



# Standard Specification for Mineral Insulating Oil Used in Electrical Apparatus<sup>1</sup>

This standard is issued under the fixed designation D 3487; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 This specification covers new mineral insulating oil of petroleum origin for use as an insulating and cooling medium in new and existing power and distribution electrical apparatus, such as transformers, regulators, reactors, circuit breakers, switchgear, and attendant equipment.

1.2 This specification is intended to define a mineral insulating oil that is functionally interchangeable and miscible with existing oils, is compatible with existing apparatus and with appropriate field maintenance,<sup>2</sup> and will satisfactorily maintain its functional characteristics in its application in electrical equipment. This specification applies only to new insulating oil as received prior to any processing.

## 2. Referenced Documents

### 2.1 ASTM Standards:

- D 88 Test Method for Saybolt Viscosity<sup>3</sup>
- D 92 Test Method for Flash and Fire Points by Cleveland Open Cup<sup>4</sup>
- D 97 Test Method for Pour Point of Petroleum Products<sup>4</sup>
- D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids<sup>4</sup>
- D 611 Test Methods for Aniline Point and Mixed Aniline Point of Petroleum Products and Hydrocarbon Solvents<sup>4</sup>
- D 877 Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes<sup>5</sup>
- D 923 Test Method for Sampling Electrical Insulating Liquids<sup>5</sup>
- D 924 Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids<sup>5</sup>
- D 971 Test Method for Interfacial Tension of Oil Against Water by the Ring Method<sup>5</sup>

- D 974 Test Method for Acid and Base Number by Color-Indicator Titration<sup>4</sup>
- D 1275 Test Method for Corrosive Sulfur in Electrical Insulating Oils<sup>5</sup>
- D 1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method<sup>4,5</sup>
- D 1500 Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)<sup>4</sup>
- D 1524 Test Method for Visual Examination of Used Electrical Insulating Oils of Petroleum Origin in the Field<sup>5</sup>
- D 1533 Test Methods for Water in Insulating Liquids (Karl Fischer Reaction Method)<sup>5</sup>
- D 1816 Test Method for Dielectric Breakdown Voltage of Insulating Oils of Petroleum Origin Using VDE Electrodes<sup>5</sup>
- D 1903 Test Method for Coefficient of Thermal Expansion of Electrical Insulating Liquids of Petroleum Origin, and Askarels<sup>5</sup>
- D 2112 Test Method for Oxidation Stability of Inhibited Mineral Insulating Oil by Rotating Bomb<sup>5</sup>
- D 2300 Test Method for Gassing of Insulating Oils Under Electrical Stress and Ionization (Modified Pirelli Method)<sup>5</sup>
- D 2440 Test Method for Oxidation Stability of Mineral Insulating Oil<sup>5</sup>
- D 2668 Test Method for 2,6-Ditertiary-Butyl Para-Cresol and 2,6-Ditertiary-Butyl Phenol in Electrical Insulating Oil by Infrared Absorption<sup>5</sup>
- D 2717 Test Method for Thermal Conductivity of Liquids<sup>6</sup>
- D 2766 Test Method for Specific Heat of Liquids and Solids<sup>6</sup>
- D 3300 Test Method for Dielectric Breakdown Voltage of Insulating Oils of Petroleum Origin Under Impulse Conditions<sup>5</sup>
- D 4059 Test Method for Analysis of Polychlorinated Biphenyls in Insulating Liquids by Gas Chromatography<sup>5</sup>
- D 4768 Test Method for Analysis of 2,6-Ditertiary-Butyl Para-Cresol and 2,6-Ditertiary-Butyl Phenol in Insulating Fluids by Gas Chromatography<sup>5</sup>
- D 5837 Test Method for Furanic Compounds in Electrical Insulating Liquids by High Performance Liquid Chromatography (HPLC)<sup>5</sup>

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee D27 on Electrical Insulating Liquids and Gases and is the direct responsibility of Subcommittee D27.01 on Mineral.

