FR3® fluid storage and handling guide

Service information
S10

Contents

IMPORTANT:

This Storage and Handling Service Information Guide is limited to apply only to FR3® fluid. This bulletin does not claim to cover all possible variables that might be encountered while receiving, handling, and storing FR3® fluid. It is the sole responsibility of the user to ensure that specific storage and handling equipment, materials, and processes are suitable.

GENERAL

Cargill FR3® fluid is a natural ester-based dielectric coolant formulated for use in distribution and power transformers. FR3 fluid is primarily used in new transformer applications. It has also been applied in transformer retrofill, new switch-gear, specialty power supplies, and other applications. Cargill's technical team can provide support for FR3 fluid application, please contact us (see details on last page).

Key drivers for the growing demand for FR3 fluid are the increased asset insulation life and performance while providing environmental benefits including renewable source, carbon neutral*, non-toxic in water and soil and readily biodegradable. While FR3 fluid is miscible and compatible with conventional transformer mineral oil, it is important that the fluid be maintained in as pure a state as when new, to avoid decreasing the performance and environmental benefits.

The chemistry of natural esters is significantly different from petroleum oils. Therefore, certain practices used for mineral oil may not necessarily be proper for the storage and handling of FR3 fluid. Adhering to the information provided by this guide helps assure that the quality of the fluid properties remain at its highest state, helps avoid damage to equipment, and increases personnel safety.

Figure 1
Prior to shipment, FR3 fluid undergoes extensive quality assurance testing. The facilities producing FR3 fluid are ISO 9001 Certified.

ENVIRONMENTAL

FR3 fluid is formulated from vegetable oils and performance enhancing additives. It passed the very sensitive acute aquatic toxicity (OECD 202 and 203), and meets the highest EPA biodegradation rate classification. Contamination by mineral oil may result in costly remediation requirements in the event of a spill.

FIRE SAFETY

FR3 fluid is UL Classified and FM Approved. It qualifies as a NEC less-flammable dielectric coolant with a flash point of approximately 330°C and a fire point of 360°C. Mineral oil concentrations in excess of 7% can reduce the fire point below the 300°C, the threshold required for NEC and IEC fire resistant classifications for certain installations where increased fire safety is required. Typically, with proper retrofilling techniques, the level of residual mineral oil that will eventually leach out of the cellulose insulation over time should not exceed 4-5% in power transformers and 5-6% in distribution transformers.

NOTE: These instructions do not claim to cover all details or variations in the equipment, procedure, or process described, nor to provide directions for meeting every contingency during installation, operation, or maintenance. When additional information is desired to satisfy a problem not covered sufficiently for the user's purpose, please contact your Cargill sales engineer.

SAFETY INFORMATION

Cargill products meet or exceed all applicable industry standards relating to product safety. We actively promote safe practices in the use and maintenance of our products through our service literature, instructional training programs, and the continuous efforts of all Cargill employees involved in product design, manufacture, marketing and service.

The instructions in this manual are not intended as a substitute for proper training or adequate experience in the safe operation of the equipment described. Only competent technicians, who are familiar with this equipment should install, operate and service it. A competent technician has these qualifications:

- Is thoroughly familiar with these instructions.
- Is trained in industry-accepted high- and low-voltage safe operating practices and procedures.
- Is trained and authorized to energize, de-energize, clear, and ground power distribution equipment.
- Is trained in the care and use of protective equipment such as flash clothing, safety glasses, face shield, hard hat, rubber gloves, hotstick, etc.

Following is important safety information. For safe installation and operation of this equipment, be sure to read and understand all cautions and warnings.

SAFETY INSTRUCTIONS

Hazard Statement Definitions

This manual may contain three types of hazard statements:

DANGER: Indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury.

WARNING: Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.

CAUTION: Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury.

Special attention statement definitions

This manual contains important statements:

IMPORTANT: Indicates information to help avoid unnecessary degradation of the product, equipment damage or application misuse, particularly if the practice differs from common practices in the storage and handling of convention transformer mineral oil.

***NOTE:** Throughout this Guide, hazard and key precautions appear. It is important to carefully read and understand all such statements.*

WARNING: Before receiving, inspecting, testing, handling, storing, applying and processing this material, carefully read, understand and follow the contents of this guide. Failure to do so can result in death, severe personal injury and equipment damage. Failure to do so can also cause a significant reduction in the electrical, physical and chemical qualities of this material.

