$1,252	$3,708	$0	$0
39	$1,274	$3,771	$0	$0
40	$1,295	$3,836	($130)	$3,706
YEAR 40 SALVAGE VALUE			$130	$130
NET PRESENT COST OF INVESTMENT			$2,145	$2,001
NET PRESENT SAVINGS				$144.43
PERCENT NET PRESENT SAVINGS ON TRANSFORMER PRICE				21.88%

A.3 25kVA Cost Analysis

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PGE SPECIFICATION COST ANALYSIS

NATURAL ESTER DIELECTRIC FLUIDS IN DISTRIBUTION TRANSFORMERS

DESCRIPTION:

This analysis determines the value of life extension associated with the purchase of distribution transformers filled with natural ester-based dielectric fluids vs. conventional mineral oil based fluids. The analysis is based on accelerated test data supplied by manufacturers showing that the life of the paper insulation more than doubles when transformers are filled with ester based fluids. It is assumed a standard industry unit will provide 30 years of trouble free service. It is then conservatively assumed that the life of a transformer will be extended by 33% by utilizing the ester-based oils. Depreciation of the assets is based on the straight line method and 10% of that depriciated value is assumed to be the salvage value of the assets.

ASSUMPTIONS:

ANTICIPATED LIFE OF STD DISTRIBUTION TRANSFORMER:	30	YEARS
Assumed life extension of 33% by use of ester-based dielectric fluid.	10	YEARS
PERCENTAGE OF TRANSFORMERS TO FAIL IN ONE LIFE	100%	
TODAY'S MATERIAL COST TO REPLACE TRANSFORMER	$865	
Loaded LABOR COST W/ OVERHEADS	$1,300	
RATE OF INFLATION	1.70%	PER YEAR
PGE DISCOUNT RATE	7.59%	PER YEAR

DIELECTRIC FLUID			**MINERAL OIL FLUID**	**NATURAL ESTER FLUID**
	Escalated Equipment Cost	Escalated Installed Cost	Projected Investment Stream	Projected Investment Stream (Assumes First Cost Equivalent to Mineral Oil)
YEAR				
0	$865	$2,165	$2,165	$2,165
1	$880	$2,202	$0	$0
2	$895	$2,239	$0	$0
3	$910	$2,277	$0	$0
4	$925	$2,316	$0	$0
5	$941	$2,355	$0	$0
6	$957	$2,395	$0	$0
7	$973	$2,436	$0	$0
8	$990	$2,477	$0	$0
9	$1,007	$2,520	$0	$0
10	$1,024	$2,562	$0	$0
11	$1,041	$2,606	$0	$0
12	$1,059	$2,650	$0	$0
13	$1,077	$2,695	$0	$0
14	$1,095	$2,741	$0	$0
15	$1,114	$2,788	$0	$0
16	$1,133	$2,835	$0	$0
17	$1,152	$2,883	$0	$0
18	$1,172	$2,932	$0	$0
19	$1,192	$2,982	$0	$0
20	$1,212	$3,033	$0	$0
21	$1,232	$3,084	$0	$0
22	$1,253	$3,137	$0	$0
23	$1,275	$3,190	$0	$0
24	$1,296	$3,244	$0	$0
25	$1,318	$3,300	$0	$0
26	$1,341	$3,356	$0	$0
27	$1,364	$3,413	$0	$0
28	$1,387	$3,471	$0	$0
29	$1,410	$3,530	$0	$0
30	$1,434	$3,590	$3,590	$0
31	$1,459	$3,651	$0	$0
32	$1,483	$3,713	$0	$0
33	$1,509	$3,776	$0	$0
34	$1,534	$3,840	$0	$0
35	$1,560	$3,905	$0	$0
36	$1,587	$3,972	$0	$0
37	$1,614	$4,039	$0	$0
38	$1,641	$4,108	$0	$0
39	$1,669	$4,178	$0	$0
40	$1,698	$4,249	($170)	$4,079
YEAR 40 SALVAGE VALUE			$170	$170
NET PRESENT COST OF INVESTMENT			$2,375	$2,215
NET PRESENT SAVINGS				$160.00
PERCENT NET PRESENT SAVINGS ON TRANSFORMER PRICE				18.50%

A.4 50kVA Cost Analysis

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PGE SPECIFICATION COST ANALYSIS

NATURAL ESTER DIELECTRIC FLUIDS IN DISTRIBUTION TRANSFORMERS

DESCRIPTION:

This analysis determines the value of life extension associated with the purchase of distribution transformers filled with natural ester-based dielectric fluids vs. conventional mineral oil based fluids. The analysis is based on accelerated test data supplied by manufacturers showing that the life of the paper insulation more than doubles when transformers are filled with ester based fluids. It is assumed a standard industry unit will provide 30 years of trouble free service. It is then conservatively assumed that the life of a transformer will be extended by 33% by utilizing the ester-based oils. Depreciation of the assets is based on the straight line method and 10% of that depriciated value is assumed to be the salvage value of the assets.

