

Dielectric Fluids

Electrical Apparatus

900-20

Envirotemp® FR3™ Fluid

DESCRIPTION

Envirotemp® FR3™ fluid is a Fire Resistant Natural Ester dielectric coolant specifically formulated for use in distribution and power transformers where its unique environmental, fire safety, chemical, and electrical properties are advantageous.

Envirotemp FR3 fluid is formulated from edible vegetable oils and food grade performance enhancing additives. It does not contain any petroleum, halogens, silicones, or any other questionable material. It quickly and thoroughly biodegrades in both soil and aquatic environments. The fluid tested non-toxic in aquatic toxicity tests. It is tinted green to reflect its favorable environmental profile and to distinguish it from mineral oil.

Envirotemp FR3 fluid has an exceptionally high fire point of 360°C and flash point of 330°C. It has the highest ignition resistance of less-flammable fluids currently available. It is referred to as a High Fire Point or "Less-Flammable" fluid, and is Listed as a Less-Flammable Dielectric Liquid by FM Global® (FM) and Underwriters Laboratories® (UL) for use in complying with the National Electric Code® (NEC) and insurance requirements.

Envirotemp FR3 fluid is compatible with standard transformer insulating materials, components and with fluid processing equipment and procedures. It demonstrates improved thermal characteristics with a viscosity closer to conventional transformer oil, superior dielectric strength in new and continued service applications, and excellent chemical stability over time. Excellent performance has been confirmed in more than 10,000 field installations since 1998.

Because of its excellent environmental, fire safety, and performance characteristics, applications for Envirotemp FR3 fluid have expanded into a variety of other equipment, including power transformers, voltage regulators, sectionalizing switches, transformer rectifiers, electromagnets, and voltage supply circuits for luminaries. The fluid is also used in retrofill applications for transformers and other fluid-filled distribution and power equipment.

TABLE 1
Typical Initial Envirotemp FR3 Fluid Properties

Property	Value	Test Method
Electrical		
Dielectric Strength	56 kV @ 25°C (2.0 mm gap)	ASTM D1816
Relative Permittivity [Dielectric Constant]	3.2 @ 25°C	ASTM D924
Dissipation Factor [Power Factor]	0.08% @ 25°C 3.0 @ 100°C	ASTM D924
Volume Resistivity	20 X 10 ¹² Ω-cm @ 25°C	ASTM D1169
Impulse Strength (Sphere to Sphere)	226 kV @ 0.15" gap	ASTM D3300
Gassing Tendency	-79 (µl/min.)	ASTM D2300
Physical and Chemical		
Relative Density	0.92 @ 25°C	ASTM D1298
Interfacial Tension	24 mN/m @ 25°C	ASTM D971
Acid (Neutralization) Number	0.04 mg KOH/g	ASTM D974
Kinematic Viscosity	34 cSt @ 40°C 8 cSt @ 100°C	ASTM D445
Water Content	30 mg/kg	ASTM 1533B
Relative Saturation of Water	2-3%	CPS Method
Air Solubility	16% @ 25°C @ 1 atm.	ASTM D2779
Appearance	Clear, Light Green	ASTM D1524
Color	L 0.5	ASTM D1500
Thermal		
Flash Point (Closed Cup)	316°C	ASTM D93
Fire Point (Open Cup)	330°C	ASTM D92
Fire Point (Open Cup)	360°C	ASTM D92
Pour Point	-21°C	ASTM D97
Thermal Conductivity	4.0 X 10 ⁻⁴ cal/(cm •sec •°C) @ 25° C	CPS Method
Coefficient of Expansion	7.4 x 10 ⁻⁴ cc/cc/°C @ 25°C	CPS Method
Heat Capacity	2.10 J/g/°C @ 50°C 2.39 J/g/°C @ 100°C	ASTM E1269
Environmental Properties		
BOB/COD Ratio	45%	SM5210B
Aquatic Biodegradation	100%	EPA OPPTS 835.3110
Acute Toxicity to Trout Fry	Zero Mortality to Test End Point	OECD G.L. 203
Ready Biodegradation	100%	EPA OPPTS 835.3110

The typical properties shown above are for new fluid prior to factory shipment. These properties are subject to change without notice. Contact CPS Dielectric Fluids Products for recommended acceptance values. Ask for Envirotemp FR3 fluid Specification Guideline, Bulletin 97080.