WARNING: This material is to be received, inspected, tested, handled, stored, processed and applied following all locally approved procedures and safety practices. Failure to comply may result in death, severe personal injury, and material and equipment damage.

WARNING: Receiving, inspecting, testing, handling, storing, applying and processing this material must be performed by competent personnel who have been trained and understand proper safety procedures. This guide is written for use by such personnel and is not a substitute for adequate training and experience in safety procedures. Failure to use competent personnel can result in death, severe personal injury, and equipment damage. Failure to do so can also cause a significant reduction in the electrical, physical and chemical qualities of this material.

WARNING: This Storage and Handling Service Information Guide is limited to apply only for FR3 fluid. This bulletin does not claim to cover all possible variables that might be encountered while receiving, handling, and storing FR3 fluid. It is the sole responsibility of the user to ensure that specific storage and handling equipment, materials, and processes are suitable.

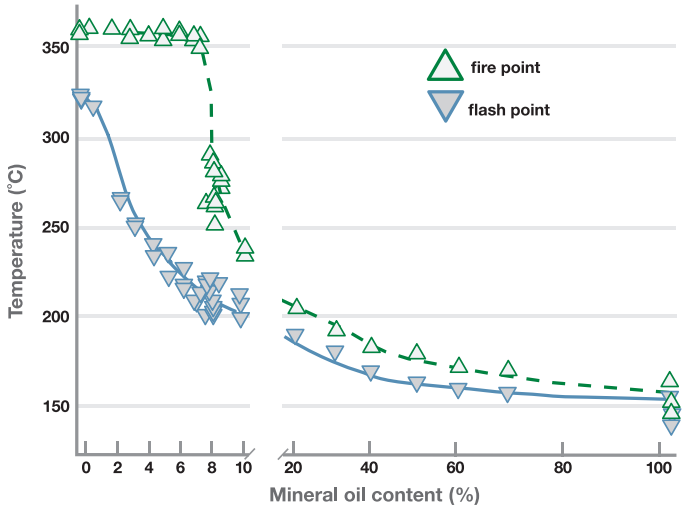


Figure 2
Flash and fire points of mixtures of FR3 fluid and conventional mineral oil as a function of mineral oil content.

Compatibility of Insulating liquids

FR3 fluid is miscible with conventional mineral oil, high molecular weight hydrocarbons, PCB (Askarel) and most PCB substitutes (such as PERC). Most relevant exception is silicone oil. FR3 fluid is not miscible with silicone oil and should not be applied in transformers previously containing silicone oil.

IMPORTANT: To prevent moisture ingress, and maintain the optimal fluid properties for its intended use as an electrical insulating fluid, exposure to oxygen, moisture, and other contaminants must be minimized.

RECEIVING

Inspection

Each lot received should be inspected for container integrity. Verify that tamper seals are intact.

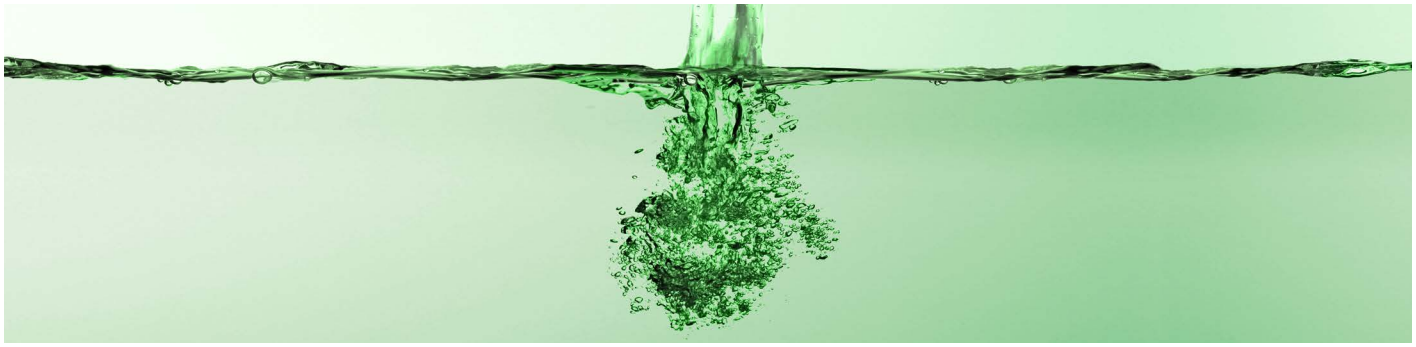
Receiving Tests

A Certificate of Analysis is included with every shipment of fluid. If independent receiving tests are required, samples should be taken from containers per ASTM D-923 Standard Test Method.