ASSUMPTIONS:

ANTICIPATED LIFE OF STD DISTRIBUTION TRANSFORMER:	30	YEARS
Assumed life extension of 33% by use of ester-based dielectric fluid.	10	YEARS
PERCENTAGE OF TRANSFORMERS TO FAIL IN ONE LIFE	100%	
TODAY'S MATERIAL COST TO REPLACE TRANSFORMER	$1,110	
Loaded LABOR COST W/ OVERHEADS	$1,365	
RATE OF INFLATION	1.75%	PER YEAR
PGE DISCOUNT RATE	7.59%	PER YEAR

DIELECTRIC FLUID			**MINERAL OIL FLUID**	**NATURAL ESTER FLUID**
	Escalated Equipment Cost	Escalated Installed Cost	Projected Investment Stream	Projected Investment Stream (Assumes First Cost Equivalent to Mineral Oil)
YEAR				
0	$1,110	$2,475	$2,475	$2,475
1	$1,129	$2,519	$0	$0
2	$1,149	$2,563	$0	$0
3	$1,169	$2,607	$0	$0
4	$1,190	$2,653	$0	$0
5	$1,211	$2,699	$0	$0
6	$1,232	$2,747	$0	$0
7	$1,253	$2,795	$0	$0
8	$1,275	$2,844	$0	$0
9	$1,298	$2,893	$0	$0
10	$1,320	$2,944	$0	$0
11	$1,343	$2,996	$0	$0
12	$1,367	$3,048	$0	$0
13	$1,391	$3,101	$0	$0
14	$1,415	$3,156	$0	$0
15	$1,440	$3,211	$0	$0
16	$1,465	$3,267	$0	$0
17	$1,491	$3,324	$0	$0
18	$1,517	$3,382	$0	$0
19	$1,543	$3,442	$0	$0
20	$1,570	$3,502	$0	$0
21	$1,598	$3,563	$0	$0
22	$1,626	$3,625	$0	$0
23	$1,654	$3,689	$0	$0
24	$1,683	$3,753	$0	$0
25	$1,713	$3,819	$0	$0
26	$1,743	$3,886	$0	$0
27	$1,773	$3,954	$0	$0
28	$1,804	$4,023	$0	$0
29	$1,836	$4,094	$0	$0
30	$1,868	$4,165	$4,165	$0
31	$1,901	$4,238	$0	$0
32	$1,934	$4,312	$0	$0
33	$1,968	$4,388	$0	$0
34	$2,002	$4,465	$0	$0
35	$2,037	$4,543	$0	$0
36	$2,073	$4,622	$0	$0
37	$2,109	$4,703	$0	$0
38	$2,146	$4,785	$0	$0
39	$2,184	$4,869	$0	$0
40	$2,222	$4,954	($222)	$4,732
YEAR 40 SALVAGE VALUE			$222	$222
NET PRESENT COST OF INVESTMENT			$2,721	$2,536
NET PRESENT SAVINGS				$184.44
PERCENT NET PRESENT SAVINGS ON TRANSFORMER PRICE				16.62%

A.5 FR3^{TM} Distribution Class Transformer Retrofilling Guide

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Dielectric Fluids

Reference Data

Guide for Atmospheric Retrofilling of 25KV (or lower) Distribution Class Transformers ≤ 7500KVA

R2010

> **IMPORTANT:**
> **This reference guide applies to retrofilling transformers in general and is not intended to convey safety information. Refer to original manufacturer's Operation and Maintenance guide for each transformer prior to beginning the retrofill process. Each installation may require additional steps. Stricter compliance with the above steps, or additional steps not listed, may be indicated by service records, test results, manufacturer and installer's recommendations, applicable code requirements, site inspection of the transformer or other industry maintenance and operating practices. All applicable safety codes and procedures must be followed.**

GENERAL

Replacing the mineral oil in a distribution transformer (retrofilling) with Envirotemp™ FR3™ fluid can be an effective way to upgrade fire safety, slow the thermal aging of cellulose insulation, and lower the environmental risk in otherwise healthy transformers.

