



Designation: D 3382 – 95 (Reapproved 2001)^{ε1}

An American National Standard

Standard Test Methods for Measurement of Energy and Integrated Charge Transfer Due to Partial Discharges (Corona) Using Bridge Techniques¹

This standard is issued under the fixed designation D 3382; 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.

ε¹ NOTE—The address in Footnote Four was editorially updated April 2001.

1. Scope

1.1 These test methods cover two bridge techniques for measuring the energy and integrated charge of pulse and pulseless partial discharges:

1.2 Test Method A makes use of capacitance and loss characteristics such as measured by the transformer ratio-arm bridge or the high-voltage Schering bridge (Test Methods D 150). Test Method A can be used to obtain the integrated charge transfer and energy loss due to partial discharges in a dielectric from the measured increase in capacitance and $\tan \delta$ with voltage.

1.3 Test Method B makes use of a somewhat different bridge circuit, identified as a charge-voltage-trace (parallelogram) technique, which indicates directly on an oscilloscope the integrated charge transfer and the magnitude of the energy loss due to partial discharges.

1.4 Both test methods are intended to supplement the measurement and detection of pulse-type partial discharges as covered by Test Method D 1868, by measuring the sum of both pulse and pulseless discharges per cycle in terms of their charge and energy.

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.* Specific precaution statements are given in Section 7.

2. Referenced Documents

2.1 ASTM Standards:

D 150 Test Methods for AC Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials²

D 1711 Terminology Relating to Electrical Insulation²

D 1868 Test Method for Detection and Measurement of Partial Discharge (Corona) Pulses in Evaluation of Insulation Systems²

3. Terminology

3.1 Definitions:

3.1.1 *pseudoglow discharge, n*—a type of partial discharge characterized by pulses of relatively small amplitude, and, generally, a long rise time.

3.1.1.1 *Discussion*—As a result of the upper frequency limitation in their Fourier frequency spectrum, pseudoglow discharges are not readily detected by conventional partial-discharge-pulse detectors. Pseudoglow discharges are also characterized by a diffused glow, that cannot be visually distinguished from that due to a true-glow discharge.

3.1.2 *pulse discharge, n*—a type of partial-discharge phenomenon characterized by a spark-type breakdown.

3.1.2.1 *Discussion*—The resultant detected pulse discharge has a short rise time and its Fourier frequency spectrum may extend as far as 100 MHz. Such a pulse discharge may be readily detected by conventional pulse detectors, that are generally designed for partial-discharge measurements within the frequency band from 30 kHz to several megahertz.

3.1.3 *pulseless-glow discharge, n*—a type of partial-discharge phenomenon characterized by a diffused glow.

3.1.3.1 *Discussion*—The overall voltage waveform across a gap-space undergoing a pulseless-glow discharge does not indicate the presence of any abrupt voltage falls, except for the two at the beginning of each half cycle (for example, thyatron behavior) (1) (2).³ Although discharge energy is expended over the pulseless region, a conventional partial-discharge-pulse detector will give no indication of this as it will only respond to the two initiating breakdowns.

3.1.4 See (3) and (4) for more information on the previous definitions.

3.1.5 For definitions of other terms pertaining to this standard refer to Terminology D 1711.

3.2 Symbols: Symbols:

¹ These test methods are under the jurisdiction of ASTM Committee D09 on Electrical and Electronic Insulating Materials and are the direct responsibility of Subcommittee D09.12 on Electrical Tests.

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² *Annual Book of ASTM Standards*, Vol 10.01.

³ The boldface numbers in parentheses refer to the list of references at the end of these test methods.

3.2.1 Refer to Annex A1 for symbols for mathematical terms used in this standard.

4. Summary of Test Methods

4.1 The dielectric characteristics of a specimen of solid insulating material may be represented by a parallel combination of capacitance and conductance. The values of capacitance and conductance remain practically constant over the useful range of alternating voltage stress at a fixed frequency. If, however, the specimen contains gaseous inclusions (cavities), incremental increases in capacitance and conductance occur as the voltage stress is raised above the value necessary to initiate partial discharges in the cavities. The energy loss in the incremental conductance is considered to be that dissipated by the partial discharges.

4.2 In Test Method A an initial measurement is made of the capacitance and loss characteristic of the specimen at an applied voltage below the discharge inception level. The voltage is then raised to the specified test value and a second measurement made. The energy loss due to partial discharges is calculated from the results of the two measurements.

4.3 In Test Method B a special bridge circuit is balanced at a voltage below the discharge inception level. The voltage is then raised to the specified test value, but the bridge is not rebalanced. Any unbalanced voltage at the detector terminals is displayed in conjunction with the test voltage on an oscilloscope. The oscilloscope pattern approximates a parallelogram, the area of which is a measure of the energy loss due to partial discharges.