When material is to be combined for use, samples may be mixed together to create a composite sample for testing. The minimum tests recommended are dielectric strength and visual inspection. Dissipation factor and water content tests are also highly recommended.

Recommended acceptance values are given in Table 1.

IMPORTANT: Although laboratory testing of FR3 fluid is done in much the same way of mineral oil, minor modifications to certain ASTM procedures are needed in order to obtain repeatable and reliable results. If your laboratory does not have experience testing FR3 fluid, have them contact Cargill for detailed test recommendations.



FR3 fluid properties: standard acceptance values and typical values

Table 1
FR3 Fluid Acceptance Limits

	Standard test methods		ASTM D6871/IEEE C57.147	IEC 62770	FR3 fluid
PROPERTY	**ASTM**	**ISO/IEC**	**As-received new fluid property requirements**	**Unused new fluid property requirements**	**TYPICAL**
Physical					
Color	D1500	ISO 2211	≤1.0	–	0.5
Flash Point PMCC (°C)	D93	ISO 2719	–	≥250	260-270
Flash Point COC (°C)	D92	ISO 2592	≥275	–	320-330
Fire Point (°C)	D92	ISO 2592	≥300	>300	350-360
Pour Point (°C)	D97	ISO 3016	<-10	≤-10	-18 to -21
Density at 20°C (g/cm³)	–	ISO 3675	–	≤1.0	0.92
Relative Density (Specific Gravity) 15°C	D1298	–	≤0.96	–	0.92
Viscosity (mm²/sec)	D445	ISO 3104			
100°C			≤15	≤15	7.7 - 8.3
40°C			≤50	≤50	32 - 34
0°C			≤500	–	190
-20°C					650*
Visual Examination	D1524	IEC 62770 4.2.1	bright and clear	clear, free from sediment and suspended matter	clear, light green
Biodegradation	OECD 301B		readily biodegradable	readily biodegradable	readily biodegradable
Aquatic and Oral Acute Toxicity	OECD 202, 203, OECD 420		non-toxic	non-toxic	non-toxic
Electrical					
Dielectric Breakdown (kV)	D877	–	≥30	–	>45
Dielectric Breakdown (kV)					
1mm gap	D1816	–	≥20	–	>25
2mm gap	D1816	–	≥35	–	>50
2.5mm gap		IEC 60156	–	≥35	>55
Dielectric Breakdown under Impulse (kV) 25.4mm gap	D3300		>130		140
Gassing Tendency (µl/min)	D2300	–	≤0	–	-79
Dissipation Factor					
25°C (%)	D924	–	≤0.20	–	0.010 - 0.15
90°C (tan δ)	–	IEC 60247	–	≤0.05	0.01 - 0.03
100°C (%)	D924	–	≤4.0	–	1.00 - 3.85
Chemical					
Corrosive Sulfur	D1275	IEC 62697	non-corrosive	non-corrosive	non-corrosive
Water Content (mg/kg)	D1533	IEC 60814	≤200	≤200	4 - 50
Acid Number (mg KOH/g)	D974	IEC 62021.3	≤0.06	≤0.06	0.01 - 0.05
PCB Content (mg/kg)	D4059	IEC 61619	not detectable	free from PCBs	not detectable
Total Additives	–	IEC 60666	–	Max weight fraction 5%	<2%
Oxidation Stability (48 hrs, 120°C)	–	IEC 61125 IEC 62770			
Total Acidity (mg KOH/g)	–	IEC 62621.3	–	≤0.6	0.1 - 0.3
Viscosity at 40°C (mm²/sec)	–	ISO 3104	–	≤ 30% increase over initial	17% - 23% increase
Dissipation Factor at 90°C (tan δ)	–	IEC 60247	–	≤ 0.5	0.1
Oxidation Induction Time 130°C/500psi (min)	D6186**				62±2 min