Extensive laboratory testing and field retrofill experience has confirmed excellent miscibility and overall retrofill compatibility for Envirotemp FR3 natural ester fluid with many dielectric fluids including conventional mineral oil, high temperature hydrocarbon fluids (i.e. R-Temp® fluid), PCBs, and most PCB substitutes except silicone. Envirotemp FR3 fluid is not miscible with silicone and should not be applied in transformers previously containing silicone.

Envirotemp FR3 fluid has service proven stability in sealed transformers. Transformers with free breathing conservators should be modified to prevent the dielectric fluid from coming in contact with replenishing air. This will help ensure long term stability of the natural ester fluid.

Draining and flushing cannot remove all the dielectric fluid from a transformer, particularly from insulating paper. The mineral oil in the paper insulation will eventually leach out into the Envirotemp FR3 fluid until equilibrium is achieved. Mineral oil is fully miscible and compatible with Envirotemp FR3 fluid; however if the concentration of residual mineral oil exceeds 7.5% by volume, then Envirotemp FR3 fluid's fire point will fall below 300°C. Following this guide should limit the residual oil to 3-5%.

A transformer designed for conventional mineral oil may run at higher temperature after retrofilling with Envirotemp FR3 fluid, up to 4-5°C increase is typical. Because insulating paper aging rate is significantly slower when impregnated with Envirotemp FR3 fluid, any typical temperature increase should not negatively impact the insulation life.

Performance issues related to deficient dielectric design and construction, such as corona or partial discharge may not be remedied by fluid replacement. Retrofilling may be viable for reducing PCB or other contamination levels. However, this guide does not address regulations for the handling or disposal of PCB or other regulated hazardous materials.

Refer to the following Envirotemp FR3 fluid documents for additional information: Envirotemp FR3 Data Sheet (R2000), Envirotemp FR3 Fluid Storage and Handling Guide (S10), Envirotemp FR3 Fluid Test Summary (R2030), and Dissolved Gas Guide (R2060), Loading Guide A and B Factors for Envirotemp FR3 Fluid and Thermally Upgraded Kraft Insulation (R2110).

TRANSFORMER CONDITION ASSESSMENT

A visual inspection to confirm integrity of all seals/bolted connections, and proper operation of gauges should be performed. This may indicate whether additional maintenance operations should be performed while the unit is out of service.

Pre-Retrofill Steps:

1. Obtain original Operation and Maintenance guide for each transformer
2. Obtain transformer gasket set
3. Order needed replacement parts
4. Note site limitations for service equipment
5. Schedule old oil disposal
6. Schedule new fluid delivery
7. Obtain container for flush fluid
8. Note location of drain, fill, & vacuum connections
9. Limit air and moisture exposure whenever possible
10. If moisture removal (dry out) of coils is required, several methods are acceptable, however hot air drying is not. Refer to Storage and Handling Guide (S10) for additional information.

IMPORTANT:

Unlike assemblies impregnated with mineral oil, hot air drying is an unacceptable process for reducing power factor of assemblies already impregnated with a natural ester fluid. For additional drying of natural ester impregnated assemblies, a method of drying that does not expose the impregnated insulation to air is required to avoid polymerization of the dielectric fluid. See Storage and Handling Guide (S10), Reprocessing Impregnated Insulation section in Power Factor Measurements for recommended procedures.

GUIDE A: REPLACING MINERAL OIL WITH ENVIROTEMP™ FR3™ FLUID IN DISTRIBUTION TRANSFORMERS < 500KVA AT A TRANSFORMER SERVICE SHOP