Current edition approved Nov. 10, 2000. Published January 2001. Originally published as D3487 – 76. Last previous edition D3487 – 88 (1993).

<sup>2</sup> Refer to American National Standard C 57.106. Guide for Acceptance and Maintenance of Insulating Oil in Equipment (IEEE Standard 64). Available from the American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 04.04.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 05.01.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 10.03.

<sup>6</sup> *Annual Book of ASTM Standards*, Vol 05.02.

### 3. Terminology Definitions

3.1 *Type I Mineral Oil*—an oil for apparatus where normal oxidation resistance is required. Some oils may require the addition of a suitable oxidation inhibitor to achieve this.

3.2 *Type II Mineral Oil*—an oil for apparatus where greater oxidation resistance is required. This is usually achieved with the addition of a suitable oxidation inhibitor.

NOTE 1—During processing of inhibited mineral oil under vacuum and elevated temperatures, partial loss of inhibitor and volatile portions of mineral oil may occur. The common inhibitors, 2,6-ditertiary-butyl para-cresol and 2,6-ditertiary-butyl phenol, are more volatile than transformer oil. If processing conditions are too severe, oxidation stability of the oil may be decreased due to loss of inhibitor. The selectivity for removal of moisture and air in preference to loss of inhibitor and oil is improved by use of a low processing temperature.

Conditions that have been found satisfactory for most inhibited mineral oil processing are:

Temperature, °C	Minimum Pressure	
	Pa	Torr, Approximate
40	5	0.04
50	10	0.075
60	20	0.15
70	40	0.3
80	100	0.75
90	400	3.0
100	1000	7.5

If temperatures higher than those recommended for the operating pressure are used, the oil should be tested for inhibitor content and inhibitor added as necessary to return inhibitor content to its initial value. Attempts to dry apparatus containing appreciable amounts of free water may result in a significant loss of inhibitor even at the conditions recommended above.

3.3 *additives*—chemical substances that are added to min-

eral insulating oil to achieve required functional properties.

3.4 *properties*—those properties of the mineral insulating oil which are required for the design, manufacture, and operation of the apparatus. These properties are listed in Section 5.

### 4. Sampling and Testing

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

4.2 Make each test in accordance with the latest revision of the ASTM test method specified in Section 5.

4.3 The oil shall meet the requirements of Section 5 at the unloading point.

NOTE 2—Because of the different needs of the various users, items relating to packaging, labeling, and inspection are considered to be subject to buyer-seller agreement.

NOTE 3—In addition to all other tests listed herein, it is sound engineering practice for the apparatus manufacturer to perform an evaluation of new types of insulating oils in insulation systems, prototype structures, or full-scale apparatus, or any combination thereof, to assure suitable service life.

4.4 Make known to the user the generic type and amount of any additive used, for assessing any potential detrimental reaction with other materials in contact with the oil.

### 5. Property Requirements

5.1 Mineral insulating oil conforming to this specification shall meet the property limits given in Table 1. The significance of these properties is discussed in Appendix X2.

