Designation: D117 – 10

Standard Guide for
Sampling, Test Methods, and Specifications for Electrical Insulating Oils of Petroleum Origin[1]

This standard is issued under the fixed designation D117; 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 (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide describes methods of testing and specifications for electrical insulating oils of petroleum origin intended for use in electrical cables, transformers, oil circuit breakers, and other electrical apparatus where the oils are used as insulating, or heat transfer media, or both.

1.2 The purpose of this guide is to outline the applicability of the available test methods. Where more than one is available for measuring a given property, their relative advantages are described, along with an indication of laboratory convenience, precision, (95 % confidence limits), and applicability to specific types of electrical insulating oils.

1.3 This guide is classified into the following categories: Sampling Practices, Physical Tests, Electrical Tests, Chemical Tests, and Specifications. Within each test category, the test methods are listed alphabetically by property measured. A list of standards follows:

Category	Section	ASTM Method
Sampling:	3	D923, D2759, D3305
Physical Tests:		
Aniline Point	4	D611
Coefficient of Thermal Expansion	5	D1903
Color	6	D1500
Examination: Visual Infrared	7	D1524, D2144
Flash and Fire Point	8	D92
Interfacial Tension	9	D971, D2285
Pour Point of Petroleum Products	10	D97
Particle Count in Mineral Insulating Oil	11	D6786
Refractive Index	12	D1218, D1807
Relative Density (Specific Gravity)	13	D287, D1217, D1298, D1481
Specific Heat	14	D2766
Thermal Conductivity	15	D2717
Turbidity	16	D6181
Viscosity	17	D88, D445, D2161
Electrical Tests:		
Dielectric Breakdown Voltage	18	D877, D1816, D3300
Dissipation Factor and Relative Permittivity (Dielectric Constant)	19	D924
Gassing Characteristic Under Thermal Stress	20	D7150
Gassing Tendency	21	D2300
Resistivity	22	D1169
Stability Under Electrical Discharge	23	D6180
Chemical Tests:		
Acidity, Approximate	24	D1534
Carbon-Type Composition	25	D2140
Compatibility with Construction Material	26	D3455
Copper Content	27	D3635
Elements by Inductively Coupled Plasma (ICP-AES)	28	D7151
Furanic Compounds in Electrical Insulating Liquids	29	D5837
Gas Analysis	30	D3612
Gas Content	31	D831, D1827, D2945
Inorganic Chlorides and Sulfates	32	D878
Neutralization (Acid and Base) Numbers	33	D664, D974
Oxidation Inhibitor Content	34	D2668, D4768
Oxidation Stability	35	D1934, D2112, D2440
Polychlorinated Biphenyl Content	36	D4059
Relative Content of Dissolved Decay	37	D6802
Sediment and Soluble Sludge	38	D1698
Sulfur, Corrosive	39	D1275
Water Content	40	D1533
Specification:		
Mineral Insulating Oil for Electrical Apparatus	41	D3487
High Firepoint Electrical Insulating Oils	42	D5222

1.4 The values stated in SI units are to be regarded as standard. The values stated in parentheses are provided for information only.

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[1] This guide is under the jurisdiction of ASTM Committee D27 on Electrical Insulating Liquids and Gasesand is the direct responsibility of Subcommittee D27.01 on Mineral.

Current edition approved Sept. 15, 2010. Published October 2010. Originally published as D117 – 21 T. Last previous edition approved in 2002 as D117 – 02. DOI: 10.1520/D0117-10.

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 limitations prior to use.*

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
D287 Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)
D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
D611 Test Methods for Aniline Point and Mixed Aniline Point of Petroleum Products and Hydrocarbon Solvents
D664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration
D831 Test Method for Gas Content of Cable and Capacitor Oils
D877 Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes
D878 Test Method for Inorganic Chlorides and Sulfates in Insulating Oils
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
D971 Test Method for Interfacial Tension of Oil Against Water by the Ring Method
D974 Test Method for Acid and Base Number by Color-Indicator Titration
D1169 Test Method for Specific Resistance (Resistivity) of Electrical Insulating Liquids
D1217 Test Method for Density and Relative Density (Specific Gravity) of Liquids by Bingham Pycnometer
D1218 Test Method for Refractive Index and Refractive Dispersion of Hydrocarbon Liquids
D1250 Guide for Use of the Petroleum Measurement Tables
D1275 Test Method for Corrosive Sulfur in Electrical Insulating Oils
D1298 Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
D1481 Test Method for Density and Relative Density (Specific Gravity) of Viscous Materials by Lipkin Bicapillary Pycnometer
D1500 Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)
D1524 Test Method for Visual Examination of Used Electrical Insulating Oils of Petroleum Origin in the Field
D1533 Test Method for Water in Insulating Liquids by Coulometric Karl Fischer Titration
D1534 Test Method for Approximate Acidity in Electrical Insulating Liquids by Color-Indicator Titration
D1698 Test Method for Sediments and Soluble Sludge in Service-Aged Insulating Oils
D1807 Test Methods for Refractive Index and Specific Optical Dispersion of Electrical Insulating Liquids
D1816 Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using VDE Electrodes
D1827 Test Method for Gas Content (Nonacidic) of Insulating Liquids by Displacement with Carbon Dioxide (Withdrawn 2009)[3]
D1903 Practice for Determining the Coefficient of Thermal Expansion of Electrical Insulating Liquids of Petroleum Origin, and Askarels
D1934 Test Method for Oxidative Aging of Electrical Insulating Petroleum Oils by Open-Beaker Method
D2112 Test Method for Oxidation Stability of Inhibited Mineral Insulating Oil by Pressure Vessel
D2140 Practice for Calculating Carbon-Type Composition of Insulating Oils of Petroleum Origin
D2144 Practices for Examination of Electrical Insulating Oils by Infrared Absorption
D2161 Practice for Conversion of Kinematic Viscosity to Saybolt Universal Viscosity or to Saybolt Furol Viscosity
D2285 Test Method for Interfacial Tension of Electrical Insulating Oils of Petroleum Origin Against Water by the Drop-Weight Method (Withdrawn 2008)[3]
D2300 Test Method for Gassing of Electrical Insulating Liquids Under Electrical Stress and Ionization (Modified Pirelli Method)
D2440 Test Method for Oxidation Stability of Mineral Insulating Oil
D2668 Test Method for 2,6-*di-tert*-Butyl- *p*-Cresol and 2,6-*di-tert*-Butyl Phenol in Electrical Insulating Oil by Infrared Absorption
D2717 Test Method for Thermal Conductivity of Liquids
D2759 Practice for Sampling Gas from a Transformer Under Positive Pressure
D2766 Test Method for Specific Heat of Liquids and Solids
D2945 Test Method for Gas Content of Insulating Oils (Withdrawn 2012)[3]
D3300 Test Method for Dielectric Breakdown Voltage of Insulating Oils of Petroleum Origin Under Impulse Conditions
D3305 Practice for Sampling Small Gas Volume in a Transformer
D3455 Test Methods for Compatibility of Construction Material with Electrical Insulating Oil of Petroleum Origin
D3487 Specification for Mineral Insulating Oil Used in Electrical Apparatus
D3612 Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography
D3635 Test Method for Dissolved Copper In Electrical

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[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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

Insulating Oil By Atomic Absorption Spectrophotometry

D4052 Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter

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

D4768 Test Method for Analysis of 2,6-Ditertiary-Butyl Para-Cresol and 2,6-Ditertiary-Butyl Phenol in Insulating Liquids by Gas Chromatography

D5185 Test Method for Multielement Determination of Used and Unused Lubricating Oils and Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)

D5222 Specification for High Fire-Point Mineral Electrical Insulating Oils

D5837 Test Method for Furanic Compounds in Electrical Insulating Liquids by High-Performance Liquid Chromatography (HPLC)

D6180 Test Method for Stability of Insulating Oils of Petroleum Origin Under Electrical Discharge

D6181 Test Method for Measurement of Turbidity in Mineral Insulating Oil of Petroleum Origin (Withdrawn 2012)[3]

D6786 Test Method for Particle Count in Mineral Insulating Oil Using Automatic Optical Particle Counters

D6802 Test Method for Determination of the Relative Content Of Dissolved Decay Products in Mineral Insulating Oils by Spectrophotometry

D7150 Test Method for the Determination of Gassing Characteristics of Insulating Liquids Under Thermal Stress at Low Temperature

D7151 Test Method for Determination of Elements in Insulating Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)

SAMPLING

3. Sampling

3.1 Accurate sampling, whether of the complete contents or only parts thereof, is extremely important from the standpoint of evaluation of the quality of the product sampled. Obviously, careless sampling procedure or contamination in the sampling equipment will result in a sample that is not truly representative. This generally leads to erroneous conclusions concerning quality and incurs loss of the time, effort, and expense involved in securing, transporting, and testing the sample.

3.2 Sample the insulating oil in accordance with Practices D923, D2759 and D3305 as appropriate.

PHYSICAL PROPERTIES

4. Aniline Point

4.1 *Scope*—This test method covers the determination of the aniline point of petroleum products, provided that the aniline point is below the bubble point and above the solidification point of the aniline-sample mixture.

4.2 *Summary of Test Method:*

4.2.1 *Test Method D611*—Equal volumes of aniline and test specimen or aniline and test specimen plus *n*-heptane are placed in a tube and mixed mechanically. The mixture is heated at a controlled rate until the two phases become miscible. The mixture is then cooled at a controlled rate, and the temperature at which the two phases separate is recorded as the aniline point.