Step	Key Points	Comments
1. Adhere to all required safety precautions, codes, and regulations	Follow manufacturer's recommendations for servicing each transformer; additionally, adhere to all required safety precautions, codes, and regulations	
2. Visual inspection	Confirm integrity of seals, bushings, and bolted connections	
3. Drain oil	Allow time for oil to drip to bottom of tank	A longer drip time is advantageous to reduce residual mineral oil
4. Rinse with Envirotemp FR3 fluid (~ 5-10% of the fluid volume)	This step rinses most of the remaining free oil to the bottom of the tank	Minimizes residual oil and other contaminants
5. Remove dregs from tank bottom	Minimizes the residual oil and other contaminants	
6. If required, dry coils	Hot air drying is unacceptable; see Storage and Handling Guide (S10) for additional information	
7. Replace Gaskets with new set	Helps ensure proper sealing	Original gaskets that weep or leak should be replaced. Elastomers including NBR types with higher nitrile content, silicone or fluoropolymer are recommended. Gaskets with higher temperature demands warrant the use of silicone or fluoropolymer (Viton) compositions.
8. Fill transformer directly from tote or drum	Heating and filtering are not required	Envirotemp FR3 fluid as-received in sealed totes and drums is satisfactory for use in small distribution transformers
9. Top off with dry air or nitrogen and bring headspace pressure to 2-3 psig (13-20 kPa)	Verify gaskets and seals are working properly	Limits exposure to oxygen and atmospheric contaminants
10. Install retrofill label	Fill out Cargill Retrofill label using indelible pen	Document Envirotemp FR3 fluid batch number from tote or drum for future reference
11. Wait to energize unit	24 hours is preferred	Allows gas bubbles to dissipate
12. Next day, check pressure to ensure proper seal	Limits exposure to oxygen and atmospheric contaminants	

GUIDE B: REPLACING MINERAL OIL WITH Envirotemp™ FR3™ FLUID IN PAD MOUNTED, NETWORK, OR DISTRIBUTION SUBSTATION TRANSFORMERS 500KVA THROUGH 7500KVA

Step	Key Points	Comments
1. Adhere to all required safety precautions, codes, and regulations	Follow manufacturer's recommendations for servicing each transformer; additionally, adhere to all required safety precautions, codes, and regulations	
2. Obtain original Operation and maintenance guide for each transformer	Follow manufacturer's recommendations for servicing each transformer, adhering to all required safety precautions, codes and regulations	
3. Access the unit	Follow applicable safety precautions and regulations. Record all nameplate information and determine allowable tank vacuum	Make sure the unit is isolated from the power system
4. Ground all equipment	Includes transformer, pump, and tanks	Ensures static discharge
5. Take oil samples if required	Take samples for fluid analysis and dissolved gas per ASTM procedures	Provides a baseline of transformer condition at the time of retrofill
6. Drain oil	If transformer is level or tilted towards the drain plug, force oil out by applying a positive pressure of 5 psig (34 kPa) using dry gas. Otherwise, pump out oil through drain valve	If required, after level is below the lower header, completely drain radiators by removing drain plugs. Properly seal drain plugs when reinstalling
7. Replace all oil-immersed gaskets	Tighten to proper compression based on component function and gasket material	Original gaskets that weep or leak should be replaced. Elastomers including NBR types with higher nitrile content, silicone or fluoropolymer are recommended. Gaskets with higher temperature demands warrant the use of silicone or fluoropolymer (Viton) compositions.
8. Allow minimum ½ hour drip after draining	>2 hours is preferred	A longer drip time is advantageous to reduce residual mineral oil. If the tank can withstand forces, pulling vacuum within tank mechanical limit will accelerate drip
9. Flush with Envirotemp FR3 fluid (≈ 5% of fluid volume)	Use minimum pressure to avoid dislodging contaminants. Flush through the fill plug or bolted access. Be sure to flush radiators. Set bolted access in place ASAP	To reduce viscosity, Cargill recommends flushing fluid temperature between 50-80°C
10. Allow ½ hour drip	A longer drip time is advantageous	
11. Remove dregs from bottom of transformer	Access can be gained by removing drain valve	Minimizes the residual mineral oil
12. Fill transformer	Bottom filling is recommended to avoid trapping air bubbles. Optimal fill process includes heating and filtering fluid. For fluid received in bulk tanker shipments, processing the fluid is mandatory	To reduce viscosity and minimize set time, Cargill recommends minimum 50°C fluid temp. Filling under vacuum or partial vacuum will limit fluid exposure to atmospheric contaminants and is the preferred method
13. Top with dry air or nitrogen blanket. Bring headspace pressure to 2-3 psig (13-20 kPa)	Verify gaskets and seals are working properly	Limits exposure to oxygen and atmospheric contaminants
14. Install retrofill label	Fill out Cargill Retrofill label using indelible pen. Attach to transformer	
15. Wait to energize unit	Wait time depends on fluid fill temperature	Allows gas bubbles to dissipate
16. a. Energize unit		
b. Connect load	Observe unit for leaks	
17. Next day, check the temperature and pressure	Observe unit for leaks and other signs of problems	
18. Follow the standard maintenance schedule and procedures	Pay close attention to signs of leaks from gaskets. Take samples, as mentioned in step 5, after six months	
19. Periodically monitor and record tank pressure to confirm tank seal	A constant 0 psig (0 kPa) on gauge, despite temperature changes, indicates an air leak	