PERFORMANCE

The unique chemical structure of Envirotemp FR3 fluid provides superior performance characteristics. The fluid maintains its dielectric strength much better than other dielectric fluids when used as a load-break switch medium, and has the lowest gassing tendencies under electrical stress. Its cooling performance is superior to other less-flammable fluids. It has lower viscosity at operating temperatures than other less-flammable fluids. The fluid exhibited no measurable change in viscosity over exhaustive testing cycles. It has superior resistance to coke and sludge formation when compared to conventional transformer oil. Under the same accelerated coking test, Envirotemp FR3 fluid produced less than 1/20 of carbonaceous coke than that produced in mineral oil. Doble Laboratories sludge-free life test resulted in no measurable sludge.

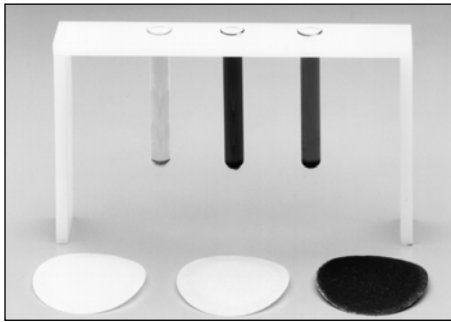


Figure 1.
Thermal Stability Test.

Left to right: Envirotemp FR3 fluid, R-Temp® fluid and Conventional Transformer Oil after 120 hours at 165°C.

Envirotemp FR3 fluid has an exceptional ability to draw out retained moisture and absorb water driven off by aging paper. It also chemically helps prevent the paper molecules from severing when exposed to heat. These attributes enable the fluid to significantly minimize the rate of aging of transformer insulating paper. Tests show that paper aged in Envirotemp FR3 fluid takes 5-8 times longer to reach the same end-of-life points as paper aged in conventional transformer oil.

The following chart shows a comparison of the time to reach insulation end-of-life for thermally upgraded Kraft paper aged in conventional transformer oil and Envirotemp FR3 fluid. Time to insulation end-of-life using **IEEE Standard C57.91™** transformer loading guide calculation is included for comparison. Similar accelerated

TABLE 2
Transformer Insulating Paper End-of-Life (Hours)

End-of-Life Basis	150°C			170°C			
	Mineral Oil	Envirotemp FR3 Fluid	IEEE Basis	Mineral Oil	Envirotemp FR3 Fluid	IEEE Basis	
Retained Tensile Strength							
	50%	3100	>4000*	1602	240	1300	323
	25%	4000	>4000*	3327	490	4000	671
Degree of Polymerization							
200	3200	>4000*	3697	480	3400	746	

* Paper did not reach end-of-life over the duration of the test. To be conservative, extrapolation was not employed.

aging tests have confirmed even greater thermal aging improvement for non-thermally upgraded Kraft paper.

FIRE SAFETY

Envirotemp FR3 fluid has a fire point of 360°C, well above the NEC minimum of 300°C. Its flash point (330°C) is higher than the fire point of most other currently available less-flammable fluids. Envirotemp FR3 fluid is certified as a less-flammable dielectric coolant by FM Global and UL in compliance with the listing requirements of the NEC. The National Fire Protection Association has no reports of fires or explosions involving transformers filled with Envirotemp FR3 fluid.

In large and small-scale tests, Envirotemp FR3 fluid has demonstrated greater fire resistance than

other askarel substitutes. Based on large-scale testing, FM Global concluded that the probability of a pool fire evolving from the fluid was so low, that heat release rate need not be determined or considered in determining the installation requirements of the fluid. FM Global accepts Envirotemp FR3 fluid for transformers Approved per FM Standard 3990. Occupational Safety & Health Administration (OSHA) has recognized this FM standard as fitting the definition of a Listed and Labeled Product per NEC Section 110-3(b). The standard permits Envirotemp FR3 fluid-filled transformers to be installed indoors, typically without sprinklers or vaults, with minimum clearance to walls of just 36 inches.