Measurement of viscosity near pour point may be inaccurate.
****A more specific version of the test indicated by ASTM D6186 is under development.***
NOTE: Specifications should be written referencing only the defined ASTM or IEC industry standard acceptance values and test methods. The listed 'typical' values are average values summarized from a significant number of data points over many years; they are not to be identified as acceptance values.
ASTM D6871 Standard Specification for Natural (Vegetable Oil) Ester Fluids Used in Electrical Apparatus. IEC 62770: Fluids for electrotechnical applications – Unused natural esters liquids for transformers and similar electrical equipment. A transformer filled with FR3 fluid complies with the transformer temperature operating range requirements defined in IEEE C57.12.00 and IEC 60076-1.

CONTAINER HANDLING

IMPORTANT: Dedicated equipment is recommended for storing, handling, and processing FR3 fluid. However, if existing equipment is used for both mineral oil and FR3 fluid, it should be drained of mineral oil and flushed with FR3 fluid to minimize mineral oil content. After use, the equipment should be drained of FR3 fluid and flushed with mineral oil.

IMPORTANT: Avoid extremes of temperature in storage. Store FR3 fluid in labeled, tightly closed containers at 10-40°C (50-104°F) in dry, isolated and well-ventilated areas, away from sources of ignition or heat.

Storage

Drums and totes of FR3 fluid are sealed at the factory to protect against foreign material and moisture contamination during shipping. Tamper-resistant seals verify that the container has not been opened. Cargill recommends storing drum and totes indoors, in a dry location, out of direct sunlight, and with ambient temperature above 10°C. If long-term outside storage cannot be avoided, drums should be stored horizontally with the bungs of the drum below fluid level. Totes and containers (IBC) must be placed in protected areas to avoid exposure to sun and rain.

Totes are designed to be stacked during storage. However, totes are not designed to, and should not be stacked during transportation.

For drum and tote storage, drip pans or basins are always recommended, and may be required by local codes. Please refer to your local authority having jurisdiction for definitive rulings.

IMPORTANT: Prolonged low temperature storage will cause the viscosity of FR3 fluid to significantly increase. Warm fluid to >10°C for efficient transfer by pump.

Heating

In the event the drums and totes have been stored in a very cold environment, or it is necessary to use cold FR3 fluid as soon as it is received, heating the containers may be necessary to reduce viscosity. Most common procedure is to keep it indoors at least one day prior to the use. If heating in a short period of time is necessary, heating ovens can be used. Cargill recommends opening the vent to provide pressure relief during heating cycle. For drums, electric drum heaters may be used, not exceeding a watt-density of 12 W/in^2 (1.86 W/cm^2).

CAUTION: A drum bung or tote cap must be loosened prior to heating to relieve internal drum and tote pressures. Immersion heaters or open flame heaters are not recommended.

Fluid Removal from Containers

Pumps with a positive suction capability are recommended to remove FR3 fluid from drums and totes. Positive displacement pumps, diaphragm, or air-operated drum pumps are satisfactory. Centrifugal pumps will prove satisfactory if the fluid is heated to obtain a suitable viscosity. This temperature will vary with the size and brand of pump. Contact your pump supplier to make sure that a centrifugal pump is correctly sized for a given viscosity (temperature) of fluid.

Totes have drain valves that permit gravity feed. The totes accept forklifts from 4 sides, and may be raised to a desired height with suitable forklifts. Gravity feed from drums can be done when properly rigged.

TANK TRUCK UNLOADING

Inspection

The receiving inspection of FR3 fluid is done similarly to inspection of conventional transformer oil. Inspection and testing should be completed prior to unloading. Refer to the Receiving Tests section and Table 1 for recommended tests and acceptance values.

If the as-received FR3 fluid does not meet the acceptance specifications, contact your supplier immediately.

Unloading FR3 fluid

When received in bulk, FR3 fluid can be unloaded using a pump or gravity feed. Particle filtration is recommended during the process of unloading into bulk storage.

Hoses and Fittings

The unloading hose should be a quality oil resistant hose designed for suction service. The hose length should be kept to a minimum. Dedicated hoses are recommended for use with FR3 fluid to minimize the possibility of contamination. Hoses previously used for electrical grade mineral oil can be used for FR3 fluid if first flushed with FR3 fluid. The minimum recommended hose size is 3 in (76.2mm) in internal diameter. When smaller ones are used, the maximum flow rate must be limited. Hose fittings should be aluminum or brass, and firmly attached to the hose. Drybreak type quick connector fittings are recommended to reduce spillage and contamination of FR3 fluid. Dust caps and plugs should be used whenever the hoses are not being used.