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A.6 FR3^{TM} Power Class Transformer Retrofilling Guide

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Dielectric Fluids

Service Information

Guide for Retrofilling Power Class Transformers > 7500KVA

R2040

IMPORTANT:

This reference guide applies to retrofilling transformers in general and is not intended to convey safety information. Refer to original manufacturer's Operation and Maintenance guide for each transformer prior to beginning the retrofill process. Each installation may require additional steps. Stricter compliance with the above steps, or additional steps not listed, may be indicated by service records, test results, manufacturer and installer's recommendations, applicable code requirements, site inspection of the transformer or other industry maintenance and operating practices. All applicable safety codes and procedures must be followed.

RETROFILLING PROCEDURE

Replacing the mineral oil in a power class transformer (retrofilling) with Envirotemp™ FR3™ fluid can be an effective way to upgrade fire safety, slow the thermal aging of insulation, lower the environmental risk and improve the short term overload-ability of an otherwise healthy transformer.

Extensive laboratory testing and field experience has confirmed excellent miscibility and overall retrofill compatibility for Envirotemp FR3 natural ester fluid with conventional mineral oil and high temperature hydrocarbon fluids (i.e. R-Temp® fluid). Envirotemp FR3 fluid is not miscible with silicone and should not be applied in transformers previously containing silicone.

Envirotemp FR3 fluid has service proven stability in sealed transformers. Transformers with free breathing conservators should be modified to prevent the dielectric fluid from coming in contact with replenishing air. This will help ensure long term stability of the natural ester fluid.

Draining and flushing cannot remove all the dielectric fluid from a transformer, particularly from insulating paper. The mineral oil in the paper insulation will eventually leach out into the Envirotemp FR3 fluid until equilibrium is achieved. Mineral oil is fully miscible and compatible with Envirotemp FR3 fluid; however if the concentration of residual mineral oil exceeds 7.5% by volume, then Envirotemp FR3 fluid's fire point will fall below 300°C. Following this guide should limit the residual oil to 3-5%.

A transformer designed for conventional mineral oil may run at higher temperature after retrofilling with Envirotemp FR3 fluid. For ratings up to 10 MVA, a 4-5°C increase is typical. Forced oil cooling design (FOA and OFAF ratings) operating temperatures will be closer to those for mineral oil. Since the fan operation is triggered by fluid temperature, the higher temperature rise will only affect operating temperatures at the fan-cooled rating. Because insulating paper aging rate is significantly slower when impregnated with Envirotemp FR3 fluid, any typical temperature increase should not negatively impact the insulation life.

It is strongly recommended that filling power class transformers be completed under vacuum, within the constraint of the tank capability. Some transformers may not be rated for full (or partial) vacuum. When filling units at atmospheric pressure with Envirotemp FR3 fluid, heating and filtering the fluid are strongly recommended to maximize performance. Fluid temperatures during tank filling operations at atmospheric pressure should be 75°-80°C (165°-175°F). Longer set times to allow for trapped air bubble gas absorption are recommended when filling at atmospheric pressure.

Performance issues related to deficient dielectric design and construction, such as corona or partial discharge may not be remedied by fluid replacement. Retrofilling may be viable for reducing PCB or other contamination levels. However, this guide does not address regulations for the handling or disposal of PCB or other regulated hazardous materials.

Refer to the following Envirotemp FR3 fluid documents for additional information: Envirotemp FR3 Data Sheet (R2000), Envirotemp FR3 Fluid Storage and Handling Guide (S10), Envirotemp FR3 Fluid Test Summary (R2030), Dissolved Gas Guide (R2060), Transformer Power Factor and Envirotemp FR3 fluid (R2100), Loading Guide A and B Factors for Envirotemp FR3 Fluid and Thermally Upgraded Kraft Insulation (R2110).