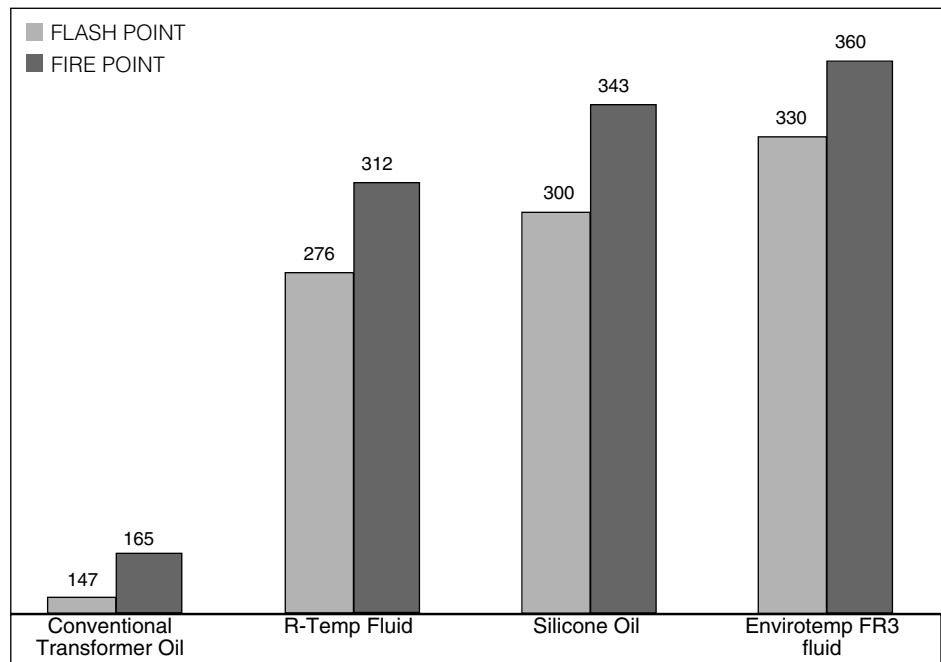


Figure 2.
Flash & Fire Point of Dielectric Fluids (°C).

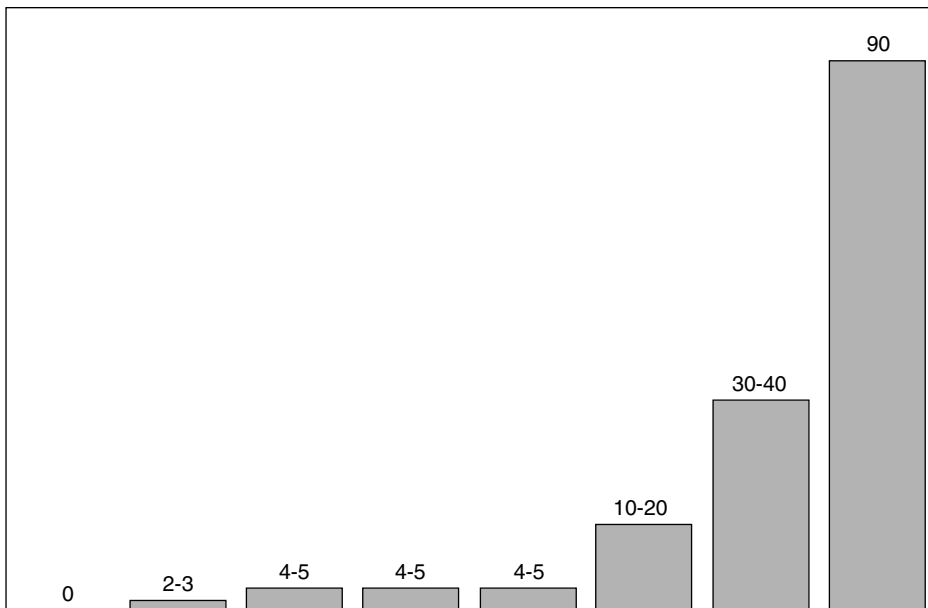


Figure 3.
Fire Hazard Rating UL Standard 340.