4.3 *Significance and Use*—The aniline point of an insulating oil indicates the solvency of the oil for some materials that are in contact with the oil. A higher aniline point implies a lower aromaticity and a lower degree of solvency for some materials.

5. Coefficient of Thermal Expansion

5.1 *Scope*—This test method covers the determination of the coefficient of thermal expansion of electrical insulating liquids of petroleum origin.

5.2 *Definition:*

5.2.1 *coefficient of thermal expansion*—the change in volume per unit volume per degree change in temperature. It is commonly stated as the average coefficient over a given temperature range.

5.3 *Summary of Test Method*—The specific gravity of insulating oils is determined at two temperatures below 90°C and separated by not less than 5°C nor more than 14°C. Test methods used may be D287, D1217, D1298, or D1481. The calculation of average coefficient of thermal expansion over this temperature range is given in Test Method D1903.

5.4 *Significance and Use*—A knowledge of the coefficient of expansion of a liquid is essential to compute the required size of a container to accommodate a volume of liquid over the full temperature range to which it will be subjected. It is also used to compute the volume of void space that would exist in an inelastic device filled with the liquid after the liquid has cooled to a lower temperature.

6. Color

6.1 *Scope*—This test method covers the visual determination of color of a wide variety of liquid petroleum products, including mineral insulating oils.

6.2 *Summary of Test Method:*

6.2.1 *Test Method D1500*—The test specimen is placed in a glass sample jar (an ordinary 125-mL test specimen bottle is satisfactory for routine tests). The color of the sample by transmitted light is compared with a series of tinted glass standards. The glass standard matching the sample is selected, or if an exact match is not possible, the next darker glass is selected. The results are reported numerically on a scale of 0.5 to 8.0.

6.3 *Significance*—A low color number is an essential requirement for inspection of assembled apparatus in a tank. An increase in the color number during service is an indicator of deterioration or contamination of the insulating oil.

7. Examination

7.1 *Scope:*

7.1.1 Both visual examination and qualitative infrared absorption are described in this section. The test methods are:

7.1.2 *Test Method D1524*—This is a visual examination of mineral insulating oils that have been used in transformers, oil circuit breakers, or other electrical apparatus as insulating or cooling media, or both. This test is intended for use in the field.

7.1.3 *Test Method D2144*—The infrared absorption from 2.5 to 25 µm (4000 to 667 cm^{-1}) is recorded as a means of (*a*) establishing continuity by comparison with the spectra of previous shipments by the same supplier, (*b*) for the detection of some types of contaminants, (*c*) for the identification of oils in storage or service. This test method is not intended for the determination of the various constituents of an oil.

7.2 *Summary of Test Methods:*

7.2.1 *Test Method D1524*—Estimate the color of the oil by use of an oil comparator, matching the oil test specimen with tinted glass color standards. Note the presence of cloudiness, particles of insulation, metal corrosion products, or other undesirable suspended materials in the oil.

7.2.2 *Test Methods D2144*—The infrared spectrum is recorded from 2.5 to 25 µm (4000 to 667 cm^{-1}) either as the absorption spectrum itself, or as the differential between the test specimen and reference oil. The spectra are compared with reference spectra to establish the identity of the oil.

7.3 *Significance and Use:*

7.3.1 *Test Method D1524*—The observation of the color and condition of the oil in a field inspection permits a determination of whether the sample should be sent to a central laboratory for full evaluation.

7.3.2 *Test Methods D2144*—The infrared spectrum of an electrical insulating oil indicates the general chemical composition of the sample. Because of the complex mixture of compounds present in insulating oils, the spectrum is not sharply defined and may not be suitable for quantitative estimation of components. The identity of the oil can be quickly established as being the same or different from previous samples by comparison with the reference spectra.

8. Flash and Fire Point

8.1 *Scope:*

8.1.1 This test method covers the determination of flash and fire points of all petroleum products except fuel oils and those having an open cup flash below 79°C (175°F).

8.1.2 This test method should be used solely to measure and describe the properties of materials in response to heat and flame under controlled laboratory conditions and should not be used for the description, appraisal, or regulation of the fire hazard of materials under actual fire conditions.

8.2 *Definitions:*

8.2.1 *flash point*—the temperature at which vapors above the oil surface first ignite when a small test flame is passed across the surface under specified conditions.

8.2.2 *fire point*—the temperature at which oil first ignites and burns for at least 5 s when a small test flame is passed across the surface under specified conditions.

8.3 *Summary of Test Method*—Fill the test cup to the specified level with the test specimen. Heat the sample initially at 14 to 17°C/min (25 to 30°F/min) until the temperature is 56°C (100°F) below the expected flash point. Reduce the rate of temperature change to 5 to 6°C/min (9 to 11°F/min) and apply the test flame every 2°C (or 5°F) until a flash occurs. Continue heating and testing every 2°C (or 5°F) until the oil continues to burn for at least 5 s. The procedure is described in Test Method D92.

8.4 *Significance and Use*—The flash point and fire point tests give an indication of the flammability of an oil. They may also be used to provide a qualitative indication of contamination with more flammable materials. In the latter context, the flash point test is more sensitive.

9. Interfacial Tension

9.1 *Scope*—These test methods cover the measurement, under nonequilibrium conditions, of the interfacial tension of insulating oils against water. These test methods have been shown by experience to give a reliable indication of the presence of hydrophilic compounds.

9.2 *Definition:*

9.2.1 *interfacial tension*—the molecular attractive force between unlike molecules at an interface. It is usually expressed in dynes per centimetre or millinewtons per metre.

9.3 *Summary of Test Methods:*

9.3.1 *Test Method D971*—Interfacial tension is determined by measuring the force necessary to detach a platinum wire upward from the oil-water interface. To calculate the interfacial tension, the force so measured is corrected by an empirically determined factor which depends upon the force applied, the densities of both oil and water, and the dimensions of the ring. The measurement is completed within 1 min of the formation of the interface.

9.3.2 *Test Method D2285*—Interfacial tension is determined by measuring the volume of a drop of water that the oil will support. The larger the drop of water, the higher the interfacial tension of the oil. The instrument used to measure the volume of the drops of water is calibrated to read approximately in dynes per centimeter interfacial tension. For better accuracy, the reading can be corrected by a factor that depends on the density of the oil. The drop is allowed to age for 30 s and to fall between 45 and 60 s after formation.

9.4 *Significance and Use*—Interfacial tension measurements on electrical insulating oils provide a sensitive means of detecting small amounts of soluble polar contaminants and products of oxidation. A high value for new mineral insulating oil indicates the absence of undesirable polar contaminants. The test is frequently applied to service-aged oils as an indication of the degree of deterioration.

10. Pour Point

10.1 *Scope*—The pour point is applicable to any petroleum oil.

10.2 *Definition:*

10.2.1 *pour point*—the lowest temperature, expressed as a multiple of 3°C at which the oil is observed to flow when cooled and examined under prescribed conditions.

10.3 *Summary of Test Method*—After preliminary heating, the test specimen is cooled at a specified rate and examined at intervals of 3°C for flow characteristics. The lowest temperature at which movement of the oil is observed within 5 s is reported as the pour point. The procedure is described in Test Method D97.

10.4 *Significance and Use:*

10.4.1 The pour point of an insulating oil gives an indication of the temperature below which it may not be possible to pour or remove the oil from its container.

10.4.2 In connection with oil for use in cable systems, the pour point may be useful to indicate the point at which no free movement will take place in the cable or to indicate the temperature at which partial separation of wax may occur.

10.4.3 The pour point of a transformer oil is important as an index of the lowest temperature to which the material may be cooled without seriously limiting the degree of circulation of the oil. Some materials are sensitive to temperature cycling or prolonged storage at low temperatures, and their pour points may not adequately predict their low temperature flow properties.

11. Particle Count in Mineral Insulating Oil Using Automatic Opticle Particle Counters

11.1 *Scope*—This test method covers the determination of particle concentration and particle size distribution in mineral insulating oil. It is suitable for testing oils having a viscosity of 6 to 20 cSt at 40°C. The test method is specific to liquid automatic particle analyzers that use the light extinction principle.

11.2 *Summary of Test Method:*

11.2.1 Samples are taken in particle-clean bottles that are suitable for particle analysis. The sample bottle is agitated to redistribute particles in the oil, then the oil is placed in an automatic particle counter, where the number of particles and their size distribution are determined by the light extinction principle.

11.2.2 As particles pass through the sensing zone of the instrument, the quantity of light reaching the detector is obscured. This signal is translated to an equivalent projected area diameter based on calibration with a NIST-traceable fluid (ISO Medium Test Dust suspension).

11.3 *Significance and Use:*

11.3.1 Particles in insulating oil can have a detrimental effect on the dielectric properties of the fluid, depending on the size, concentration, and nature of the particles. The source of these particles can be external contaminants, oil degradation byproducts, or internal materials such as metals, carbon, or cellulose fibers.

11.3.2 Particle counts provide a general degree of contamination level and may be useful in assessing the condition of specific types of electrical equipment. Particle counts can also be used to determine filtering effectiveness when processing oil.