**TABLE 1 Property Requirements**

Property	Limit		ASTM Test Method
	Type I	Type II	
<i>Physical:</i>			
Aniline point, °C	(63–84) <sup>A</sup>	(63–84) <sup>A</sup>	D 611
Color, max	0.5	0.5	D 1500
Flash point, min, °C	145	145	D 92
Interfacial tension at 25°C, min, dynes/cm	40	40	D 971
Pour point, max, °C	–40 <sup>B</sup>	–40 <sup>B</sup>	D 97
Relative Density (Specific gravity), 15°C/15°C max	0.91	0.91	D 1298
Viscosity, max, cSt (SUS) at:			
100°C	3.0 (36)	3.0 (36)	D 445 or D 88
40°C	12.0 (66)	12.0 (66)	
0°C	76.0 (350)	76.0 (350)	
Visual examination	clear and bright	clear and bright	D 1524
<i>Electrical:</i>			
Dielectric breakdown voltage at 60 Hz:			
Disk electrodes, min, kV	30	30	D 877
VDE electrodes, min, kV 0.040-in. (1.02-mm) gap	20 <sup>C</sup>	20 <sup>C</sup>	D 1816
0.080-in. (2.03-mm) gap	35 <sup>C</sup>	35 <sup>C</sup>	
Dielectric breakdown voltage, impulse conditions			D 3300
25°C, min, kV, needle negative to sphere grounded,	145 <sup>D</sup>	145 <sup>D</sup>	
1-in. (25.4-mm) gap			
Gassing tendency, max, µL/min	+30	+30	D 2300
Dissipation factor (or power factor), at 60 Hz max, %:			D 924
25°C	0.05	0.05	
100°C	0.30	0.30	
<i>Chemical:</i> <sup>E</sup>			
Oxidation stability (acid-sludge test)			D 2440
72 h:			
% sludge, max, by mass	0.15	0.1	
Total acid number, max, mg KOH/g	0.5	0.3	
164 h:			
% sludge, max, by mass	0.3	0.2	
Total acid number, max, mg KOH/g	0.6	0.4	
Oxidation stability (rotating bomb test), min, minutes	—	195	D 2112
Oxidation inhibitor content, max, % by mass	0.08	0.3	D 4768 or D 2668 <sup>F</sup>
Corrosive sulfur		noncorrosive	D 1275
Water, max, ppm	35	35	D 1533
Neutralization number, total acid number, max, mg KOH/g	0.03	0.03	D 974
PCB content, ppm	not detectable	not detectable	D 4059

<sup>A</sup> The value shown represents current knowledge.

<sup>B</sup> It is common practice to specify a lower or higher pour point, depending upon climatic conditions.

<sup>C</sup> These limits by Test Method D 1816 are applicable only to as received new oil (see Appendix X2.2.1.2). A new processed oil should have minimum breakdown strengths of 28 kV and 56 kV for a 0.04 in. (1.02 mm) or 0.08 in. (2.03 mm) gap respectively.

<sup>D</sup> Currently available oils vary in impulse strength. Some users prefer oil of a 145 kV minimum for certain applications, while others accept oil with impulse strength as low as 130 kV for other applications.

<sup>E</sup> Furanic compounds, as determined by Test Method D 5837, are useful for assessing the level of cellulose degradation that has occurred in oil impregnated paper systems. Specifying maximum allowable furan levels in new oils for this purpose should be by agreement between user and supplier.

<sup>F</sup> Both 2,6-ditertiary-butyl para-cresol and 2,6-ditertiary butylphenol have been found to be suitable oxidation inhibitors for use in oils meeting this specification.

Preliminary studies indicate both Test Methods D 2668 and D 4768 are suitable for determining concentration of either inhibitor or their mixture.

## APPENDIXES

### (Nonmandatory Information)

#### X1. SUPPLEMENTARY DESIGN INFORMATION

X1.1 The following values are typical for presently used mineral insulating oils. For oils derived from paraffinic or mixed-base crudes, the apparatus designer needs to know that these properties have not changed.

Property	Typical Values	ASTM Test Method
Coefficient of expansion, /° C from 25 to 100°C	0.0007 to 0.0008	D 1903
Property	Typical Values	ASTM Test Method
Dielectric constant, 25°C	2.2 to 2.3	D 924
Specific heat, cal/g, 20°C	0.44	D 2766
Thermal conductivity, cal/cm-s-°C, from 20 to 100°C	(0.30 to 0.40) × 10 <sup>-3</sup>	D 2717

## X2. SIGNIFICANCE OF PROPERTIES OF MINERAL INSULATING OIL

### X2.1 Physical Properties

X2.1.1 *Aniline Point*—The aniline point of a mineral insulating oil indicates the solvency of the oil for materials that are in contact with the oil. It may relate to the impulse and gassing characteristics of the oil.