UL developed Standard 340 to compare the fire hazard rating of different fluids. The following graph demonstrates the favorable rating assigned to Envirotemp FR3 fluid. See the UL Marking on page 7 for transformer installation requirements.

FM Global also recognizes their approved fire-resistant fluids for use in transformers containing up to 10,000 gallons of fluid as close as 5 feet to buildings and other equipment without fire walls or extinguishing systems.

MEETING THE CODE

Less-Flammable fluids are recognized as a fire safeguard by Section 15 of the National Electrical Safety Code (Accredited Standards Committee C2) for generation and distribution substations. Envirotemp FR3 fluid meets the National Electrical Code Section 450-23 requirements as a listed less-flammable liquid. It is covered by OSHA Article §1910.305, Section 5(v).

Envirotemp FR3 fluid is FM Approved and UL Classified "Less-Flammable" per NEC Article 450-23, fitting the definition of a Listed Product per NEC. For additional information, request the NEC Requirements Guidelines, Bulletin 92046.

ENVIRONMENTAL & HEALTH

Envirotemp FR3 fluid is specifically formulated to minimize health and environmental risk. It is made of food grade vegetable oils and food grade performance enhancing additives. The base oils come from renewable resources - commodity seeds - and are easily recyclable and reusable. Envirotemp FR3 fluid does not require genetically altered vegetable oils. It has a trademark green tint to help differentiate it from other dielectric fluids. Its biodegradation rate is as good as the Environmental Protection Agency® (EPA) standard reference material, deemed "ultimately biodegradable" per EPA.

In one of the most extremely sensitive acute toxicity tests, the Trout Fry Acute Toxicity test OECD 203, Envirotemp FR3 fluid out-performed other dielectric fluids by achieving a zero mortality rate throughout the entire test period.

Because Envirotemp FR3 fluid is formulated from food-grade oils and additives, it is not subject to the Federal Regulation of Used Oils (Title 40, No. 270). It is instead covered by the Edible Oil Regulatory Reform Act (US Public Law 104-55, 1995), and therefore eligible for current and future regulatory relief. The option of alternative spill response procedures, such as natural bio-remediation, are now more viable. The fluid's slightly higher viscosity when compared to conventional transformer oil, combined with its ability to polymerize when thin layers are exposed to warmth and air flow, help prevent migration along the surface and into subsurface soils.

Envirotemp FR3 fluid is not listed as hazardous by the EPA, OSHA, or the Department of Transportation (DOT). Oral toxicity animal tests reported no signs of toxicological reactions, nor have human contact reactions been reported. Envirotemp FR3 fluid is not classified as bioaccumulating or mutagenic. It is a candidate for classification as an "Environmentally Preferred Product". Its Hazardous Material Information System (HMIS) rating is 0 for both health and reactivity. It is not listed as a carcinogen by National Toxicology Program (NTP), International Agency for Research on Cancer (IARC) monographs and OSHA Regulation. The thermal decomposition by-products from Envirotemp FR3 fluid are essentially limited to CO₂ and H₂O, with trace CO depending on the availability of

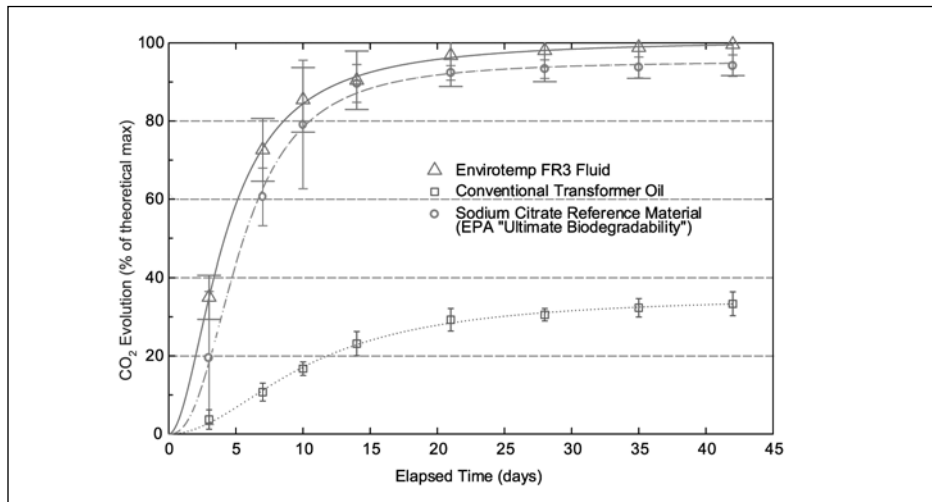


Figure 4.
Aerobic Aquatic Biodegradation Graph EPA Test OPPTS 835.3100

oxygen and temperature. Envirotemp FR3 fluid can not produce PCDFs (Furans), PCDDs (Dioxins), nor silicates.