11.3.3 If more specific knowledge of the nature of the particles is needed, other tests such as metals analysis or fiber identification and counting must be performed.

12. Refractive Index and Specific Optical Dispersion

12.1 *Scope:*

12.1.1 *Test Method D1218*—Describes a precision method for determining refractive index accurate to 0.00006 and refractive dispersion accurate to 0.00012. The liquid must be transparent, no darker than ASTM 4.0 color (see Test Method D1500) and have a refractive index between 1.33 and 1.50. The specific optical dispersion is calculated by dividing the refractive dispersion value by the specific gravity of the liquid.

12.1.2 *Test Method D1807*—Describes a routine method for measuring refractive index accurate to three units in the fourth decimal place, measuring refractive dispersion, and calculating specific optical dispersion accurate to three units in the fourth decimal place. The oils must be transparent and light colored.

12.2 *Definitions:*

12.2.1 *refractive index*—the ratio of the velocity of light in air to its velocity in the substance under test.

12.2.2 *specific optical dispersion* —the difference between the refractive indexes of light of two different wave lengths, both indexes measured at the same temperature, the difference being divided by the specific gravity also measured at the test temperature. For convenience, the specific dispersion value is multiplied by 10^4.

12.3 *Summary of Test Method:*

12.3.1 The two methods differ in the accuracy of the refractometer used. After adjusting the instrument temperature to 25°C, apply the test specimen to the refracting prism, read the refractive index, and read the compensator dial reading. From the correlation tables supplied with the instrument obtain the refractive dispersion. Calculate the specific optical dispersion by dividing refractive dispersion by the specific gravity of the oil.

12.4 *Significance and Use:*

12.4.1 *Refractive Index* of an insulating liquid varies with its composition and with the nature and amount of contaminants held in solution. Where the refractive index of an insulating liquid when new is known, determinations made on the same liquid after periods of service may form a basis for estimating any change in composition or the degree of contamination acquired through solution.

12.4.2 *Specific Optical Dispersion* serves as a quick index to the amount of unsaturated compounds present in an oil. As the dispersion values for paraffinic and naphthenic compounds are nearly the same and are essentially independent of molecular weight and structural differences, values above a minimum of about 97 bear a direct relationship to the amount of aromatic compounds present in insulating oil.

13. Relative Density (Specific Gravity)

13.1 *Scope:*

13.1.1 The methods used to measure relative density (specific gravity) may use a hydrometer, pycnometer, or an oscillating tube.

13.1.1.1 *Test Method D287*—Uses an API hydrometer and is limited to liquids having a Reid vapor pressure of 180 kPa (26 psi) or less.

13.1.1.2 *Test Method D1217*—Covers the use of a pycnometer to measure the relative density (specific gravity) of petroleum fractions.

13.1.1.3 *Test Method D1298*—Covers the use of a hydrometer to measure relative density (specific gravity) directly or the measurement of API gravity followed by conversion to relative density (specific gravity). This test method is limited to liquids having a Reid vapor pressure of 179 kPa (26 psi) or less. This test method is most suitable for use with mobile transparent liquids, although it can also be used with viscous oils if sufficient care is taken in the measurement.

13.1.1.4 *Test Method D1481*—Covers the determination of the densities of oils more viscous than 15 cSt at 20°C. The liquid should not have a vapor pressure greater than 13 kPa (100 mm Hg) at the test temperature. To measure the density of less viscous liquids more accurately than permitted by the hydrometer method, Test Method D1217 is available.

13.1.1.5 *Test Method D4052*—Covers the measurement of relative density (specific gravity) by the measurement of change in oscillation frequency of a vibrating glass tube filled with test liquid.

13.2 *Definition:*

13.2.1 *relative density (specific gravity)*—the ratio of the mass (weighed in vacuum) of a given volume of liquid at 15.6°C (60°F) to the mass of an equal volume of pure water at the same temperature. When reporting results, explicitly state the reference temperature, for example, specific gravity 15.6/15.6°C.

13.3 *Summary of Test Method:*

13.3.1 API gravity may be measured at the oil temperature using a hydrometer (Test Methods D287 or D1298) and converting to 15.6°C using Guide D1250.

13.3.2 Relative density (specific gravity) may be measured at the oil temperature using a hydrometer (Test Method D1298) and converted to 15.6°C using Guide D1250.

13.3.3 *Test Method D1481*—The liquid is drawn into the bicapillary pycnometer through the removable siphon arm and adjusted to volume at the temperature of test. After equilibration at the test temperature, liquid levels are read; and the pycnometer is removed from the thermostated bath, cooled to room temperature, and weighed. Density or relative density (specific gravity), as desired, is then calculated from the volume at the test temperature, and the weight of the sample. The effect of air buoyancy is included in the calculation.

13.4 *Significance and Use:*

13.4.1 Electrical insulating oils are usually sold on the basis of volume delivered at 15.6°C (60°F). Delivery is often made on the basis of net weight of product in drums, and the specific gravities often are measured at temperatures other than 15.6°C. The values of relative density (specific gravity) at 15.6°C must be known to calculate the volume at 15.6°C of the oil delivered.

13.4.2 The relative density (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 certain cold climates, ice may form in de-energized transformers exposed to temperatures below 0°C, and the maximum specific gravity of the oil used in such equipment should be at a value that will ensure that ice will not float in the oil at any temperature the oil might attain.

13.4.3 When making additions of insulating liquid to apparatus in service, a difference in relative density (specific gravity) may indicate a tendency of the two bodies of liquid to remain in separate layers rather than mixing into a homogeneous single body of liquid. Such conditions have caused serious overheating of self-cooled apparatus. Suitable precautions should be taken to ensure mixing.

14. Specific Heat

14.1 *Scope*—This test method covers determination of the specific heat of electrical insulating liquids of petroleum origin.

14.2 *Definition:*

14.2.1 *specific heat (or heat capacity) of a substance*—a thermodynamic property that is a measure of the amount of energy required to produce a given temperature change within a unit quantity of that substance. The standard unit of heat capacity is Joules/Kg°C at some defined temperature; specific heat is dimensionless as it is the ratio of the substance's heat capacity relative to that of water.

14.3 *Summary of Test Method*—The specific heat is determined by Test Method D2766. The measurement is made by heating a test specimen at a known and fixed rate. Once dynamic heating equilibrium is obtained, the heat flow is recorded as a function of temperature. The heat flow normalized to specimen mass and heating rate is directly proportional to the specimen's specific heat capacity.

14.4 *Significance and Use*—A knowledge of the specific heat is helpful in designing adequate heat transfer properties for electrical apparatus. A higher specific heat value indicates a more efficient heat transfer medium.

15. Thermal Conductivity

15.1 *Scope*—This test method covers the determination of the thermal conductivity of electrical insulating liquids of petroleum origin.

15.2 *Definition:*

15.2.1 *thermal conductivity*—the ability of a substance to transfer energy as heat in the absence of mass transport phenomena. The standard unit of thermal conductivity is as follows:

$$W/(mK)\ (\mathrm{Cal/cm\ s\ °C})$$

15.3 *Summary of Test Method*—The thermal conductivity is determined by Test Method D2717. This test method measures the temperature gradient produced across the liquid by a known amount of energy introduced into the test cell by an electrically heated platinum element.

15.4 *Significance and Use*—A knowledge of thermal conductivity is helpful in designing adequate heat transfer properties for electrical apparatus. A high value indicates a good heat transfer efficiency property for the liquid.

16. Turbidity

16.1 *Scope*—This test method determines the amount of suspended particulate matter in electrical insulating oil of petroleum origin.

16.2 *Definition:*

16.2.1 *turbidity, n*—the reduction of transparency due to presence of particulate matter. The standard unit of turbidity is the nephelometric turbidity unit (NTU), which is defined as the intensity of light scattered by a known aqueous suspension of formazine.

16.3 *Summary of Test Method*—The turbidity is determined by Test Method D6181. This test method measures the scattered light at 0.5 π rad (90°) or 0.5 and 1.5 π rad (90° and 270°) angles to the incident beam using a nephelometer that has been calibrated with a standard aqueous suspension of formazine.

16.4 *Significance and Use*—Turbidity measures particulate contamination in electrical insulating oil that may not be apparent to the unaided human eye and could affect the performance of the dielectric fluid.

17. Viscosity

17.1 *Scope:*

17.1.1 *Test Method D88*—Covers the empirical measurement of Saybolt viscosity of petroleum products using the Saybolt viscometer at temperatures between 25.1 and 98.9°C (70 and 210°F).

17.1.2 *Test Method D445*—Covers the determination of the kinematic viscosity of liquid petroleum products by measuring the time for a volume of liquid to flow under gravity through a calibrated glass capillary viscometer.

17.1.3 *Practice D2161*—Provides tables or equations for the conversion of centistokes into Saybolt Universal Seconds or Saybolt Furol Seconds at the same temperatures.

17.2 *Summary of Test Methods:*

17.2.1 *Test Method D88*—The efflux time in seconds for 60 mL of test specimen to flow through a calibrated orifice in the Saybolt viscometer is measured under carefully controlled conditions, particularly temperature and liquid head. The time is converted by an orifice factor and reported as the viscosity of the sample at that temperature.

17.2.2 *Test Method D445*—The time is measured in seconds for a fixed volume of liquid to flow under gravity through the capillary of a calibrated viscometer under a reproducible driving head and at a closely controlled temperature. The kinematic viscosity is the product of the measured flow time and the calibration constant of the viscometer.

