Designation: D 6871 – 03

Standard Specification for Natural (Vegetable Oil) Ester Fluids Used in Electrical Apparatus[1]

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1. Scope

1.1 This specification covers a high fire point natural vegetable oil ester insulating fluid for use as a dielectric and cooling medium in new and existing power and distribution electrical apparatus such as transformers and attendant equipment.

1.2 Natural vegetable oil ester insulating fluid differs from conventional mineral oil and other high fire point (or "less-flammable") fluids in that it is an agricultural product derived from vegetable oils rather than refined from petroleum base stocks or synthesized from organic precursors.

1.3 This specification is intended to define a natural vegetable oil ester electrical insulating fluid that is compatible with typical materials of construction of existing apparatus and will satisfactorily maintain its functional characteristic in this application. The material described in this specification may not be miscible with some synthetic electrical insulating liquids. The user should contact the manufacturer of the natural ester insulating fluid for guidance in this respect.

1.4 This specification applies only to new insulating fluid as received prior to any processing. The user should contact the manufacturer of the equipment or fluid if questions of recommended characteristics or maintenance procedures arise.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 88 Test Method for Saybolt Viscosity[2]

D 92 Test Method for Flash and Fire Points by Cleveland Open Cup[3]

D 97 Test Method for Pour Point of Petroleum Products[3]

D 117 Guide for Sampling, Test Methods, and Specifications for Electrical Insulating Oils of Petroleum Origin[4]

D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (the Calculation of Dynamic Viscosity)[3]

D 877 Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes[4]

D 923 Practices for Sampling Electrical Insulating Liquids[4]

D 924 Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids[4]

D 974 Test Method for Acid and Base Number by Color-Indicator Titration[3]

D 1275 Test Method for Corrosive Sulfur in Electrical Insulating Oils[4]

D 1298 Practice for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method[3]

D 1500 Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)[3]

D 1524 Test Method for Visual Examination of Used Electrical Insulating Oils of Petroleum Origin in the Field[4]

D 1533 Test Methods for Water in Insulating Liquids by Coulometric Karl Fischer Titration[4]

D 1816 Test Method for Dielectric Breakdown Voltage of Insulating Oils of Petroleum Origin Using VDE Electrodes[4]

D 1903 Test Method for Coefficient of Thermal Expansion of Electrical Insulating Liquids of Petroleum Origin, and Askarels[4]

D 2300 Test Method for Gassing of Insulating Liquids Under Electrical Stress and Ionization (Modified Pirelli Method)[4]

D 2717 Test Method for Thermal Conductivity of Liquids[3]

D 2766 Test Method for Specific Heat of Liquids and Solids[3]

D 2864 Terminology Relating to Electrical Insulating Liquids and Gases[4]

D 3300 Test Method for Dielectric Breakdown Voltage of Insulating Oils of Petroleum Origin Under Impulse Conditions[4]

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[1] This specification is under the jurisdiction of ASTM Committee D27 on Electrical Insulating Liquids and Gases and is the direct responsibility of Subcommittee D27.02 on Gases and Synthetic Liquids.

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[2] *Annual Book of ASTM Standards*, Vol 04.04.

[3] *Annual Book of ASTM Standards*, Vol 05.01.

[4] *Annual Book of ASTM Standards*, Vol 10.03.

TABLE 1 As-Received New Fluid Property Requirements

Property	Limit	ASTM Test Method
Physical:		
Color, max	1.0	D 1500
Fire point, min, °C	300	D 92
Flash point, min, °C	275	D 92
Pour point, max, °C	−10	D 97
Relative density (specific gravity) 15°C/15°C, max	0.96	D 1298
Viscosity, max, cSt at:		D 445 or D 88
100°C (212°F)	15	
40°C (104°F)	50	
0°C (32°F)	500	
Visual Examination	Bright and Clear	D 1524
Electrical:		
Dielectric breakdown voltage at 60 Hz		
Disk electrodes, min, kV	30	D 877
VDE electrodes, min, kV at:		D 1816
1 mm (0.04 in.) gap	20	
2 mm (0.08 in.) gap	35	
Dielectric breakdown voltage, impulse conditions 25°C, min, kV, needle negative to sphere grounded, 1 in. (25.4 mm) gap	130	D 3300
Dissipation factor (or power factor) at 60 Hz, max, %		D 924
25°C	0.20	
100°C	4.0	
Gassing tendency, max, µl/min	0	D 2300
Chemical:		
Corrosive sulfur	not corrosive	D 1275
Neutralization number, total acid number, max, mg KOH/g	0.06	D 974
PCB content, ppm	not detectable	D 4059
Water, max, mg/kg	200	D 1533[A]

[A] As stated in Test Methods D 1533 Annex A1 "Alternative Solvent Systems," alternate reagents may be needed for certain natural ester formulations. Consult the manufacturer for recommendations. Reagents for aldehydes and ketones (such as Coulomat AK and CG-K) should be used if the additives are unknown. When alternate reagents are needed, using the Test Methods D 1533 reagents may yield elevated and erratic water content results.