Natural seed oil-based dielectric fluid use has been afforded U.S. Federal Government procurement preference by the U.S. Department of Agriculture (USDA) as a bio-based material per 7 CFR 2902, February 10, 2005. It is an excellent option for ISO 14000 or other similar environmental programs that promote the use of environmentally preferable alternative materials and procedures.

Additional product safety information is provided in the Envirotemp FR3 fluid Material Safety Data Sheet (MSDS), Bulletin 98082, available upon request.

APPLICATIONS

New Transformers

Transformers filled with Envirotemp FR3 fluid for indoor, submersible and outdoor applications are available from several manufacturers worldwide.

For indoor applications, Envirotemp FR3 fluid-filled transformers not only provide the proven performance of liquid-filled design, but at a lower total life cycle cost than other alternatives with equal ratings.

Envirotemp FR3 fluid-filled transformers are also an excellent choice for outdoor, network or subsurface vault installations where an extra margin of safety against explosion and fire is required. It is also preferred where protection from adverse environmental impact is desired as compared to other dielectric fluids such as conventional transformer oil. Outdoor applications where enhanced safety is recommended include close proximity to buildings or valuable equipment, rooftop installations and close proximity to pedestrian areas. Types of transformers presently operating with Envirotemp FR3 fluid include pole-mounted, pad-mounted, small, medium and large power substations. Envirotemp FR3 fluid-filled transformers are accepted in both industry and government. The fluid's favorable health and environmental properties make Envirotemp FR3 fluid-filled transformers a frequent choice in food and pharmaceutical processing plants. Contact Cooper Power Systems Dielectric Fluids Products or your equipment supplier for a copy of the Envirotemp FR3 fluid User's List, Bulletin 99020.

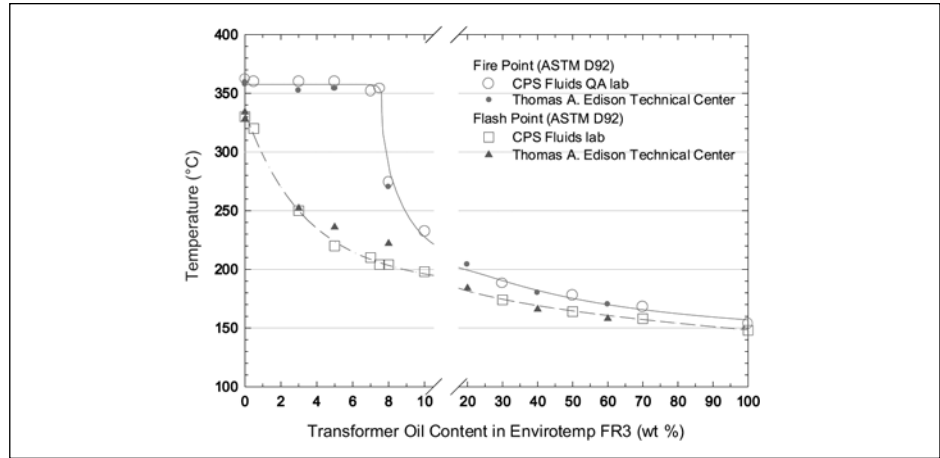


Figure 5. Envirotemp FR3 fluid Flash & Fire Point Variation with Conventional Transformer Oil Content.