17.2.3 *Practice D2161*—The Saybolt Universal viscosity equivalent to a given kinematic viscosity varies with the temperature at which the determination is made. The basic conversion values are given in Table 1 of this practice for 37.8°C (100°F). Factors are given for converting units at other temperatures. The Saybolt Furol viscosity equivalents are given in Table 3 of this practice for 50.0 and 98.9°C (122 and 210°F) only.

17.3 *Significance and Use:*

17.3.1 The fundamental and preferred method for measuring kinematic viscosity is by use of Test Method D445. The Saybolt instrument in Test Method D88, being of all-metal construction, may be more rugged for field use, but values obtained are significantly less accurate than those obtained by the use of the capillary viscometers in Test Method D445.

17.3.2 Viscosity of electrical insulating oils influences their heat transfer properties, and consequently the temperature rise of energized electrical apparatus containing the liquid. 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 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). Viscosity affects pressure drop, oil flow, and cooling rates in circulating oil systems, such as in pipe-type cables and transformers.

ELECTRICAL PROPERTIES

18. Dielectric Breakdown Voltage

18.1 *Scope:*

18.1.1 There are two standard test methods for determining the dielectric breakdown voltage of electrical insulating fluids at commercial power frequencies, D877 and D1816, and one standard test method for determining the dielectric breakdown voltage of insulating oils under impulse conditions, D3300.

18.1.2 *Test Method D877*—Applicable to liquid petroleum oils, hydrocarbons, and askarels commonly used as insulating and cooling media in cables, transformers, oil circuit breakers, and similar apparatus. The suitability of Test Method D877 for testing liquids having viscosities exceeding 900 cSt (5000 SUS) at 40°C (104°F) has not been determined.

18.1.3 *Test Method D1816*—Applicable to liquid petroleum oils commonly used as an insulating and cooling medium in cables, transformers, oil circuit breakers, and similar apparatus. The suitability of Test Method D1816 for testing oils having viscosities of more than 19 cSt (100 SUS) at 40°C (104°F) has not been determined.

18.1.4 *Test Method D3300*—Applicable to any liquid commonly used as an insulating and cooling medium in high-voltage apparatus subjected to impulse conditions, such as transient voltage stresses arising from such causes as nearby lightning strikes and high-voltage switching operations.

18.2 *Definition:*

18.2.1 *dielectric breakdown voltage*—the potential difference at which electrical failure occurs in an electrical insulating material or insulation structure, under prescribed test conditions.

18.3 *Summary of Test Methods:*

18.3.1 *Test Method D877*—The insulating liquid is tested in a test cup between two 25.4-mm (1-in.) diameter disk electrodes spaced 2.54 mm (0.100 in.) apart. A 60-Hz voltage is applied between the electrodes and raised from zero at a uniform rate of 3 kV/s. The dielectric breakdown voltage is recorded, prior to the occurrence of disruptive discharge, when the voltage across the specimen has dropped to less than 100 V. In the referee procedure, one breakdown test is made on each of five fillings of the test cup, and the average and individual values of breakdown voltage are reported.

18.3.2 *Test Method D1816*—The oil is tested in a test cell between spherically capped (VDE) electrodes spaced either 1 mm (0.040 in.) or 2 mm (0.080 in.) apart. The oil is stirred before and during application of voltage by means of a motor-driven stirrer. A 60-Hz voltage is applied between the electrodes and raised from zero at a uniform rate of ½ kV/s. The voltage at which the current produced by breakdown of the oil reaches the range of 2 to 20 mA, tripping a circuit breaker, is considered to be the dielectric breakdown voltage. In the procedure, five breakdown tests are made on one filling of the test cell. If the five breakdowns fall within the statistical requirements, the average value is reported. If not, five additional breakdowns are required with the average of the ten values reported.

18.3.3 *Test Method D3300*—The electrode system consists of either: (*1*) two 12.7-mm (0.5-in.) diameter spheres spaced 3.8 mm (0.15 in.) apart or (*2*) a 12.7-mm (0.5-in.) diameter sphere and a steel phonograph needle of 0.06-mm radius of curvature of point, spaced 25.4 mm (1.0 in.) apart. The polarity of the needle with respect to the sphere can be either positive or negative. The electrodes are immersed in the oil in a test cell. An impulse wave of 1.2 by 50 µs wave shape (times to reach crest value and to decay to half of crest value, respectively) is applied at progressively higher voltages until breakdown occurs.

18.4 *Significance and Use:*

18.4.1 *Power Frequencies (Test Methods D877 and D1816)*—The dielectric breakdown voltage of an insulating liquid at commercial power frequencies is of importance as a measure of the liquid's ability to withstand electric stress. It is the voltage at which breakdown occurs between two electrodes under prescribed test conditions. It also serves to indicate the presence of contaminating agents, such as water, dirt, moist cellulosic fibers, or conducting particles in the liquid, one or more of which may be present when low dielectric breakdown values are found by test. However, a high dielectric breakdown voltage does not indicate the absence of all contaminants. See Appendix X1 of either test method for other influences that affect the dielectric breakdown voltage of a liquid.

18.4.1.1 The ability of a fluid to resist breakdown under the test conditions is an indication of the ability of the fluid to perform its insulating function in electrical apparatus. The average breakdown voltage is commonly used in specifications for the qualification and acceptance of insulating fluids. It is also used as a control test for the refining of new or reclaiming of used insulating fluids. Because of the complex interactions of the factors affecting dielectric breakdown voltage the values obtained cannot be used for design purposes.

18.4.1.2 The square-edged disk electrodes of Test Method D877 are relatively insensitive to dissolved water in concentrations below 60 % of the saturation level. This method is recommended for acceptance tests on unprocessed insulating liquids received from vendors in tank cars, tank trucks, and drums. It also may be used for the routine testing of liquids from selected power systems apparatus.

18.4.1.3 The more uniform electric field associated with VDE electrodes employed in Test Method D1816 is more sensitive to the deleterious effects of moisture in solution, especially when cellulosic fibers are present in the oil, than is the field in Test Method D877. Test Method D1816 can be used for processed or as received oils. Filtering and dehydrating the oil may increase Test Method D1816 dielectric breakdown voltages substantially.

18.4.2 *Impulse Conditions (Test Method D3300):*

18.4.2.1 This test method is most commonly performed using a negative polarity point opposing a grounded sphere (NPS). The NPS breakdown voltage of fresh unused oils measured in the highly divergent field in this configuration depends on oil composition; decreasing with increasing concentration of aromatic, particularly polyaromatic, hydrocarbon molecules.

18.4.2.2 This test method may be used to evaluate the continuity of composition of an oil from shipment to shipment. The NPS impulse breakdown voltage of an oil can also be substantially lowered by contact with materials of construction, by service aging, and by other impurities. Test results lower than those expected for a given fresh oil may also indicate use or contamination of that oil.

18.4.2.3 Although polarity of the voltage wave has little or no effect on the breakdown strength of an oil in uniform fields, polarity does have a marked effect on the breakdown voltage of an oil in nonuniform electric fields.

19. Dissipation Factor and Relative Permittivity (Dielectric Constant)

19.1 *Scope:*

19.1.1 This test method covers new electrical insulating liquids as well as liquids in service or subsequent to service in cables, transformers, oil circuit breakers, and other electrical apparatus.

19.1.2 This test method provides a procedure for making referee and routine tests at a commercial frequency of approximately 60 Hz.

19.2 *Summary of Test Method:*

19.2.1 The loss characteristic is commonly measured in terms of dissipation factor (tangent of the loss angle) or of power factor (sine of the loss angle). For values up to 0.05, dissipation factor and power factor values are equal to each other within about one part in one thousand and the two terms may be considered interchangeable.

19.2.2 *Test Method D924*—The oil test specimens are tested in a three-terminal or guarded electrode test cell maintained at the desired test temperature. Using a bridge circuit, measure the loss characteristics and capacitance following the instructions appropriate to the bridge being used. For routine tests, a two-electrode cell may be used.

19.3 *Significance and Use:*

19.3.1 *Dissipation Factor (or Power Factor)*—This property is a measure of the dielectric losses in an oil, and hence, of the amount of energy dissipated as heat. A low value of dissipation factor (or power factor) indicates low dielectric losses and a low level of soluble polar ionic or colloidal contaminants. This characteristic may be useful as a means of quality control and as an indication of oil changes in service resulting from contamination and oil deterioration.

19.3.2 *Relative Permittivity (Dielectric Constant)*—Insulating liquids are used in general either to insulate components of an electrical network from each other and from ground, alone or in combination with solid insulating materials, or to function as the dielectric of a capacitor. For the first use, a low value of relative permittivity is often desirable in order to have the capacitance be as small as possible, consistent with acceptable chemical and heat transfer properties. However, an intermediate value of relative permittivity may sometimes be advantageous in achieving a better voltage distribution between the liquid and solid insulating materials with which the liquid may be in series. When used as the dielectric in a capacitor, it is desirable to have a higher value of relative permittivity so the physical size of the capacitor may be as small as possible.