If the viscosity of cold fluid hampers unloading, hoses and transfer lines should be heat traced.

BULK STORAGE SYSTEMS

Location

The location and type of storage tanks will depend on the user's physical plant arrangement. Tanks located indoors are ideal. An indoor location may reduce the need for heating the fluid to maintain proper pumping and filtering temperatures. Tanks located outdoors where ambient temperatures fall below 0°C may require insulation and heaters to warm the fluid. Tanks placed underground should be below the frost line to minimize the effect of winter temperatures. For new underground installations, a thermal insulating backfill should be considered to reduce heat loss.

Storage Temperatures

FR3 fluid can be pumped directly from either indoor or outdoor storage tanks. If suction line lengths or suction lifts are excessive, heating fluid will reduce the viscosity and ease pumping. A temperature of FR3 fluid above 10°C is recommended for pumping.

Recommended types of heating systems are:

- Indirect heating, such as a steam-jacketed storage tank, is preferred. The watt-density of the heating systems should be 12 W/in^2 (1.86 W/cm^2) or less.
- A circulating pump and in-line heater having a watt density of 12 W/in^2 (1.86 W/cm^2) or less can be attached to a storage tank to maintain temperatures of 38°C (100°F) or higher. (A 20 GPM [76 liters] pump with a 10 kW heater will maintain a temperature of 43°C (110°F) in a 5,000 gallon (approx. 19,000 liters) storage tank if heat losses to the environment are not excessive).
- Do not use immersion heaters.

For cold weather pumping outdoors, pipes should be heated with either steam coils or electric resistance tracing. A means for keeping FR3 fluid above 10°C is needed for ease of handling. In addition, the tank and piping should be insulated for low ambient temperatures in order to minimize heating costs.

Storage Tanks

Standard steel storage tanks such as those used for conventional transformer oil are satisfactory. All tanks should conform to local codes and standards. New tanks are preferred, and should have at least one manhole.

Before use, the inside of the tanks should be sandblasted and primed with a coating that is compatible with vegetable oils.

Existing storage tanks used for conventional transformer oil can be used for FR3 fluid if the following conditions are met:

- The tank is of proper capacity and the lines for filling and suction are adequate.
- The tank is thoroughly cleaned and inspected closely to insure suitable condition.

Do not use free breathing tanks. Use a dry nitrogen headspace in the storage tank. Do not vent to atmosphere.

Pumps

CAUTION: As with other dielectric fluids, flowing FR3 fluid can produce a significant high voltage static charge during pumping operations. We recommend that all equipment, winding leads, containers, and piping be grounded both during pumping and for one hour after fluid flow has stopped.

Capacity

FR3 fluid is more viscous than conventional mineral oil. Select the proper pump size based on the required flow rate, head pressure, and fluid temperature (viscosity) (see Figure 3). Determine the maximum flow rate required. Select a pump and motor for use at the lowest temperature (highest viscosity) that will be encountered.

Type

Positive-displacement pumps are commonly used to pump FR3 fluid. A standard iron pump with either a mechanical seal or stuffing box is satisfactory. When specifying the correct size pump and motor, the pump supplier should be made aware of the viscosity, pumping rate required, suction lift, and discharge head. For capacities up to 76 l/min (20 GPM), direct driven pumps have proved to be satisfactory. For higher pumping rates, a reduction gear or belt driven pump may be required. Other pump types used successfully are the air-operated diaphragm pump, progressive cavity pump, and flexible impeller pump.

Horsepower

If pumps used for conventional transformer oil are used in an FR3 fluid system, it is necessary to check the motor horsepower to make sure it has sufficient capacity. Many times, the existing pump will be entirely satisfactory, or may be made satisfactory by a change in the motor horsepower or using a slower pump speed.

NOTE: *If a larger motor is used, ensure that the pump and drive coupling will withstand the increased horsepower. If a change to a lower RPM is made, ensure that the required pumping rate will be obtained at the lower RPM.*

PIPES, VALVES, AND FITTINGS

Pipe

All piping, valves, and fittings should be properly labeled to avoid cross-contamination and to comply with applicable OSHA guidelines. As a general rule, all piping, two inches and larger, should be welded with flanged connections.