X2.1.2 *Color*—A low color number is an essential requirement for inspection of assembled apparatus in the tank. An increase in the color number during service is an indicator of deterioration of the mineral insulating oil.

X2.1.3 *Flash Point*—The safe operation of the apparatus requires an adequately high flash point.

X2.1.4 *Interfacial Tension*—A high value for new mineral insulating oil indicates the absence of undesirable polar contaminants. This test is frequently applied to service-aged oils as an indicator of the degree of deterioration.

X2.1.5 *Pour Point*—The pour point of mineral insulating oil is the lowest temperature at which the oil will just flow and many of the factors cited under viscosity apply. The pour point of  $-40^{\circ}\text{C}$  may be obtained by the use of suitable distillates, refining processes, the use of appropriate long life additives, or any combination thereof. If a pour point additive is used, it is necessary to make known the amount and chemical composition.

X2.1.6 *Relative Density (Specific Gravity)*—The specific gravity of a mineral insulating oil influences the heat transfer rates and may be pertinent in determining suitability for use in specific applications. In extremely cold climates, specific gravity has been used to determine whether ice, resulting from freezing of water in oil-filled apparatus, will float on the oil and possibly result in flashover of conductors extending above the oil level. See, for example, “The Significance of the Density of Transformer Oils.”<sup>7</sup>

X2.1.7 *Viscosity*—Viscosity influences the heat transfer and, consequently, the temperature rise of apparatus. At low temperatures, the resulting higher viscosity influences the speed of moving parts, such as those in power circuit breakers, switchgear, load tapchanger mechanisms, pumps, and regulators. Viscosity controls mineral insulating oil processing conditions, such as dehydration, degassification and filtration, and oil impregnation rates. High viscosity may adversely affect the starting up of apparatus in cold climates (for example, spare transformers and replacements).

X2.1.8 *Visual Examination*—A simple visual inspection of mineral insulating oil may indicate the absence or presence of undesirable contaminants. If such contaminants are present, more definitive testing is recommended to assess their effect on other functional properties.

### X2.2 Electrical Properties

X2.2.1 *Dielectric Breakdown Voltage, 60 Hz*—The dielectric breakdown voltage of a mineral insulating oil indicates its ability to resist electrical breakdown at power frequencies in electrical apparatus.

X2.2.1.1 *Dielectric Breakdown—Disk Electrodes*—The test utilizing disk electrodes is useful in assessing the quality of the mineral insulating oil as received in tank cars, tank trucks, or drums. It is not sensitive enough to determine if an oil meets the minimum acceptable breakdown strength needed for processed oil used in some equipment.

X2.2.1.2 *Dielectric Breakdown—VDE Electrodes*—The VDE method (Test Method D 1816) is sensitive to contaminants, such as water, dissolved gases, cellulose fibers, and conductive particles in oil. Processing involves filtering, dehydration, and degassing, which generally improve the breakdown strength of the oil. As a general guide, the moisture and dissolved gas content by volume in processed oils should be less 15 ppm and 0.5 % respectively. The minimum breakdown strength for as received oils is typically lower than that of processed oils because of higher levels of contaminants.

X2.2.2 *Dielectric Breakdown Voltage—Impulse*—The impulse strength of oil is critical in electrical apparatus. The impulse breakdown voltage of an oil indicates its ability to resist electrical breakdown under transient voltage stresses (lightning and switching surges). The functional property is sensitive to both polarity and electrode geometry.

X2.2.3 *Dissipation Factor*—Dissipation factor (power factor) is a measure of the dielectric losses in an oil. A low dissipation factor indicates low dielectric losses and a low level of soluble contaminants.