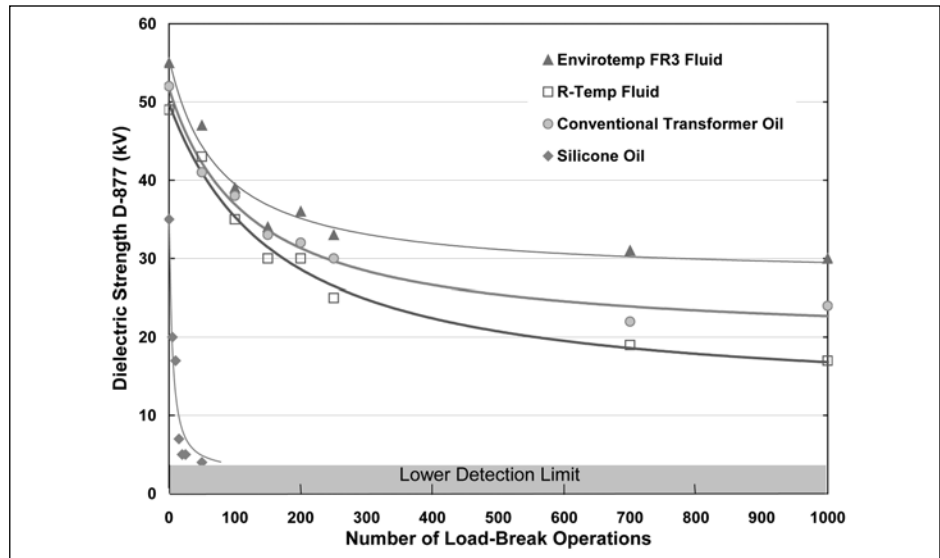


Figure 6. Fluid loadbreak dielectric strength retention comparison.

Retrofilling Transformers Filled With Conventional Transformer Oil

Envirotemp FR3 fluid is well-suited as a replacement fluid for upgrading the safety margin of fluid-filled transformers from both an environmental and fire safety aspect. It is fully miscible with conventional transformer oil, High Molecular Weight Hydrocarbons (HMWH), and most askarel substitutes. Unlike retrofilling with other less-flammable fluids, the residual transformer oil that remains in the transformer typically will not reduce the fire point below the NEC minimum of 300°C. This is true even after full equilibrium has been achieved between the replacement fluid and the residual oil in the paper.

Additional advantages of retrofilling with Envirotemp FR3 fluid include high dielectric strength, dielectric constant very close to kraft paper insulation, excellent lubricity, material compatibility, and a coefficient of expansion similar to conventional transformer oil. The fluid also acts as a drying agent for transformer insulation that has become wet from aging, this property helps extend the useful life of the transformer insulation system.

Envirotemp FR3 fluid does not cause foaming in transformer oil as trace amounts of silicone oil can under vacuum degassification. Unlike silicone, it does not cause paint adhesion problems, nor form the carbon silicates during switching that can lead to a severe reduction in dielectric strength.

Refer to Envirotemp FR3 fluid Storage and Handling Guide, Section S900-20-1, and retrofit guide section S900-20-2 or contact Cooper Power Systems Dielectric Fluids Products for additional recommendations.

Loadbreak Switching Devices

Excellent dielectric strength retention, lubricity, essentially non-coking, and a very low gassing tendency make Envirotemp FR3 fluid an excellent loadbreak switching medium at temperatures above -10°C. Proven applications include new and retrofilled sectionalizing switches, and transformers with loadbreak accessories such as bay-o-net fusing, on-off switches, sectionalizing switches and Vacuum Fault Interruption protection devices.

Due to viscosity differences compared to conventional transformer oil, suitability of each application should be reviewed by the equipment manufacturer particularly for very low ambient temperature installations.

Other Applications

The inherent safety and performance properties of Envirotemp FR3 fluid have led to its application in electrical equipment other than transformers, including industrial electromagnets, klystron modulators, transformer/rectifier sets, power supplies for luminaires, and heat transfer applications for testing equipment. Envirotemp FR3 fluid has excellent lubricity, an important characteristic for application in equipment with movable parts. High voltage oil impregnated paper, cable, and bushing application also appear very promising due to the fluid's excellent ability to minimize insulating paper degradation and its desirable gassing tendency value of -79 µl/min.

The suitability of each application of Envirotemp FR3 fluid is the responsibility of the user. Contact Cooper Power Systems Dielectric Fluids Products for application guidelines.