Piping with screw-type fittings should be standard schedule 40 black iron with forged fittings. Teflon tape should be used to seal fittings.

All new piping should be flushed with either hot FR3 fluid or hot standard conventional transformer oil before use in order to remove any dirt or mill scale in the pipe.

Valves

Valves suitable for use with conventional transformer oil have been successfully used with FR3 fluid.

NOTE: *A vacuum degassing and dehydration system requires temperatures of 60-80°C (140-175°F). Be sure to select components compatible with the fluid and process temperatures. Consult with the component manufacturer for the proper selection.*

ACCESSORIES

Accessories such as pressure gauges, thermometers, and flow switches should be compatible with vegetable oil and process temperatures.

Gaskets and packing compatible with vegetable oil should be used. Buna-N and nitrile seals may be satisfactory to about 120°C (250°F). For extended service at higher temperatures, fluorocarbon-based and fluorosilicon seals such as Viton® seals are recommended.

FILTERS

Types

Most types of filters used for conventional transformer oil service can be used with FR3 fluid. The cartridge-type filter is best suited for this service. It is offered in various micron ranges and sizes for either low or high flow rates.

Adsorption filters such as activated clay (Fuller's earth) can be used, up to process temperatures of 60-65°C. Contact Cargill for advice on reclaiming aged FR3 fluid.

Flow rate

If filters sized for conventional transformer oil are used, flow rates may decrease due to the higher viscosity of FR3 fluid. Heating the fluid decreases its viscosity. Consult Figure 3 to determine the temperature needed to obtain the desired viscosity.

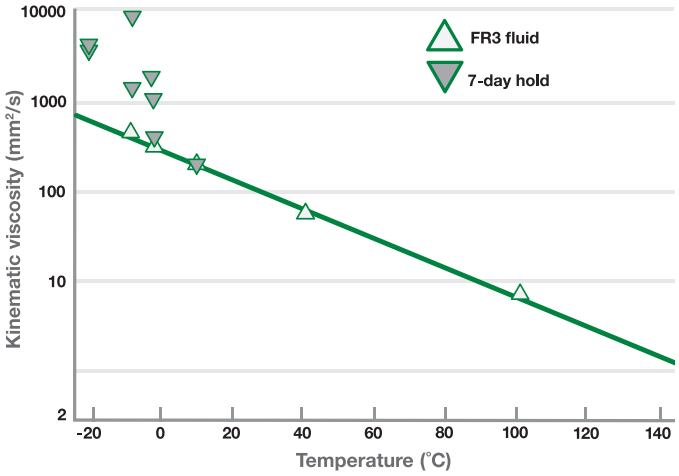


Figure 3
Kinematic viscosity of FR3 fluid as measured using ASTM-D445

Degree of Filtration

For maximum dielectric strength, filter FR3 fluid just prior to introduction into the electrical apparatus. A particulate filter with a nominal pore size of 0.5 microns is recommended. Confirm also the filter has a "beta ratio" of, at least, 200 (99.5% efficiency).

Moisture Removal Filters

FR3 fluid can tolerate much more water than conventional mineral oil before compromising its electrical characteristics.

If moisture content of FR3 fluid increases above acceptable limits, additional treatment is required. Moisture can present itself in two forms in the oil: free water and dissolved moisture.

Free Water Removal

- If the moisture is in the form of free water, filter units such as the AMF CUNO Zeta-Plus® and HILCO® blotter paper cartridge filters can be used effectively. Desiccant packaged filter cartridges should be specified to ensure dryness of the filter media.
- Free water can also be removed by raising the temperature of the bulk fluid to 105°C (220°F). Agitation of the fluid will speed this process. A dry nitrogen gas atmosphere is recommended for this process. See dissolved moisture reduction for additional requirements.

Dissolved Moisture Reduction

- If the dissolved moisture content must be lowered, a high vacuum dehydration system may be required. An advantage of vacuum dehydration is that dissolved gases are also removed. (See the Vacuum Filling in the Electrical Equipment Filling section).
- Molecular sieve filters are also satisfactory if the quantity of moisture to be removed is not excessive. Activated grade 3A or 4A molecular sieves are recommended for moisture removal from FR3 fluid,

and are effective over a broad temperature range, provided adequate care is taken in filter selection to ensure sufficient residence time in the filter.