### X2.3 Chemical Properties

X2.3.1 *Oxidation Inhibitor Content*—Oxidation inhibitor added to mineral insulating oil retards the formation of oil sludge and acidity under oxidative conditions. It is important to know if an oxidation inhibitor has been added to the oil and the amount. 2,6-Ditertiary-butyl para-cresol and 2,6-ditertiary butylphenol have been found suitable for use in mineral insulating oils complying with this specification. It is anticipated that other oxidation inhibitors will be accepted.

X2.3.2 *Corrosive Sulfur*—The absence of elemental sulfur and thermally unstable sulfur-bearing compounds is necessary to prevent the corrosion of certain metals such as copper and silver in contact with the mineral insulating oil.

X2.3.3 *Water Content*—A low water content of mineral insulating oil is necessary to achieve adequate electrical strength and low dielectric loss characteristics, to maximize the insulation system life, and to minimize metal corrosion.

X2.3.4 *Neutralization Number*—A low total acid content of a mineral insulating oil is necessary to minimize electrical conduction and metal corrosion and to maximize the life of the insulation system.

X2.3.5 *Oxidation Stability*—The development of oil sludge and acidity resulting from oxidation during storage, processing, and long service life should be held to a minimum. This minimizes electrical conduction and metal corrosion, maximizes insulation system life and electrical breakdown strength, and ensures satisfactory heat transfer. The limiting values in accordance with Table 1, as determined by Test Methods D 2112 and D 2440, best achieve these objectives.

<sup>7</sup> Mulhall, V. R., “The Significance of the Density of Transformer Oils,” *IEEE Transactions on Electrical Insulation*, Vol 15, No. 6, December 1980, pp. 498–499.

X2.3.6 *Gassing*—The gassing tendency of a mineral insulating oil is a measure of the rate of absorption or desorption of hydrogen into or out of the oil under prescribed laboratory conditions. It reflects, but does not measure, aromaticity of the oil. Most oil-filled transformers are blanketed with nitrogen or oxygen-depleted air. The gassing tendency of oil under nitrogen does not directly relate to its gassing tendency under hydrogen. No quantitative relationship has been established between the gassing tendency of an oil, as indicated by the results of Test Method D 2300, and the performance or life of that oil in service.

X2.3.7 *PCB Content*—United States regulations specify

procedures to be followed for the use and disposal of electrical apparatus and electrical insulating fluids containing PCB (polychlorinated biphenyls). The procedure to be used for a particular apparatus or lot of insulating fluid is determined from its PCB content. New mineral insulating oil of the type covered by this specification should not contain any detectable PCB. A nondetectable PCB concentration measured by Test Method D 4059 provides documentation to permit the insulating oil and apparatus containing it to be used without the labeling, recordkeeping, and disposal restrictions required of PCB-containing materials.

### **X3. CRUDE OILS, REFINING PROCESSES, AND SHIPPING CONTAINERS**

X3.1 *Crude Oils*—Mineral insulating oils are presently refined from predominantly naphthenic crude oils. As the supply of such crude oils diminishes, paraffinic or mixed base crudes may be used to provide mineral insulating oil for use in electrical apparatus. As the new crudes are developed for this use, additional tests peculiar to the chemistry of these oils will need to be defined.

X3.2 *Refining Processes*—Distillates from crude oils may be refined by various processes such as solvent extraction, dewaxing, hydrogen treatment, or combinations of these methods to yield mineral insulating oil meeting the requirements of this specification. The generic process should be specified upon request.

X3.3 *Shipping Containers*—Mineral insulating oil is usually shipped in rail cars, tank trucks (trailers), or drums. Rail cars used for shipping mineral insulating oil are usually not used for shipping other products and are more likely to be free of contamination. Tank trucks may be used for many different products and are more subject to contamination. Oil drums are most often used for shipping small quantities. All shipping containers, together with any attendant pumps and piping, should be cleaned prior to filling with oil and should be properly sealed to protect the oil during shipment.

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