20. Gassing Characteristics of Insulating Liquids Under Thermal Stress at Low Temperature

20.1 *Scope:*

20.1.1 This test method describes the procedures to determine the low temperature (120°C) gassing characteristics of insulating liquids specifically and without the influence of other electrical apparatus materials or electrical stresses. This test method was primarily designed for insulating mineral oil. It can be applied to other insulating liquids in which dissolved gas-in-oil analysis (Test Method D3612) is commonly performed.

20.1.2 This test method is particularly suited for detection of the phenomenon sometimes known as "stray gassing" and is also referred to in CIGRE TF11 B39. 1.3 This test method is performed on transformer insulating liquids to determine the propensity of the oil to produce certain gases such as hydrogen and hydrocarbons at low temperatures.

20.1.3 This test method details two procedures:

20.1.3.1 Method A describes the procedure for determining the gassing characteristics of a new, unused insulating liquid, as received, at 120°C for 164 h.

20.1.3.2 Method B describes the procedure for processing the insulating liquid through an attapulgite clay column to remove organic contaminants and other reactive groups that may influence the gassing behavior of an insulating liquid, which is suspected of being contaminated. This procedure applies to both new and used insulating liquids.

20.2 *Summary of Test Method:*

20.2.1 *Method A*—Insulating liquid is filtered through a mixed cellulose ester filter. A portion of the test specimen is sparged for 30 min with dry air. A test specimen is then placed into a glass syringe, capped and aged at 120 ± 2°C for 164 h. The test is run in duplicate. The other portion of the test specimen is sparged for 30 min with dry nitrogen. A test specimen is then placed into a glass syringe, capped and aged at 120°C ± 2°C for 164 h. The test is run in duplicate. After, the test specimens have cooled, dissolved gas-in-oil analysis is then performed according to Test Method D3612.

20.2.2 *Method B*—Insulating oil is passed through a heated (60 to 70°C) attapulgite clay column at a rate of 3 to 5 mL per minute. The insulating liquid is contacted with the attapulgite clay at a ratio of 1 g clay to 33 mL (range: 30 to 35 mL) of insulating liquid (0.25 lb clay: 1 gal of insulating liquid). The insulating liquid is collected and subjected to the testing as outlined in 4.1.

20.3 *Significance and Use:*

20.3.1 Generation of combustible gases is used to determine the condition of oil-filled electrical apparatus. Many years of empirical evidence has yielded guidelines such as those given in IEEE C 57.104, IEC 60599 and IEC 61464. Industry experience has shown that electric and thermal faulted in oil-filled electrical apparatus are the usual sources that generate gases. Experience has shown that some of the gases could form in the oil at low temperatures or as a result of contamination, without any other influences.

20.3.2 Some severely hydro-treated transformer oils subjected to thermal stress and oils that contain certain types of contamination may produce specific gases at lower temperatures than normally expected for their generation and hence, falsely indicate abnormal operation of the electrical apparatus. Some new oils have produced large amounts of gases, especially hydrogen, without the influence of other electrical apparatus materials or electrical stresses. This renders interpretation of the dissolved gas analysis more complicated.

20.3.3 Heating for 164 h has been found to be a sufficient amount of time to reach a stable and characteristic gassing pattern.

20.3.4 This method uses both dry air and dry nitrogen as the sparging gas. This is to reflect either a electrical apparatus preservation system that allows oxygen to contact the oil or one that is sealed from the outside atmosphere. Oils sparged with air generally produce much more hydrogen as a percentage of the total combustible gas content as compared to oils sparged with nitrogen as these produce more hydrocarbons in relation to hydrogen.

21. Gassing Tendency

21.1 *Scope*—Test Method D2300 describes a procedure to measure the rate at which gas is evolved or absorbed by insulating oils when subjected to electrical stress of sufficient intensity to cause ionization. The oil test specimen is initially saturated with a selected gas (usually hydrogen) at atmospheric pressure.

21.2 *Summary of Test Method:*

21.2.1 *Test Method D2300*—After being saturated with a gas (usually hydrogen) the oil is subjected to a radial electrical stress at a controlled temperature. The gas space above the oil is ionized due to the electrical stresses; and therefore, the oil surface at the oil-gas interface is subjected to ion bombardment. The evolution or absorption of gas is measured with a gas burette and reported in µL/min.

21.3 *Significance and Use*—This test method indicates whether insulating oils are gas absorbing or gas evolving under the test conditions. Numerical results obtained in different laboratories may differ significantly in magnitude, and the results of this test method should be considered as qualitative in nature.

21.3.1 For certain applications when insulating oil is stressed at high voltage gradients, it is desirable to be able to determine the rate of gas evolution or gas absorption under specified test conditions. At the present time, correlation of such test results with equipment performance is limited.

22. Resistivity

22.1 *Scope:*

22.1.1 This test method covers the determination of specific resistance (resistivity) applied to new electrical insulating liquids, as well as to liquids in service, or subsequent to service, in cables, transformers, circuit breakers, and other electrical apparatus.

22.1.2 This test method covers a procedure for making referee and routine tests with dc potential.

22.2 *Definition:*

22.2.1 *specific resistance (resistivity)—of a liquid,* the ratio of the dc potential gradient in volts per centimetre paralleling the current flow within the test specimen, to the current density in amperes per square centimetre at a given instant of time and under prescribed conditions. This is numerically equal to the resistance between opposite faces of a centimetre cube of a liquid. It is measured in ohm centimetres.

22.3 *Summary of Test Method:*

22.3.1 *Test Method D1169*—The oil test specimen is tested in three-terminal, or guarded-electrode test cell maintained at the desired test temperature. A dc voltage is applied of such magnitude that the electric stress in the liquid is between 200 and 1200 V/mm (5 to 30 V/mL). The current flowing between the high-voltage and guarded measuring electrode is measured at the end of 1 min of electrification and the resistivity calculated using specified equations appropriate to the method of measurement used. A two-electrode cell may be used for routine tests.

22.4 *Significance and Use*—The resistivity of a liquid is a measure of its electrical insulating properties under conditions comparable to those of the test. High resistivity reflects low content of free ions and ion-forming particles and normally indicates a low concentration of conductive contaminants.

23. Stability Under Electric Discharge

23.1 *Scope*—Test Method D6180 measures the relative stability of new, used, or reclaimed insulating oils of petroleum origin in the presence of a controlled electric discharge by monitoring the pressure increase in the evacuated discharge chamber.

23.2 *Summary of Test Method*—A test specimen is introduced into a discharge cell and degassed under vacuum at room temperature. An ac potential of 10 KV is applied for 300 min. The gradual rise of pressure inside the discharge cell is measured as a function of time. The dissipation factor of the oil at 100°C is determined before and after the stability test using Test Method D924.

23.3 *Significance and Use*—The changes observed in the generation of gases as noted by pressure change and the composition modification as reflected in dissipation factor increases may provide a relative assessment of the stability of the oil for high voltage application.

CHEMICAL PROPERTIES

24. Acidity, Approximate

24.1 *Scope*—Test Method D1534 covers the determination of the approximate total acid value of used electrical insulating liquids, in general, those having viscosities less than 24 cSt at 40°C. It is a simple procedure that can be applied in the field. Where a quantitative neutralization value is required, use Test Method D664 or D974. These test methods should be applied in the laboratory.

24.2 *Summary of Test Method:*

24.2.1 *Test Method D1534*—To determine whether the acidity is greater or less than a fixed arbitrary value, a fixed volume of liquid to be tested is added to the test bottle or graduated cylinder, together with a small amount of indicator (phenolphthalein) and the appropriate quantity of standard potassium hydroxide solution. The mixture is shaken and allowed to separate. The color of the aqueous layer at the bottom of the container when testing mineral oils, or at the top when testing askarels, determines whether the acidity is less than or greater than the arbitrary value chosen.

24.3 *Significance and Use:*

24.3.1 The approximate acidity of used electrical insulating oils is an estimate of the total acid value of the oil. As acid values increase, usually due to oxidation of the oil in service, the impairment of those oil qualities, important to proper functioning of specific apparatus, increases. In general, acidic by-products produce increased dielectric loss, increased corrosivity, and may cause thermal difficulties attributable to insoluble components called "sludge." This test method is adapted to a specific volume of oil; total acid values of 0.05 to 0.5 mg of potassium hydroxide per gram of oil is a range which is functionally significant.

25. Carbon-Type Composition

25.1 *Scope*—This test method covers the determination of carbon-type composition of insulating oils by correlation with basic physical properties. Carbon-type composition is expressed as percentage of aromatic carbons, percentage of naphthenic carbons, and percentage of paraffinic carbons. Viscosity, relative density (or specific gravity), and refractive index are the only measurements required for use of this test method.

25.2 *Summary of Test Method:*

25.2.1 *Test Method D2140*—The viscosity, density and specific gravity, and refractive index of the oil are measured. From these values, the viscosity-gravity constant and refractivity intercept are calculated. Using these two computed values, percentage of aromatic carbons, naphthenic carbons, and paraffinic carbons are estimated from a correlation chart.

25.3 *Significance and Use*—The primary purpose of this test method is to characterize the carbon-type composition of an oil. It is also applicable in observing the effect on oil constitution of various refining processes, such as solvent extraction, acid treatment, and so forth. It has secondary application in relating the chemical nature of an oil to other phenomena that have been demonstrated to be related to oil composition.

26. Compatibility with Construction Material

26.1 *Scope*—This test method covers screening for the compatibility of materials of construction with electrical insulating oil for use in electrical equipment. Solid materials that can be tested for compatibility include varnishes, dip coatings, core steel, core steel coatings, gaskets, and wire enamels.