Moisture removal filters should be located upstream of the final particulate filter in the fluid handling system.

HEATERS

Types

Indirect heaters such as steam jackets are recommended. Electric in-line heaters may be used for heating FR3 fluid, provided sufficient fluid flow is present.

Use a heater with a watt density rating of 12 W/in^2 (1.86 W/cm^2). Immersion heaters are not recommended.

Controls

All heating systems should have a reliable temperature controller. When multiple heaters are used in parallel, a stepping type controller is recommended.

Each heater should also have a high temperature shut-off thermostat set at a maximum of 115°C (240°F). In systems where a heater is fed by a pump, a flow interlock must be installed in the heater outlet piping. The heaters must be de-energized when fluid flow is inadequate to prevent potential localized overheating of the fluid.

A time delay on the pump shut-off is recommended to de-energize the heaters prior to stopping the circulating pump.

ELECTRICAL EQUIPMENT FILLING

Vacuum filling

When possible, fill the tank with hot degassed fluid at a rate that maintains the required (partial) vacuum. If foaming occurs when filling under vacuum conditions, degas the FR3 fluid.

Degassing process is recommended to be carried out at 60-65°C (140-150°F), and at as low pressure as practical, typically less than 100 Pa prior to introduction into the equipment. Degassing and dehydration units are available for processing oils to acceptable levels of dissolved moisture and dissolved air.

After FR3 fluid is degassed, it should be introduced directly into the tank under vacuum. If this is not possible, a storage tank that can be maintained under a vacuum at least equal to, or greater than, the vacuum maintained in the transformer, is recommended. Otherwise, the FR3 fluid may absorb gases and foam during filling.

Dedicated equipment is recommended for processing FR3 fluid. However, if existing equipment is used for both mineral oil and FR3 fluid, it should be drained of mineral oil and flushed with FR3 fluid to minimize contamination. After processing FR3 fluid, it should be drained and flushed with mineral oil.

Atmospheric Filling

Vacuum filling, even with only a partial vacuum, is preferable to atmospheric filling. Typically, atmosphere filling is only acceptable for voltage class up to 69 kV. When filling units with FR3 fluid at atmospheric pressure, heating and filtering the fluid are strongly recommended to maximize performance. Fluid temperatures during such tank filling operations should be 60-65°C (140-150°F).

Use a dry nitrogen blanket during tank draining and filling operations.

If a new set of core and coils (active part) must be filled under atmospheric conditions, heat the coils to 100°C and keep FR3 fluid around 60-80°C (140-175°F) to promote more complete impregnation. The impregnation rate is much slower than mineral oil. Higher voltage rated units will require longer impregnation times. The thicker the pressboard, the longer the impregnation time required.

When retrofilling transformers under atmospheric conditions, FR3 fluid should be filtered and heated to 60~65°C (140~150°F).

NOTE: *Insure no residual FR3 fluid is on the surface of insulators after filling the equipment. Wipe the insulators with a suitable cleaner.*

Impregnation

Due to its viscosity, impregnation rate of solid insulating materials with FR3 fluid is slower than mineral oil. Increasing the temperature of the FR3 fluid minimizes the required extra time.

Keeping the FR3 fluid temperature at 60-80°C (140-175°F) during the process, impregnate insulating materials under vacuum and increase impregnation time in at least 50% are recommended actions for a transformer immersed in FR3 fluid.

POWER FACTOR MEASUREMENTS

Transformer power factor measurements using FR3 fluid typically are higher than the same insulation assembly using mineral oil. The change depends on the percentage of fluid in the insulation space being measured and the condition of the insulating fluids. For power transformers, a mineral oil-impregnated insulation assembly retrofilled with FR3 fluid will typically have a power factor of about twice the percentage power factor measured with mineral oil if the fluid occupies a high percentage of the insulation clearance spacing being measured.

Maximum power factor limits used for mineral oil units should typically be doubled for transformers containing FR3 fluid.

See Cargill's R2100 for further details

DRYING IMPREGNATED INSULATION

Drying impregnated insulation by exposure to hot FR3 fluid, kerosene vapors, or nitrogen is acceptable.

WARNING: Kerosene vapors must be handled under approved procedures and safety practices.

