



Designation: D6871 – 17

Standard Specification for Natural (Vegetable Oil) Ester Fluids Used in Electrical Apparatus¹

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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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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 Non-Mineral Oil Liquids.

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2. Referenced Documents

2.1 ASTM Standards:²

- D88 Test Method for Saybolt Viscosity
- D92 Test Method for Flash and Fire Points by Cleveland Open Cup Tester
- D97 Test Method for Pour Point of Petroleum Products
- D117 Guide for Sampling, Test Methods, and Specifications for Electrical Insulating Oils of Petroleum Origin
- D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
- D877 Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes
- D923 Practices for Sampling Electrical Insulating Liquids
- D924 Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids
- D974 Test Method for Acid and Base Number by Color-Indicator Titration
- D1275 Test Method for Corrosive Sulfur in Electrical Insulating Liquids
- D1298 Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
- D1500 Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)
- D1524 Test Method for Visual Examination of Used Electrical Insulating Liquids in the Field
- D1533 Test Method for Water in Insulating Liquids by Coulometric Karl Fischer Titration
- D1816 Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using VDE Electrodes
- D1903 Practice for Determining the Coefficient of Thermal Expansion of Electrical Insulating Liquids of Petroleum Origin, and Askarels
- D2300 Test Method for Gassing of Electrical Insulating Liquids Under Electrical Stress and Ionization (Modified Pirelli Method)

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

TABLE 1 As-Received New Fluid Property Requirements

Property	Limit	ASTM Test Method
<i>Physical:</i>		
Color, max	1.0	D1500
Fire point, min, °C	300	D92
Flash point, min, °C	275	D92
Pour point, max, °C	–10	D97
Relative density (specific gravity) 15 °C/15 °C, max	0.96	D1298
Viscosity, max, cSt at:		D445 or D88
100 °C (212 °F)	15	
40 °C (104 °F)	50	
0 °C (32 °F)	500	
Visual Examination	Bright and Clear	D1524
<i>Electrical:</i>		
Dielectric breakdown voltage at 60 Hz		
Disk electrodes, min, kV	30	D877
VDE electrodes, min, kV at:		D1816
1 mm (0.04 in.) gap	20	
2 mm (0.08 in.) gap	35	
Dielectric breakdown voltage, impulse conditions	130	D3300
25 °C, min, kV, needle negative to sphere grounded,		
1 in. (25.4 mm) gap		D924
Dissipation factor (or power factor) at 60 Hz, max, %		
25 °C	0.20	
100 °C	4.0	
Gassing tendency, max, µl/min	0	D2300
<i>Chemical:</i>		
Corrosive sulfur	not corrosive	D1275
Neutralization number, total acid number, max,	0.06	D974
mg KOH/g		
PCB content, ppm	not detectable	D4059
Water, max, mg/kg	200	D1533 ^A

^A As stated in Test Method D1533 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 Method D1533 reagents may yield elevated and erratic water content results.

D2717 Test Method for Thermal Conductivity of Liquids
D2766 Test Method for Specific Heat of Liquids and Solids
D2864 Terminology Relating to Electrical Insulating Liquids and Gases

D3300 Test Method for Dielectric Breakdown Voltage of Insulating Oils of Petroleum Origin Under Impulse Conditions

D4059 Test Method for Analysis of Polychlorinated Biphenyls in Insulating Liquids by Gas Chromatography

2.2 National Fire Protection Association Standard:
National Electrical Code Article 450-23³

3. Terminology

3.1 *Definitions*—Definitions of terms related to this specification are given in Terminology D2864. Vegetable oil natural ester: vegetable oil containing ester linkages, typically triglyc-

erides. Most often obtained from seed crops (a “natural” source of esters, as opposed to synthesized esters).

4. Sampling and Testing

4.1 Take all fluid samples in accordance with Practices D923.

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 D117 and Appendixes X2.1 – X2.3.

6. Keywords

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

³ National Electrical Code, NFPA 70, National Fire Protection Association Inc.

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	D1903
Dielectric Constant, 25 °C	3.1 to 3.3	D924
Specific Heat, cal/g, 20 °C	0.45 to 0.60	D2766
Thermal Conductivity, (cal/cm·s·°C)	0.00035 to 0.00045	D2717

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 D117.

X2.1 Physical Properties

X2.1.1 *Aniline Point*—The aniline point of natural ester insulating fluids varies 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.

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