26.2 *Summary of Test Method:*

26.2.1 *Test Methods D3455*—The electrical insulating oil and the material whose compatibility is being tested are aged for 164 h at 100°C. Changes in the oil and compatibility sample are observed and appropriate tests conducted.

26.3 *Significance and Use:*

26.3.1 The magnitude of the change in the electrical properties of the insulating oil is of importance in determining the contamination of the oil by the test specimen.

26.3.2 Physical and chemical changes in the oil such as color, interfacial tension, and acidity also indicate solubility or other adverse effects of the test specimen on the oil.

26.3.3 The physical changes of the test specimen, such as hardness, swelling, and discoloration, show the effect of the oil on the test specimen and are used to determine the suitability of the material for use in insulating oil.

26.3.4 A material meeting the criteria recommended does not necessarily indicate suitability for use in electrical equipment. Other properties must also be considered. Additionally, certain materials containing additives may meet the requirements of this procedure, yet be unsatisfactory when subjected to longer term evaluations.

27. Copper Content

27.1 *Scope:*

27.1.1 *Test Method D3635*—Covers the determination of copper in new or used electrical insulating oil. For flame atomization, the lower limit of detectability is of the order of 0.1 ppm. For nonflame atomization, the lower limit of detectability is less than 0.01 ppm.

27.2 *Summary of Test Method:*

27.2.1 *Test Method D3635*—The test specimen of oil is diluted with an appropriate organic solvent and analyzed in an atomic absorption spectrophotometer. Alternative procedures are provided for instruments employing flame and nonflame atomization. Concentration is determined by means of calibration curves prepared from standard samples.

27.3 *Significance and Use*—Electrical insulating oil may contain small amounts of dissolved metals derived either directly from the base oil or from contact with metals during refining or service. When copper is present, it acts as a catalyst in promoting oxidation of the oil. This test method is useful for research and to assess the condition of service-aged oils.

28. Elements in Insulating Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)

28.1 *Scope:*

28.1.1 This test method describes the determination of metals and contaminants in insulating oils by inductively coupled plasma atomic emission spectrometry (ICP-AES). The specific elements are listed in Table 1 of Test Method D7151. This test method is similar to Test Method D5185, but differs in methodology, which results in the greater sensitivity required for insulating oil applications.

28.1.2 This test method uses oil-soluble metals for calibration and does not purport to quantitatively determine insoluble particulates. Analytical results are particle size dependent, and low results are obtained for particles larger than several micrometers.

28.1.3 This test method determines the dissolved metals (which may originate from overheating) and a portion of the particulate metals (which generally originate from a wear mechanism). While this ICP method detects nearly all particles less than several micrometers, the response of larger particles decreases with increasing particle size because larger particles are less likely to make it through the nebulizer and into the sample excitation zone.

28.1.4 This test method includes an option for filtering the oil sample for those users who wish to separately determine dissolved metals and particulate metals (and hence, total metals).

28.1.5 Elements present at concentrations above the upper limit of the calibration curves can be determined with additional, appropriate dilutions and with no degradation of precision.

28.2 *Summary of Test Method:*

28.2.1 A weighed portion of a thoroughly homogenized insulating oil is diluted 2.5:1 by weight with kerosine or other suitable solvent. Standards are prepared in the same manner. An internal standard is added to the solutions to compensate for variations in test specimen introduction efficiency. The solutions are introduced to the ICP instrument by a peristaltic pump. If free aspiration is used, an internal standard must be used. By comparing emission intensities of elements in the test specimen with emission intensities measured with the standards, the concentrations of elements in the test specimen are calculated.

28.3 *Significance and Use:*

28.3.1 This test method covers the rapid determination of 12 elements in insulating oils, and it provides rapid screening of used oils for indications of wear. Test times approximate several minutes per test specimen, and detectability is in the 10-100 µg/kg range.

28.3.2 This test method can be used to monitor equipment condition and help to define when corrective action is needed. It can also be used to detect contamination such as from silicone fluids (via silicon) or from dirt (via silicon and aluminum).

28.3.3 This test method can be used to indicate the efficiency of reclaiming used insulating oil.

29. Furanic Compounds in Electrical Insulating Liquids

29.1 *Scope*—Test Method D5837 covers the determination, in electrical insulating liquids, of the products of the degradation of cellulosic materials such as paper, pressboard, and cotton material typically found as insulating materials in electrical equipment. These degradation products are substituted furan derivatives, commonly referred to as furanic compounds or furans.

29.1.1 The commonly identified furans that may be identified by this method include: *5-hydroxymethyl-2-furaldehyde* , *furfuryl alcohol*, *2-furaldehyde* , *2-acetylfuran*, and *5-methyl-2-furaldehyde* .

29.2 *Summary of Test Method*—Furanic compounds in electrical insulating liquids are extracted from a known volume of test specimen by means of a liquid/liquid extraction or solid-phase extraction. A method for direct introduction of oil into the chromatograph is also described. An aliquot of the extract is introduced into a High Performance Liquid Chromatography (HPLC) system equipped with a suitable analytical column and UV detector. Furanic compounds in the test specimen are identified and quantified by comparison to standards of known concentration.

29.3 *Significance and Use*—Furanic compounds are generated by the degradation of cellulosic materials used in solid insulation systems of electrical equipment. Furanic compounds which are oil soluble to an appreciable degree will migrate into the insulating liquid. High concentrations or unusual increases in the concentration of furanic compounds in oil may indicate cellulose degradation from aging or incipient fault conditions.

30. Gas Analysis

30.1 *Scope:*

30.1.1 This test method covers three procedures for the extraction and measurement of gases dissolved in electrical insulating oil having a viscosity of 20 cSt (100 Saybolt Universal seconds) or less at 40°C (104°F), and the identification and determination of the individual component gases extracted.

30.1.2 The individual component gases that may be identified and determined include: hydrogen, oxygen, nitrogen, carbon monoxide, carbon dioxide, methane, ethane, ethylene, acetylene, propane, and propylene.

30.2 *Summary of Test Methods:*

30.2.1 *Method A (Test Method D3612)*—Dissolved gases are extracted from a sample of oil by introduction of the oil sample into a pre-evacuated known volume. The evolved gases are compressed to atmospheric pressure and the total volume measured.

30.2.2 *Method B (Test Method D3612)*—Dissolved gases are extracted from a sample of oil by sparging the oil with the carrier gas on a stripper column containing a high surface area bead.

30.2.3 *Method C (Test Method D3612)* —The sample is brought in contact with a gas phase in a sealed vial and the dissolved gases are allowed to equilibrate with the gas phase. The headspace above the oil is sampled and analyzed. The amount of dissolved gasses in the oil is calculated from predetermined partition coefficients for each gas.

30.2.4 There may be some differences in limits of detection and precision and bias between Methods A, B, and C for the various gases.

30.2.5 A portion of the extracted gases (Methods A and C) or all of the gases extracted (Method B) are introduced into a gas chromatograph equipped with suitable adsorption column(s). The composition of the sample is calculated from its chromatogram by comparing the area of the peak of each component with the area of the peak of the same component on a reference chromatogram made on a standard mixture of known composition.

30.3 *Significance and Use:*

30.3.1 Oil and oil-immersed electrical insulating materials may decompose under the influence of thermal and electrical stresses and in doing so generate gaseous decomposition products of varying composition, which dissolve in the oil. The nature and amount of the individual component gases that may be recovered and analyzed may be indicative of the type and degree of the abnormality responsible for the gas generation. The rate of gas generation and changes in concentration of specific gases over time are also used to evaluate the condition of the electric apparatus.

31. Gas Content

31.1 *Scope:*

31.1.1 *Test Method D831*—Electrical insulating oils of low and medium viscosities up to 190 cSt at 40°C (corresponding to 1000 SUS at 100°F), including oils used in capacitors and paper-insulated electric cables and cable systems of the oil-filled type.

31.1.2 *Test Method D1827*—Electrical insulating liquids with a viscosity of 216 cSt (1000 SUS) or less at 100°C. Acidic gases absorbed by a strong caustic solution are not detectable. Carbon dioxide and hydrogen chloride will not be included in gas content determined by this test method.

31.1.3 *Test Method D974*—Electrical insulating oils of up to 19 cSt at 40°C (corresponding to 100 SUS at 100°F). This test method is suitable for either field or laboratory use. It was designed to use a self-contained apparatus in the analysis of oils of low gas content. Unlike Test Methods D831 and D1827, gas content is not corrected for ambient temperature or pressure.

31.2 *Definition:*

31.2.1 *gas content of an oil by volume*—The total volume of gases, corrected to 101 kPa (760 mm Hg) and 0°C, contained in a given volume of oil, expressed as a percentage.

31.3 *Summary of Test Methods:*

31.3.1 *Test Method D831*—The oil is fed slowly into a degassing chamber, located in an oven and initially evacuated to a pressure below 13 Pa (0.1 Torr) with a vacuum pump, so that the oil is thoroughly exposed to the vacuum. Condensable gases are removed from the system by a cold trap. The gas volume is calculated from the increase in pressure in the degassing chamber, measured by a McLeod gage.