NOTE: *To maintain the optimal fluid properties for its intended use as an electrical insulating fluid, exposure to oxygen, moisture, and other contaminants must be minimized. Except for short storage periods, material that has been immersed in Envirotemp FR3 fluid should not be exposed to air. Thin films of natural esters tend to polymerize much faster than conventional transformer oil. For equipment drained of Envirotemp FR3 fluid, it is recommended that the equipment be placed in an inert gas environment or be re-immersed as soon as is practical. Hot air drying is an unacceptable process for assemblies already impregnated with a natural ester fluid. For impregnated assemblies that require additional drying, 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 Section S900-20-1 for additional information.*

FIELD PERFORMANCE HISTORY

Since the energization of prototypes in 1996, thousands of Envirotemp FR3 fluid-filled distribution transformers and equipment have been installed, accumulating tens of thousands of unit-years of reliable field service. Fluid performance and fire safety record has been flawless. In addition to new transformer application, conventional transformer oil-filled units have also been successfully retrofilled and operated with Envirotemp FR3 fluid. The monitoring of operating Envirotemp FR3 fluid-filled transformers, including the earliest prototypes, has demonstrated Envirotemp FR3 fluid to be exceptionally stable. Dissolved gas analysis has proven to be functional for transformer preventative maintenance.

GENERAL INFORMATION

Storage and Handling

The same basic procedures for storing and handling conventional transformer oil should be followed with Envirotemp FR3 fluid. To help maintain the extremely low percent moisture saturation at time of fluid manufacture, it is recommended that exposure time to air be as minimal as practical. Drum and tote storage should be indoors or outdoors protected from the elements. For additional storage and handling information contact Cooper Power Systems Dielectric Fluids Products or your equipment supplier and request Storage and Handling Guide, Section S900-20-1.



Figure 7. Prior to shipment, Envirotemp FR3 fluid undergoes extensive quality assurance testing. The facility where Envirotemp FR3 fluid is produced is ISO 9001 Certified.

Fluid Maintenance

Periodic maintenance tests for Envirotemp FR3 fluid-filled equipment should follow the same schedule used for transformers filled with conventional transformer oil. Recommended maintenance tests include:

1. Dielectric strength per ASTM D1816. The acceptable limit for continued use of service-aged Envirotemp FR3 fluid is 30 kV minimum (69 kV equipment and below). For applications >69 kV line voltage contact Cooper Power Systems Dielectric Fluids for recommendations.
2. Flash Point and Fire Point. Relatively small amounts of conventional oil should not significantly reduce the flash point and fire point of Envirotemp FR3 fluid. Contamination above 7.5% may reduce the fire point to below 300°C. If it is suspected that the fluid may be contaminated, flash point and fire point should be measured in accordance with ASTM D92.

TABLE 3
Properties for Envirotemp FR3 Fluid-Filled Equipment

Property	ASTM Method	New Fluid as Received in Drums	Continued Use of Service Aged Fluid
Dielectric Strength 2 mm gap (kV)	D1816	≥ 40	≥ 30
Dissipation Factor °C (%) 25° 100°	D924	≤ 0.20 ≤ 4.0	– –
Neutralization Number (mg KOH/g)	D974	≤ 0.06	≤ 2.5
Flash Point (°C)	D92	≥ 300	–
Fire Point (°C)	D92	≥ 340	≥ 300
Viscosity (°cSt) 100°C 40°C	D445	≤ 10 ≤ 40	– –
Pour Point (°C)	D97	≤ -18	–
Moisture Content (mg/kg)	D1533B	≤ 200	≤ 400

- Dissolved Gas Analysis.
Recommended particularly for high value equipment or equipment servicing critical loads. **ANSI®/IEEE guide C57.104-1991™** for detection and analysis of generated gases can be applied, except ratio methods.
- Testing dissipation factor, neutralization number and interfacial tension provides a good indication of possible fluid contamination or unusual degradation. Acceptable limits for continued use of service-aged Envirotemp FR3 fluids are listed in Table 3.