TRANSFORMER CONDITION ASSESSMENT

A visual inspection to confirm integrity of all seals/ bolted connections, and proper operation of gauges should be performed. This may indicate whether additional maintenance operations should be performed while the unit is out of service.

Pre-Retrofill Steps:

1. Adhere to all safety precautions, codes and regulations. Follow all locally approved safety practices and procedures.
2. Obtain original Operation and Maintenance guide for each transformer
3. Obtain transformer gasket set
4. Order needed replacement parts
5. Note site limitations for service equipment
6. Schedule old oil disposal
7. Schedule new fluid delivery
8. Obtain container for flush fluid
9. Note location of drain, fill, & vacuum connections
10. Limit air and moisture exposure whenever possible
11. If moisture removal (dry out) of coils is required, several methods are acceptable, however hot air drying is not. Refer to Storage and Handling Guide (S10) for additional information.

Step	Key Points	Comments
1. Adhere to all required safety precautions, codes, and regulations	Follow manufacturer's recommendations for servicing each transformer; additionally, adhere to all required safety precautions, codes, and regulations	
2. Access the unit	Follow applicable safety precautions and regulations	Record all nameplate information and determine allowable tank vacuum. Make sure the unit is isolated from the power system.
3. Ground all equipment	Includes transformer, pump, and tanks	Ensures static discharge
4. Take oil samples	Take samples for fluid analysis and dissolved gas per ASTM procedures.	Provides a baseline of transformer condition at the time of retrofill.
5. Drain oil	If transformer is level or tilted towards the drain plug, force oil out by applying a positive pressure of 5 psig (34 kPa) using dry gas. Otherwise, pump out oil through drain valve.	Radiators must be completely drained by removing drain plugs after oil level is below the lower headers, if upper headers are not accessible for flushing (see Step 8).
6. Replace all oil-immersed gaskets	Tighten to proper compression based on component function and gasket material.	Original gaskets that weep or leak should be replaced. Elastomers including NBR types with higher nitrile content, silicone or fluoropolymer are recommended. Gaskets with higher temperature demands warrant the use of silicone or fluoropolymer (Viton) compositions.
7. Allow minimum ½ hour drip after draining	Two hours is preferred. Pulling vacuum within tank mechanical limit will accelerate drip.	A longer drip time is advantageous to reduce residual mineral oil
8. Flush with hot Envirotemp™ FR3™ fluid (≈ 5% of fluid volume)	Use minimum pressure to avoid dislodging contaminants. Flush through the fill plug or bolted access. Be sure to flush radiators. Set bolted access in place ASAP.	To reduce viscosity, Cargill recommends flushing fluid temperature between 50-80°C.
9. Allow ½ hour drip	A longer drip time is advantageous.	
10. Remove dregs from bottom of transformer	Access can be gained by removing drain valve.	Minimizes the residual mineral oil.
11. Fill Transformer	Pull vacuum within tank mechanical limits. Start fill through drain plug when base pressure is reached.	Minimum 50°C fluid temp. Use 0.5 µm filters. Limit base pressure to tank rating.
12. Top with dry air or nitrogen blanket. Bring headspace pressure to 2-3 psig (13-20 kPa).	Verify gaskets and seals are working properly	Limits exposure to oxygen and atmospheric contaminants.
13. Install retrofill label	Fill out label using #2 pencil.	
14. Wait to energize unit	24 hours is preferred. Wait time depends on fluid fill temperature.	Allows gas bubbles to dissipate.
15. Take oil samples	Check & maintain positive pressure. Take samples as in 4.	Verifies the unit is leak-free. Provides a base line for new fluid.
16. **a.** Energize unit (no load)		
b. Wait prior to adding load	Three hours minimum.	
c. Connect load	Observe unit for leaks.	
17. Next day, check the temperature and pressure	Observe unit for leaks and other signs of problems.	
18. Follow the standard maintenance schedule and procedures	Pay close attention to signs of leaks from gaskets. Take samples as in 4 after six months.	
19. Periodically monitor and record tank pressure to confirm tank seal.	A constant 0 psig (0 kPa) on gauge, despite temperature changes, indicates a leak.	