31.3.2 *Test Method D1827*—A small liquid sample is purged of dissolved gases with pure carbon dioxide gas. The gas stream is then led into a gas burette containing a potassium hydroxide solution. The carbon dioxide and any other acidic gases are completely absorbed, and the volume of the remaining gas is measured.

31.3.3 *Test Method D974*—The oil sample is allowed to flow as a thin film into a chamber evacuated by the lowering of a connecting mercury reservoir. By raising the mercury reservoir, the pressure is returned to atmospheric, and the volume of the evolved gases is measured. No correction is made for atmospheric pressure or ambient temperature.

31.4 *Significance and Use:*

31.4.1 Some types of electrical equipment require use of electrical insulating liquids of low gas content. Capacitors and certain types of electrical cable, particularly where used at high voltages, may suffer from the formation of gas bubbles with consequent gaseous ionization if gas content is not sufficiently reduced. In filling electrical apparatus, a low gas content reduces foaming and also reduces available oxygen in sealed equipment, increasing the service life of the insulating oil.

31.4.2 These tests are not intended for use in purchase specifications because the oil is customarily degassed immediately before use. These test methods can be used, however, as a factory control test and a control and functional test in installation and maintenance work by utilities. These tests require care in manipulation and the availability of trained, careful personnel.

31.5 *Precision:*

31.5.1 The precisions of two of the test methods are given in the table below. Refer to the original test methods for the conditions under which these precision values are applicable.

Test Method	Unit	Repeatability	Reproducibility
D831	Gas Content % (if 0.1 %)	...	±0.02
D1827	Gas Content % (0.1 to 15 %)	...	±0.05

32. Inorganic Chlorides and Sulfates

32.1 *Scope*—This test method covers the qualitative determination of inorganic chlorides and sulfates in electrical insulating oils.

32.2 *Summary of Test Method:*

32.2.1 *Test Method D878*—The electrical insulating oil is extracted with water. The water layer is tested with silver nitrate solution for the presence of chlorides and with barium chloride for the presence of sulfates. If a precipitate is obtained with either reagent, report the corresponding ion as present.

32.3 *Significance and Use*—The presence of inorganic chlorides or sulfates may be due either to improper refining or to contamination from outside sources. The presence of these contaminants may affect the corrosivity or dielectric properties of the oil and may adversely affect its ability to function properly under service conditions.

33. Neutralization Number

33.1 *Scope:*

33.1.1 The two procedures available determine the acidic or basic constituents in petroleum products. Because the titration end points of these methods differ, results may differ between the test methods.

33.1.2 *Test Method D664*—Resolves the constituents into weak-acid and strong-acid components, provided the dissociation constants of the more highly ionized compounds are at least 1000 times that of the next weaker group. Because the end point is determined potentiometrically, this test method is suitable for use with very dark samples.

33.1.3 *Test Method D974*—Applicable for the determination of acids or bases whose dissociation constants in water are larger than 10^{-9}. Constituents are classified as strong acid, weak acid, or strong base. Excessively dark-colored oils cannot be tested by this test method due to obscuration of the color indicator end point.

33.2 *Definitions:*

33.2.1 *total acid number*—the number of milligrams of KOH required to neutralize all acidic constituents present in 1 g of test specimen. When neutralization number is specified without further qualification, total acid number is implied.

33.2.2 *strong acid number*—the number of milligrams of KOH required to neutralize the strong acid constituents present in 1 g of test specimen.

33.3 *Summary of Test Methods:*

33.3.1 *Test Method D664*—The test specimen is dissolved in a mixture of toluene and isopropyl alcohol containing a small amount of water and titrated potentiometrically with alcoholic potassium hydroxide or hydrochloric acid solution, using a glass-indicating electrode and a calomel reference electrode. The meter readings are plotted against the respective volumes of titrating solution, and the end points are taken at the inflections in the resulting curve. When no definite inflections are obtained, end points are taken at meter readings corresponding to those found for standard nonaqueous acidic and basic buffer solutions.

33.3.2 *Test Method D974*—To determine the total acid or strong base number, the test specimen is dissolved in a mixture of toluene and isopropyl alcohol containing a small amount of water, and the resulting single-phase solution is titrated at room temperature with standard alcoholic base or alcoholic acid solution, respectively, to the end point indicated by the color change of the added *p*-naphtholbenzein solution. To determine the strong acid number, a separate portion of the sample is extracted with hot water, and the aqueous extract is titrated with potassium hydroxide solution, using methyl orange as an indicator.

33.3.3 *Modified Test Method D974*—For acid numbers less than 0.04, use of a closed microburet (5 mL, 0.02-mL subdivisions) with preneutralized titration solvent, shielding the titration flask with a rubber cap through which the buret tip extends, is recommended.

33.3.3.1 For service-aged test specimens from electrical apparatus in which insulation deterioration could result in the solution of carbon dioxide in electrical insulating oil, the test specimen may be freed of carbon dioxide by blowing for 2 min at room temperature with nitrogen prior to testing.

33.3.3.2 When using the modification of Test Method D974 as noted in 28.3.3, the following precision applies:

33.3.3.3 *Repeatability*—Duplicate determinations by the same operator should not differ by more than 0.008. For two operators in the same laboratory, each making duplicate determinations and comparing average values, results should not differ by more than 0.005 (95 % probability).

33.3.3.4 *Reproducibility*—Results from two different laboratories, comparing average values from duplicate determinations, should not differ by more than 0.015 (95 % probability).

33.4 *Significance and Use:*

33.4.1 A low total acid content of an insulating oil is necessary to minimize electrical conduction and metal corrosion and to maximize the life of the insulation system.

33.4.2 In used insulating oils, an increase in total acid number from the value of the unused product indicates contamination by substances with which the oil has been in contact or a chemical change in the oil from processes such as oxidation. An increase in total acid number may indicate the desirability of replacing used with fresh oil, provided suitable rejection limits have been established and other tests confirm the need for the change.

34. Oxidation Inhibitor Content

34.1 *Scope:*

34.1.1 New electrical insulating oil may contain inhibitors to inhibit oxidation. Two test methods are available for the determination of the commonly used inhibitors.

34.1.2 *Test Method D2668*—Determines the concentration of either inhibitor, or their mixtures, in concentrations up to 0.5 mass %, by measuring the infrared absorbance of the oil at selected frequencies.

34.1.3 *Test Method D4768*—This test measures the concentration of either inhibitors or their mixtures, in concentrations up to 0.5 % mass, by gas chromatographic separation and quantitation to a suitable standard.

34.2 *Summary of Test Methods:*

34.2.1 *Test Method D2668*—The infrared absorbance of the test specimen is measured at the frequencies appropriate to 2,6-ditertiary-butyl para-cresol and 2,6-ditertiary-butyl phenol and the concentrations calculated from a calibration curve.

34.2.2 *Test Method D4768*—A column clean-up is employed to remove interfering substances, followed by a gas chromatographic separation and concentration measured by comparison to suitable standards.

34.3 *Significance and Use*—The quantitative determination of 2,6-ditertiary-butyl para-cresol or 2,6-ditertiary-butyl phenol measures the amount of this material that has been added to new electrical insulating oil as protection against oxidation or the amount remaining in a used oil. These test methods are also suitable for manufacturing control and for use as specification acceptance tests.

35. Oxidation Stability

35.1 *Scope:*

35.1.1 Three oxidation test methods are applied to insulating oil:

35.1.2 *Test Method D1934*—Covers two procedures for subjecting electrical insulating oils to oxidative aging: Procedure A, without a metal catalyst, and Procedure B, with a metal catalyst.

35.1.2.1 This test method is applicable to oils used as impregnating or pressure media in electrical power transmission cables as long as less than 10 % of the oil evaporates during the aging procedures. It applies and is generally useful primarily in the evaluation and quality control of unused oils, either inhibited or uninhibited.

35.1.2.2 The precision statement for Test Method D1934 should be the standard deviation of the logarithm of the dissipation factor ratios rather than the coefficient of the variation of the ratios.

35.1.3 *Test Method D2112*—Is intended as a rapid method for the evaluation of the oxidation stability of new mineral insulating oils containing oxidation inhibitor. This test is considered of value in checking the oxidation stability of new mineral insulating oils containing synthetic oxidation inhibitor in order to control the continuity of this property from shipment to shipment. The applicability of this procedure for use with inhibited insulating oils of more than 12 cSt at 40°C has not been established.

35.1.4 *Test Method D2440*—Covers the evaluation of the acid- and sludge-forming tendency of new mineral transformer oils. It is considered of value in studying the acid- and sludge-forming propensity of a new grade of mineral transformer oil before commercial application.

35.2 *Summary of Test Methods:*

35.2.1 *Test Method D1934*—This test method consists of exposing for 96 h 300 mL of oil in a 400-mL beaker to moving air in an oven controlled at 115°C, with or without $15\ \text{cm}^2$ of metal catalyst. Changes in such properties as color, total acid number, power factor, and resistivity of the aged oil can be used to determine the oxidative deterioration of the oil.

35.2.2 *Test Method D2112*—The test specimen is agitated by rotating axially at 100 rpm at an angle of 30° from the horizontal under an initial oxygen pressure of 620 kPa (90 psi) in a pressure vessel with a glass sample container and copper catalyst coil, in the presence of water, at a bath temperature of 140°C. The time for an oil to react with a given volume of oxygen is measured; completion of the test is indicated by a 172 kPa (25 psi) drop in pressure.