D 4059 Test Method for Analysis of Polychlorinated Biphenyls in Insulating Liquids by Gas Chromatography[4]

2.2 *National Fire Protection Association Standard:*

National Electrical Code Article 450-23[5]

3. Terminology

3.1 *Definitions*—Definitions of terms related to this specification are given in Terminology D 2864. Vegetable oil natural ester: vegetable oil containing ester linkages, typically triglycerides. Most often obtained from seed crops (a "natural" source of esters, as opposed to synthesized esters).

[5] *National Electrical Code*, NFPA 70, National Fire Protection Association Inc.

4. Sampling and Testing

4.1 Take all fluid samples in accordance with Test Methods D 923.

4.2 Perform each test in accordance with the ASTM test method specified in Table 1.

5. Property Requirements

5.1 Natural ester insulating fluid, as received, shall conform to the requirements of Table 1. The significance of these properties is covered in Guide D 117 and Appendixes X2.1-X2.3.

6. Keywords

6.1 electrical insulating fluid; fire point; flammability; insulating fluid; natural ester

APPENDIXES

(Nonmandatory Information)

X1. SUPPLEMENTARY DESIGN INFORMATION

X1.1 The following values are typical for natural ester insulating fluids.

Property	Typical Values	ASTM Test Method
Coefficient of Expansion, $°C^{-1}$	0.0007 to 0.0008	D 1903
Dielectric Constant, 25°C	3.1 to 3.3	D 924
Specific Heat, cal/g, 20°C	0.45 to 0.60	D 2766
Thermal Conductivity, (cal/cm·s·°C)	0.00035 to 0.00045	D 2717

X2. SIGNIFICANCE OF PROPERTIES PARTICULAR TO NATURAL ESTER INSULATING OIL

NOTE X2.1—The significance of common electrical insulating fluid properties not listed here may be found in Guide D 117.

X2.1 Physical Properties

X2.1.1 *Aniline Point*—The aniline point of natural ester insulating fluids vary dramatically from source to source. The variation is such that the aniline point may not be a dependable indicator of solvency of some materials in natural ester insulating fluids.

X2.1.2 *Interfacial Tension*—Interfacial tension performance criteria are being assessed; therefore, requirements have not been established. Interfacial tension of new natural ester insulating fluids, typically in the 26 to 30 mN/m range, is lower than that of new mineral oil.

X2.1.3 *Pour Point*—The pour point of a natural ester insulating fluid is important as an index of the lowest temperature to which the material may be cooled without seriously limiting the degree of circulation. Some natural ester fluids are sensitive to prolonged storage at low temperatures, and their pour points may not adequately predict their low temperature flow properties.

X2.2 Electrical Properties

X2.2.1 *Dissipation Factor*—Dissipation factor (power factor) is a measure of the dielectric losses in fluid. A low dissipation factor indicates low dielectric losses and a low level of soluble contaminants. Natural ester insulating fluids usually have higher dissipation factors than mineral insulating oils, especially at elevated temperatures.

X2.3 Chemical Properties

X2.3.1 *Water Content*—A low water content of natural ester insulating fluid is necessary to achieve adequate electrical strength and low dielectric loss characteristics, to maximize the insulation system life, and to minimize metal corrosion. Reagents for aldehydes and ketones should be used. The standard reagents for mineral oil may yield both elevated and erratic results. The amount of water required to saturate natural ester insulating fluid at room temperature is roughly 20 times that of mineral insulating oil. Comparisons to mineral insulating oil should be made on a percent saturation (relative saturation) basis rather than using absolute water content.

X2.3.2 *Neutralization Number*—A low total acid content of a natural ester insulating fluid is necessary to minimize electrical conduction and metal corrosion and to maximize the life of the insulation system. The neutralization numbers typical of natural ester insulating fluids are usually higher than those of mineral insulating oils. Natural ester insulating oils tend to form long-chain fatty acids. Mineral insulating oils tend to form shorter chain organic acids.

X2.3.3 *Oxidation Inhibitor Content*—The oxidation inhibitor additives that may be present in natural ester insulating fluids vary by manufacturer. The manufacturer should be contacted to obtain information and recommended analysis methods for additives.

X2.3.4 *Oxidation Stability*—Oxidation stability requirements and appropriate test methods for natural ester insulating fluids have not been established. Oxidation stability performance criteria are being assessed, and may differ for sealed systems, conservators, and free-breathing apparatus.