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A.7 FR3™ Material Safety Data Sheet

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MATERIAL SAFETY DATA SHEET

1. Product and Company Identification

Material name	**ENVIROTEMP FR3 FLUID**
Version #	01
Issue date	06-13-2012
Revision date	-
Supersedes date	-
CAS #	Mixture
MSDS Number	12.55.1
Product use	Dielectric Coolant
Manufacturer/Supplier	Industrial Oils & Lubricants 9320 Excelsior Blvd. Hopkins, Minnesota 55343 US IOLCustomerService@cargill.com
General Information:	1-800-842-3631
Emergency	Emergency Telephone: 1-800-424-9300

2. Hazards Identification

Physical state	Liquid.
Appearance	Green Liquid.
Emergency overview	CAUTION! Prolonged or repeated skin contact may cause drying, cracking, or irritation.
OSHA regulatory status	This product is not hazardous according to OSHA 29CFR 1910.1200.
Potential health effects	
Routes of exposure	Skin contact.
Eyes	Direct contact with eyes may cause temporary irritation.
Skin	Prolonged or repeated contact may cause itching, redness, and rash in some individuals.
Inhalation	Under normal conditions of intended use, this material is not expected to be an inhalation hazard.
Ingestion	No harmful effects expected in amounts likely to be ingested by accident.

3. Composition / Information on Ingredients

Components	CAS #	Percent
Vegetable Oil	8001-22-7	> 98.5

Composition comments All concentrations are in percent by weight unless ingredient is a gas. Gas concentrations are in percent by volume.

4. First Aid Measures

First aid procedures	
Eye contact	Any material that contacts the eye should be washed out immediately with water. If easy to do, remove contact lenses. Get medical attention promptly if symptoms occur after washing.
Skin contact	Wash skin with soap and water. Get medical attention promptly if symptoms occur after washing.
Inhalation	If symptomatic, move to fresh air. Get medical attention if symptoms persist.
Ingestion	First aid is normally not required. However, if greater than 1/2 liter (pint) ingested, seek medical attention.

5. Fire Fighting Measures

Flammable properties No unusual fire or explosion hazards noted.

Extinguishing media	
Suitable extinguishing media	Water. Water fog. Foam. Dry chemical powder. Carbon dioxide (CO_2).
Fire fighting equipment/instructions	Self-contained breathing apparatus and full protective clothing must be worn in case of fire.
Hazardous combustion products	Carbon oxides.

6. Accidental Release Measures

Personal precautions	Wear appropriate personal protective equipment (See Section 8).
Environmental precautions	Environmental manager must be informed of all major releases.
Methods for cleaning up	Absorb spill with vermiculite or other inert material, then place in a container for chemical waste. Large Spills: Flush area with water. Prevent runoff from entering drains, sewers, or streams. Dike for later disposal.

7. Handling and Storage

Handling	Observe good industrial hygiene practices.
Storage	Keep container closed.

8. Exposure Controls / Personal Protection

Occupational exposure limits	No exposure limits noted for ingredient(s).
Engineering controls	Ensure adequate ventilation, especially in confined areas.
Personal protective equipment	
Eye / face protection	Wear safety glasses with side shields (or goggles).
Skin protection	Wear chemical-resistant gloves, footwear and protective clothing appropriate for risk of exposure. Contact glove manufacturer for specific information.
Respiratory protection	If engineering controls do not maintain airborne concentrations below recommended exposure limits (where applicable) or to an acceptable level (in countries where exposure limits have not been established), an approved respirator must be worn. Respirator type: Air-purifying respirator with an appropriate, government approved (where applicable), air-purifying filter, cartridge or canister.
General hygiene considerations	Always observe good personal hygiene measures, such as washing after handling the material and before eating, drinking, and/or smoking. Routinely wash work clothing and protective equipment to remove contaminants.

9. Physical & Chemical Properties

Appearance	Green Liquid.
Physical state	Liquid.
Form	Liquid.
Color	Green.
Odor	Mild.
Odor threshold	Not available.
pH	Neutral
Vapor pressure	< 0.01 mm Hg @ 20 °C
Vapor density	Not available.
Boiling point	> 680 °F (> 360 °C)
Melting point/Freezing point	Not Available
Solubility (water)	Insoluble
Specific gravity	0.92
Flash point	590 - 608 °F (310 - 320 °C) Closed Cup
Flammability limits in air, upper, % by volume	Not Available.
Flammability limits in air, lower, % by volume	Not Available.
Auto-ignition temperature	753.8 - 759.2 °F (401 - 404 °C)

VOC	< 0.001 g/l
Viscosity	33 - 35 mm²/s @ 40 °C
Other data	
Decomposition temperature	Not Available.