35.2.3 *Test Method D2440*—The test oil is charged to a glass oxidation tube containing copper wire catalyst. The tube is placed in an oil bath at 110°C, and oxygen is bubbled through separate oil samples for 72 and 164 h. The *n*-heptane insoluble sludge and total acid number of the aged oil is measured to determine the extent of oxidation.

35.3 *Significance and Use:*

35.3.1 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.

35.3.2 The oxidation stability tests described in Section 35 may be used to evaluate the tendency to form sludge or acids under oxidizing conditions, to ensure the continuity of quality of mineral insulating oil shipments, and for specification purposes. A low tendency to form sludge and acid in laboratory tests is desirable, although the oil showing the least deterioration in the laboratory is not necessarily the best in service.

35.3.3 The oxidation stability tests are used in the following specifications for insulating oils:

D3487, D5222	Mineral Insulating Oil Used in Electrical Apparatus	D2112, D2440

36. Polychlorinated Biphenyl Content

36.1 *Scope:*

36.1.1 *Test Method D4059*—Describes a quantitative technique for determining the concentration of polychlorinated biphenyls (PCBs) in electrical insulating liquids by gas chromatography.

36.2 *Definition:*

36.2.1 *PCB concentration*—is normally expressed in units of parts per million (PPM) on a weight by weight basis. Standard chromatograms of Aroclors[4] 1242, 1254, and 1260 are used to determine the concentration of PCB in the sample.

36.3 *Summary of Test Method*—Following dilution of the test specimen in a suitable solvent, the solution is treated to remove interfering substances. A small portion is then injected into a gas chromatographic column where the components are separated and their presence measured by an electron capture or halogen-specific electrolytic conductivity detection. The test method is made quantitative by comparing the response of a sample to that of a known quantity of one or more standard Aroclors obtained under the same conditions.

36.4 *Significance and Use*—United States' regulations require that electrical apparatus and electrical insulating fluids containing PCB be handled and disposed of through the use of specific procedures as determined by the PCB content of the fluid. The results of this test method can be useful in selecting appropriate handling and disposal procedures.

37. Relative Content of Dissolved Decay Products in Mineral Insulating Oil by Spectrophotometry

37.1 *Scope:*

37.1.1 This test method characterizes by spectrophotometry the relative level of dissolved decay products in mineral insulating oils of petroleum origin. While new oil is almost transparent to a monochromatic beam of light in the visible spectrum, the increasing concentration of dissolved decay products shift the absorbance curve to longer wavelengths.

37.1.2 This test method is applicable to compare the extent of dissolved decay products for oils in service. It can assess the effectiveness of used or stored oil purification during the reclamation process, as well.

37.2 *Summary of Test Method*—A test specimen of mineral insulating oil is placed in a 10-mm path length glass cuvette, which is installed in an UV-VIS scanning spectrophotometer. The instrument is first zeroed with spectral grade heptane. The absorbance curve of oil is then recorded from 360 to 600 nm. Integration of the area under this curve indicates the numeric value of the dissolved decay products in the oil sample. Because of the high sensitivity of spectral analysis, the deterioration of oil purity can be assessed in the early stages of the decay process.

37.3 *Significance and Use*—The content of dissolved decay products in insulating oils is made up of a variety of compounds, such as peroxides, aldehydes, ketones, and organic acids. Each of them is partially adsorbed on the large surface of paper insulation leading to the premature aging of power transformers. The relative assessment of byproduct formation, therefore, can be used as an indicator of the aging of the mineral oil.

38. Sediment and Soluble Sludge

38.1 *Scope*—This test method covers the determination of sediment and soluble sludge in service-aged insulating oils of petroleum origin. Also, provision is made for determining organic and inorganic content of the sediment. The test method is intended primarily for oils of comparatively low viscosity, for example, 7 to 15 cSt at 40°C. Suitability for high-viscosity oils has not been determined.

38.2 *Summary of Test Method:*

38.2.1 *Test Method D1698*—A test specimen portion is centrifuged to separate sediment from the oil. The upper, sediment-free portion is decanted and retained for determination of soluble sludge. The sediment is dislodged and filtered through a specially prepared Gooch crucible. After drying and weighing to obtain total sediment, the crucible is ignited at 500°C and reweighed. Loss in weight is organic and remainder is inorganic content of sediment. Soluble sludge is determined on sediment-free portion by dilution with *n*-pentane to precipitate *n*-pentane insolubles, and filtration through a Gooch crucible.

38.3 *Significance and Use:*

38.3.1 Sediment in insulating oil may deposit on transformer parts and interfere with heat transfer, and may choke oil ducts, and so hinder oil circulation and heat dissipation. Inorganic sediment usually indicates contamination of some type, and organic sediment indicates either deterioration of the oil or contamination.

38.3.2 Soluble sludge indicates deterioration of the oil, presence of contaminants, or both. It serves as a warning that formation of sediment may be imminent.

38.3.3 The determination of sediment and soluble sludge in a used insulating oil assists in deciding whether the oil may continue to be used in its existing condition or should be replaced, reclaimed, or reconditioned.

39. Sulfur, Corrosive

39.1 *Scope*—This test method covers the detection of corrosive sulfur compounds in electrical insulating oils of petroleum origin. Compounds capable of severely discoloring a copper surface under prescribed test conditions are reported as corrosive.

39.2 *Summary of Test Method:*

39.2.1 *Test Method D1275*—250 mL of oil is aged in a sealed flask for 19 h at 140°C in the presence of a copper strip.

39.2.2 *Test Method D1275*—B: 220 mL of oil is aged in a sealed heavy walled bottle for 48 h at 150°C in the presence of a copper strip. This is the preferred method.

39.3 *Significance and Use*—In most of their uses, insulating oils are continually in contact with metals that are subject to corrosion. The presence of corrosive sulfur compounds will result in deterioration of these metals. The extent of deterioration is dependent upon the quantity and type of corrosive agent

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[4] Registered trademark of Monsanto Co.

and time and temperature factors. Detection of these undesirable impurities, even though not in terms of quantitative values, is a means for recognizing the hazard involved.

40. Water Content

40.1 *Scope*—Test Method D1533 covers the determination of water present in insulating liquids, in concentrations most commonly below 200 ppm.

40.2 *Summary of Test Method:*

40.2.1 This test method is based on the reduction of iodine in accordance with the traditional Karl Fischer reaction.

40.2.2 Test Method D1533 electrochemically generates the iodine required for Karl Fischer titration.

40.2.3 This automatic coulometric titration procedure requires the use of an instrument that is designed and calibrated to deliver a known electrical current which generates sufficient iodine to neutralize a known weight of water per minute. The two-part titration solution is first brought to near a zero dryness by iodine produced by the generator when the controls are placed in the "standby" setting. The test specimen is added; and the titration begun, allowing the test specimen to be automatically titrated by producing iodine at the generator anode until the equivalent point is reached and the titration is complete. Water content is read directly on the meter in micrograms (or parts per million).

40.3 *Significance and Use*—A low water content of 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. Water in solution cannot be detected visually and must be determined by other means. This test shows the presence of water that may not be evident from electrical tests.

SPECIFICATIONS

41. Mineral Insulating Oil for Electrical Apparatus

41.1 *Scope:*

41.1.1 *Specification D3487*—The physical, chemical, and electrical properties of two types of 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 are given in this specification.

41.1.2 Type I oil has a maximum oxidation inhibitor content of 0.08 mass % and Type II oil a maximum of 0.3 mass %. Except for the inhibitor content and oxidation stability requirements, the two oils have similar performance properties.

41.1.3 Specification D3487 is intended to define a mineral insulating oil that is functionally interchangeable with existing oils, is compatible with existing apparatus and with appropriate field maintenance, and will satisfactorily maintain its functional characteristics in its application in electrical equipment. This specification applies only to new insulating oil prior to introduction into apparatus.

42. High Fire-Point Electrical Insulating Oils

42.1 *Scope:*

42.1.1 Specification D5222 describes a high fire-point mineral oil based insulating fluid, for use as a dielectric and cooling medium in new and existing power and distribution electrical apparatus, such as transformers and switchgear.

42.1.2 High fire-point insulating oil differs from conventional mineral insulating oil by possessing a fire-point of at least 300°C. High fire-point mineral insulating oils are also referred to as "less flammable" mineral insulating oils. This property is necessary in order to comply with certain application requirements of the National Electric Code (Article 450-23) or other agencies. The material discussed in this specification is miscible with other petroleum based insulating oils. Mixing high fire-point liquids with lower fire-point hydrocarbons insulating oils (for example, Specification D3487 mineral oil) may result in fire points less the 300°C.

42.1.3 This specification is intended to define a high fire point electrical mineral insulating oil that is compatible with typical material of construction of existing apparatus and will satisfactorily maintain its functional characteristic in its application. The material described in this specification may not be miscible with electrical insulating liquids of non-petroleum origin. The user should contact the manufacturer of the high fire point insulating oil for guidance in this respect.

42.1.4 This specification applies only to new insulating material, oil as received prior to any processing. Information on in-service maintenance testing is available in appropriate guides. The user should contact the manufacturer of the equipment if questions of recommended characteristics or maintenance procedures arise.

43. Keywords

43.1 chemical properties; electrical insulating oils; electrical properties; measured; physical properties; properties; sampling ; specification