"Hot FR3 fluid dryout" for insulation previously impregnated with FR3 fluid:

- Disable radiator cooling, either by lowering the fluid level well below the radiator inlet, but above all current carrying parts or closing the valves.
- If reducing the level, seal the tank with a nitrogen atmosphere over the fluid. Use a pressure relief device to protect against over-pressure.
- Heat the transformer until the top fluid temperature is about 110°C by means of a fluid heater or by using short circuit heating (generating load losses).
- Using a nitrogen backfill, drain the fluid from the tank. Place the tank under vacuum to dry the insulation. Do not exceed the vacuum rating of the tank. Cold traps (water vapor condenser) will make the system more effective.
- Vacuum fill with dry FR3 fluid or break vacuum with dry nitrogen if the unit must be stored prior to vacuum filling.

Repeat as needed to obtain the required insulation dryness. Vapor phase drying of FR3 fluid impregnated assemblies can be used. Remove the residual FR3 fluid from the vapor condensation chamber. The user is responsible for developing a procedure compatible with their manufacturing or repair process.

See more details in Cargill's R2200.

TRANSFORMER REPAIR AND RETROFILL

If it is necessary to drain and refill the transformer, take special care to store FR3 fluid in appropriate sealed containers, with a nitrogen headspace to minimize moisture ingress or other contamination. Except for short storage periods, material that has been immersed in FR3 fluid should not be exposed to air. See Cargill's R2200 for detailed information. Thin films of vegetable oils tend to polymerize much faster than conventional transformer oil. See recommendations in Electrical Equipment Filling section above, or refer to Cargill Bulletin R2040, "Power Class Transformer Retrofill Guide > 7500KVA" and R2010, "Distribution Transformer Retrofill Guide ≤ 7500KVA".

CLEANING PROCEDURES

A thin film of FR3 fluid will polymerize over time making it increasingly more difficult to clean. The extent of polymerization depends on air exposure time, temperature and UV or sunlight. For example, the extent of polymerization of a thin film of FR3 fluid after 1 day at 40°C (100°F) in air is minimal, while after 7 days it would be partially polymerized and tacky to the touch. Exposure of a thin film of FR3 fluid to air at 95°C (200°F) during 5 days would result in polymerization to a dry state, similar to a varnish.

Cleanup of FR3 fluid on surfaces is most effective when the FR3 fluid spills and drips are fresh. S-34™ aqueous cleaner and Amerisolve 123 are examples of cleaners found to be effective. Apply cleaner with a pump spray or cloth, followed by hand wiping with a clean cloth and/or spray washing. Refer to the Material Safety Data Sheet.

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.

For partially polymerized (sticky) FR3 fluid, apply the cleaner with a pump spray and allow a 15 minute soak time at 20°C (70°F), followed by hand wiping with a clean cloth using moderate rubbing. Multiple applications may be necessary depending upon the extent of polymerization of the FR3 fluid. Use shorter soak time at higher temperatures and longer soak time at lower temperatures.

For larger spills on impervious surfaces, wet down the area, apply powder based #15 Economy Floor Cleaner™. Let sit for 15 minutes, wash down using hot water.

For FR3 fluid polymerized to semi-hard or hard consistency, scraping, light sanding or paint touch-up may be required in addition to vigorous scrubbing. Users should consult with their company's policy regarding the use of personal protective equipment.

REFERENCES AND FOOTNOTES

*According to Building Environmental Economic Sustainability [BEES] lifecycle analysis

FR3® is a valuable trademark of Cargill, Incorporated.

S-34™ is a trademark of Ecolink, Inc.

AMF CUNO Zeta-Plus® is a registered trademark of 3M Company.

HILCO® is a registered trademark of Hilliard Corporation.

VITON® is a registered trademark of DuPont Company.

#15 Economy Floor Cleaner™ is a trademark of Crown Chemicals.

For more information on S-34 cleaner, contact Ecolink, Inc. 1481 Rock Mtn Blvd., Stone Mountain, GA 30083, 800-886-8240, www.ecolink.com

For more information on Amerisolve 123, contact American Research Specialty Products, 2325 Palos Verdes Dr. West #208 Palos Verdes CA, 90274, (310) 541-1512, http://www.americanresearchproducts.com/product/amerisolve-123/

Contact us -
FR3fluid.com

Cargill® Helping the world *thrive*