Designation: D924 – 23

Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids[1]

This standard is issued under the fixed designation D924; 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.

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

1. Scope

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

1.2 This test method provides a procedure for making referee tests at a commercial frequency of between 45 Hz and 65 Hz.

1.3 Where it is desired to make routine determinations requiring less accuracy, certain modifications to this test method are permitted as described in Sections 16 to 24.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and to determine the applicability of regulatory limitations prior to use.* Specific warnings are given in 11.3.3.

1.6 *Mercury has been designated by the EPA and many state agencies as a hazardous material that can cause nervous system, kidney and liver damage. Mercury, or its vapor, may be hazardous to health and corrosive to materials. Caution should be taken when handling mercury and mercury containing products. See the applicable product Safety Data Sheet (SDS) for details and the EPA's website for additional information. Users should be aware that selling mercury and/or mercury containing products into your state may be prohibited by state law.*

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulation
D923 Practices for Sampling Electrical Insulating Liquids
D2864 Terminology Relating to Electrical Insulating Liquids and Gases
D2865 Practice for Calibration of Standards and Equipment for Electrical Insulating Materials Testing
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

2.2 *IEEE Standard:*[3]

Standard 4 IEEE Standard Techniques for High-Voltage Testing

3. Terminology

3.1 *Definitions*—Definitions of terms used in this test method are given in Terminology D2864. Also refer to Test Methods D150 for detailed discussion of terms.

4. Significance and Use

4.1 *Dissipation Factor (or Power Factor)*—This is a measure of the dielectric losses in an electrical insulating liquid when used in an alternating electric field and of the energy dissipated as heat. A low dissipation factor or power factor indicates low ac dielectric losses. Dissipation factor or power factor may be useful as a means of quality control, and as an

---

[1] This test method is under the jurisdiction of ASTM Committee D27 on Electrical Insulating Liquids and Gases and is the direct responsibility of Subcommittee D27.05 on Electrical Test.

Current edition approved Dec. 1, 2023. Published December 2023. Originally approved in 1947 as D924 – 47 T. Last previous edition approved in 2015 as D924 – 15. DOI: 10.1520/D0924-23.

[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] Available from Institute of Electrical and Electronic Engineers, 445 Hoes Lane, Piscataway, NJ 08854, www.ieee.org.

indication of changes in quality resulting from contamination and deterioration in service or as a result of handling.

4.1.1 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) and may be expressed as a decimal value or as a percentage. For decimal values up to 0.05, dissipation factor and power factor values are equal to each other within about one part in one thousand. In general, since the dissipation factor or power factor of insulating oils in good condition have decimal values below 0.005, the two measurements (terms) may be considered interchangeable.

4.1.2 The exact relationship between dissipation factor (*D*) and power factor (*PF*) is given by the following equations:

$$PF = \frac{D}{\sqrt{1+D^2}} \qquad D = \frac{PF}{\sqrt{1-(PF)^2}} \tag{1}$$

The reported value of *D* or *PF* may be expressed as a decimal value or as a percentage. For example:

$$D \text{ or } PF \text{ at } 25°C = 0.002 \text{ or } 0.2\% \tag{2}$$

4.2 *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 of ac electric fields 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.

4.3 Theory relating to dielectric measurement techniques and to sources of dielectric loss is given in Test Methods D150.

5. Sampling

5.1 Sample electrical insulating liquids in accordance with Practices D923. Samples to be subjected to this test should preferably be obtained through a closed system. If exposed to atmospheric conditions, it is preferable to take the sample when the relative humidity is 50 % or less. If it is not feasible, the length of time the sample is exposed to atmospheric conditions must be kept to a minimum.

5.2 Some liquids, in certain applications, require special handling and processes in the sampling, and these will be found in the governing procedures. Consult such procedures before samples are taken.

5.3 The quantity of sample taken for this test shall be sufficient for at least three separate determinations of loss characteristics and relative permittivity.

5.4 The loss characteristic measurement (dissipation factor or power factor) may be affected by contamination introduced during sampling and subsequent handling.

PROCEDURE FOR MAKING REFEREE TESTS

6. Apparatus

6.1 Measuring equipment used in these procedures shall be in accordance with Test Methods D150.

6.2 Use only a three-terminal cell for these tests.

6.3 The design of test cells that conform to the general requirements given in the Annex are considered suitable for use in making these tests.

6.4 *Forced-Draft Oven:*

6.4.1 When the tests are to be made above room temperature, a suitable forced-draft, thermostatically controlled oven shall be used as the test chamber. The oven must be capable of meeting the temperature requirements set out in Section 11. For tests at room temperature the unheated oven can be conveniently used as the test chamber.

6.4.2 Provide the test chamber with an opening in the wall through which two lengths of TFE-fluorocarbon-insulated (or similar) shielded cable pass to make electrical connection from the measuring equipment and high-voltage transformer, respectively, to the test cell. Use a perforated ceramic plate or disk to insulate the test cell from the metal flooring of the oven if the flooring is not insulated from the oven. Provide a safety interlock on the door of the oven so that the electrical circuit supplying voltage to the test cell will be broken when the oven door is opened.

6.4.3 A cross-sectional view of the test chamber with a three-electrode test cell in place and with test cables connected is shown in Fig. 1.

6.5 *Automatic Thermo-Regulator Cell:*

6.5.1 When tests are to be made above room temperature but below the flash point, an automatic thermo-regulator cell can be used as long as it provides uniform heating of the test cell.

6.5.2 The automatic thermo-regulator cell must be able to provide rapid, controlled rate of temperature rise, and be able to maintain a liquid temperature constant to within ±1 °C.

7. Calibration

7.1 Calibration of test instruments shall be traceable to national standards.

7.2 Verify the calibration at least annually using reference devices that are traceable to national standards.

7.3 Refer to Practice D2865 and IEEE Standard 4 for guidelines on calibrating test equipment.

8. Test Temperature

8.1 The temperature at which a referee test is made shall be mutually agreed upon between the purchaser and the seller. Measurements are made at many different temperatures. For acceptance tests, it is generally made at a temperature of 100 °C, while for routine testing it is usually made at 25 °C, 90 °C, or 100 °C. In some research investigations, tests may be made at considerably higher temperatures while in other cases, particularly for tests on cable oils in service, tests may be made over a range of temperatures.