For fluid that cannot be reconditioned, recommended disposal options include selling to processors for recycling/refining, or conversion into bio-diesel oil, or blending with fuel oil for industrial grade boilers and industrial furnaces. Assuming that the fluid has not been contaminated by controlled materials, the used fluid is not under the jurisdiction of the Federal Used Oil Regulation (Title 40, No. 279).

Refer to Envirotemp FR3 fluid Storage and Handling Guide, Section S900-20-1 and Testing Guide, Section R900-20-12, or contact Cooper Power Systems Dielectric Fluids for additional recommendations.

Specification Guideline

The dielectric coolant shall be a listed less-flammable fluid meeting the requirements of National Electrical Code Section 450-23 and the requirements of the National Electrical Safety Code (**IEEE Standard C2-1997™**), Section 15. The fluid shall be non-toxic, non-bioaccumulating and be readily and completely biodegradable per EPA OPPTS 835.3100. It shall be comprised of edible oils and food grade performance enhancing additives. It shall result in zero mortality when tested on trout fry per OECD 203. It shall not require oils derived from genetically altered seeds. It shall be FM Global Approved and UL Classified, Envirotemp FR3 fluid or equal. It's compatibility with transformer components shall be verified. It shall have a minimum open cup flash point of ≥ 300°C and a fire point of ≥ 340°C.

ORDERING INFORMATION

To order Envirotemp FR3 fluid, specify:

	Catalog Number
Bulk	0425200A03
330 gallon Ecobulk container	0425589A05
55 gallon drum	0425589A08
5 gallon container	0425589A09

For warranty, sales terms and conditions information contact Cooper Power Systems or your equipment supplier for Cooper Power Systems Terms and Conditions Sheet.

TABLE 4
UL Classification Marking



CLASSIFIED BY UNDERWRITERS LABORATORIES INC.® AS TO FIRE HAZARD ONLY.

Envirotemp® FR3™ Fluid Classed 4 to 5 less hazardous than paraffin oil in respect to Fire Hazard.

CLASSIFIED BY UNDERWRITERS LABORATORIES INC.® AS TO SECTION 450-23 OF THE 2005 NATIONAL ELECTRICAL CODE.

Classified as a "Less-flammable liquid" as specified in the National Electrical Code when used in 3-phase transformers, 45 through 10,000 kVA with the following "use restrictions":

- A For use only in 3-phase transformers having tanks capable of withstanding an internal pressure of 12 psig without rupture,
- B Required use of pressure relief devices on transformer tank in accordance with the following tabulation to limit internal pressure buildup and prevent tank rupture due to gas generation under low current arcing faults, and
- C1 Required use of current-limiting fusing in the transformer primary having I²t characteristics not exceeding the values in the following tabulation. Under-fluid expulsion fuses may be used in series with the current-limiting fuses, in accordance with the manufacturer's protection scheme,
or
- C2 Required use of overcurrent protection in the transformer primary having I²t characteristics not exceeding the values in the following tabulation. If the fuse is designed to vent during operation (such as an expulsion fuse), it shall be located external to the transformer tank.

TRANSFORMER	REQUIRED PROTECTION		REQUIRED PRC
	Required Current Limiting Fusing (+) Maximum I ² t (A ² s)	Required Overcurrent Protection (+) Maximum I ² t (A ² s)	Minimum Required Pressure Relief Capacity, (++) SCFM at 15 psi
3-Phase Transformer Rating, kVA			
45	500,000	700,000	35
75	500,000	800,000	35
112.5	550,000	900,000	35
150	600,000	1,000,000	50
225	650,000	1,200,000	100
300	750,000	1,400,000	100
500	900,000	1,900,000	350
750	1,100,000	2,200,000	350
1,000	1,250,000	3,400,000	350
1,500	1,500,000	4,500,000	700
2,000	1,750,000	6,000,000	700
2,500	2,000,000	7,500,000	5,000
3,000	2,250,000	9,000,000	5,000
3,750	2,500,000	11,000,000	5,000
5,000	3,000,000	14,000,000	5,000
7,500	3,000,000	14,000,000	5,000
10,000	3,000,000	14,000,000	5,000

(+) This is an additional requirement to the overcurrent protection required in accordance with Section 450-3 of the 2005 National Electrical Code.

(++) Opening pressure, 10 psig maximum.

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