10. Chemical Stability & Reactivity Information

Chemical stability	Material is stable under normal conditions.
Conditions to avoid	Excessive heat.
Incompatible materials	Strong oxidizing agents.
Hazardous decomposition products	No hazardous decomposition products are known.
Possibility of hazardous reactions	Hazardous polymerization does not occur.

11. Toxicological Information

Sensitization	No sensitizing effects known.
Acute effects	Prolonged or repeated skin contact may cause drying, cracking, or irritation.
Local effects	High mist concentrations may cause irritation of respiratory tract.
Carcinogenicity	This product is not considered to be a carcinogen by IARC, ACGIH, NTP, or OSHA.
Symptoms and target organs	Prolonged or repeated skin contact may cause drying, cracking, or irritation.

12. Ecological Information

Ecotoxicity	Not expected to be harmful to aquatic organisms.
Persistence and degradability	No data available.
Bioaccumulation / Accumulation	No data available.
Mobility in environmental media	No data available.

13. Disposal Considerations

Disposal instructions	Dispose of contents/container in accordance with local/regional/national/international regulations.
Waste from residues / unused products	Dispose of in accordance with local regulations.
Contaminated packaging	Since emptied containers may retain product residue, follow label warnings even after container is emptied.

14. Transport Information

DOT

Not regulated as a hazardous material by DOT.

IATA

Not regulated as dangerous goods.

IMDG

Not regulated as dangerous goods.

TDG

Not regulated as dangerous goods.

15. Regulatory Information

US federal regulations	This product is not hazardous according to OSHA 29CFR 1910.1200. All components are on the U.S. EPA TSCA Inventory List.

TSCA Section 12(b) Export Notification (40 CFR 707, Subpt. D)

Not regulated.

CERCLA (Superfund) reportable quantity (lbs) (40 CFR 302.4)

None

Superfund Amendments and Reauthorization Act of 1986 (SARA)

Hazard categories	Immediate Hazard - No Delayed Hazard - No Fire Hazard - No Pressure Hazard - No Reactivity Hazard - No
Section 302 extremely hazardous substance (40 CFR 355, Appendix A)	No
Section 311/312 (40 CFR 370)	No

Drug Enforcement Administration (DEA) (21 CFR 1308.11-15) Not controlled

WHMIS status Non-controlled

Inventory status

Country(s) or region	**Inventory name**	**On inventory (yes/no)***
Canada	Domestic Substances List (DSL)	Yes
Canada	Non-Domestic Substances List (NDSL)	No
United States & Puerto Rico	Toxic Substances Control Act (TSCA) Inventory	Yes

*A "Yes" indicates this product complies with the inventory requirements administered by the governing country(s)

State regulations This product does not contain a chemical known to the State of California to cause cancer, birth defects or other reproductive harm.

US - California Proposition 65 - Carcinogens & Reproductive Toxicity (CRT): Listed substance

Not listed.

US. Massachusetts RTK - Substance List

Vegetable Oil (CAS 8001-22-7) Listed.

US. New Jersey Worker and Community Right-to-Know Act

Not regulated.

US. Pennsylvania RTK - Hazardous Substances

Vegetable Oil (CAS 8001-22-7) Listed.

16. Other Information

Further information HMIS® is a registered trade and service mark of the NPCA.

HMIS® ratings
Health: 1
Flammability: 1
Physical hazard: 0

NFPA ratings
Health: 1
Flammability: 1
Instability: 0

Disclaimer To the best of our knowledge, the information contained herein is accurate. However, neither the above named supplier nor any of its subsidiaries assumes any liability whatsoever for completeness of the information contained herein. Final determination of suitability of any material is the sole responsibility of the user. All materials may present unknown hazards and should be used with caution. Although certain hazards are described herein, we cannot guarantee that these are the only hazards that exist.

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Authors

Nicole Zimmerman, is an MS candidate in the Electrical & Computer Engineering department at Portland State University. Her research and studies have focused on power engineering topics, especially power quality issues associated with electric vehicle charging infrastructure.

Robert Bass, Ph.D., is an associate professor in the Department of Electrical & Computer Engineering at Portland State University. His research is focused on electrical power systems, particularly distributed & renewable generation resources, optimization methods for multi-unit generation and the overlaying smart grid methods that link them together. Dr. Bass specializes in teaching undergraduate and graduate courses on electric power, electromechanical energy conversion, distributed energy resources, control theory and power systems analysis.

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