5. Significance and Use

5.1 These test methods are useful in research and quality control for evaluating insulating materials and systems since they provide for the measurement of charge transfer and energy loss due to partial discharges (5) (6) (7).

5.2 Pulse measurements of partial discharges indicate the magnitude of individual discharges. However, if there are numerous discharges per cycle it may be important to know their charge sum, since this sum can be related to the total volume of internal gas spaces that are discharging, if it is assumed that the gas cavities are simple capacitances in series with the capacitances of the solid dielectrics (8).

5.3 Internal (cavity-type) discharges may be of a glow, pulseless, or pseudoglow nature, which are not indicated by conventional pulse-discharge detectors (1) (2) (5). Pseudoglow discharges are detected primarily in terms of their effects upon $\tan \delta$ and capacitance, since their rise times are much too long to excite pulse detectors as covered in Test Method D 1868.

5.4 Pseudoglow discharges have been observed to occur in air, particularly when a partially conducting surface is involved. Such partially conducting surfaces may develop with polymers that are exposed to partial discharges for sufficiently long periods to accumulate acidic degradation products. Also in some applications, like turbogenerators, where a low molecular weight such as hydrogen or helium is used as a coolant, pseudoglow discharges may develop.

6. Sources of Errors

6.1 *Surface Discharges*—All discharges in the test specimen are measured, whether on the surface or in internal cavities. If it is desired to measure only internal cavities, the other discharges must be avoided. In the case of an insulated conductor with an outer electrode on the surface (such as a cable or generator coil), the surface discharges at the end of this outer electrode can be removed from the measurement with a closely-spaced guard ring connected to ground. See Section 4 of Test Methods D 150.

6.2 Since tests will be made at ionizing voltage, all connections making up the complete high-voltage circuit should be free of corona to avoid measurement interference. See Section 5 of Test Method D 1868.

6.3 Other phenomena in addition to partial discharges may produce anomalous changes in insulation losses with changes in voltage stress. Such losses are a source of error in these methods, since they are indistinguishable from discharge losses. However, these losses are often negligible in comparison with partial discharge losses.

6.4 Any temperature change in the specimen between the times at which the low-voltage and high-voltage measurements are taken may cause a change in the normal losses and appear as changes in discharge energy, thus causing an error in test results. This situation can be recognized in Method B and corrective action taken (see 11.3).

6.5 Paint used to grade potential on the surface of some insulation specimens (for example, generator stator coil) should not be included in the measurement, since the conductance of such paints may change with voltage and affect the accuracy of the method as a measure of discharge energy. It is sometimes possible to exclude the painted surfaces from the measuring circuit by the use of guarding or shielding techniques.

7. Hazards

7.1 **Warning**—*Lethal voltages may be present during this test. It is essential that the test apparatus, and all associated equipment that may be electrically connected to it, be properly designed and installed for safe operation. Solidly ground all electrically conductive parts that any person might come in contact with during the test. Provide means for use at the completion of any test to ground any parts which: were at high voltage during the test; may have acquired an induced charge during the test; may retain a charge even after disconnection of the voltage source. Thoroughly instruct all operators in the proper way to conduct tests safely. When making high voltage tests, particularly in compressed gas or in oil, the energy released at breakdown may be sufficient to result in fire, explosion, or rupture of the test chamber. Design test equipment, test chambers, and test specimens so as to minimize the possibility of such occurrences and to eliminate the possibility of personal injury.*

7.2 **Warning**—*Ozone is a physiologically hazardous gas at elevated concentrations. The exposure limits are set by governmental agencies and are usually based upon recommendations made by the American Conference of Governmental and Industrial Hygienists.*

Industrial Hygienists.⁴ Ozone is likely to be present whenever voltages exist which are sufficient to cause partial, or complete, discharges in air or other atmospheres that contain oxygen. Ozone has a distinctive odor which is initially discernible at low concentrations but sustained inhalation of ozone can cause temporary loss of sensitivity to the scent of ozone. Because of this it is important to measure the concentration of ozone in the atmosphere, using commercially available monitoring devices, whenever the odor of ozone is persistently present or when ozone generating conditions continue. Use appropriate means, such as exhaust vents, to reduce ozone concentrations to acceptable levels in working areas.

TEST METHOD A

8. Procedure

8.1 Conventional circuits for the measurement of alternating-voltage capacitance and loss characteristics of insulation may be used for this method. The transformer-ratioarm bridge shown in Fig. 1, or the Schering bridge shown in Fig. X4.2 of Test Methods D 150 are well suited to this application.

8.2 Energize the test specimen at a low voltage, V_1 , below the discharge-inception voltage, and measure capacitance C_{x1} and dissipation factor $\tan \delta_1$. Raise the voltage to a specified test level, V_2 , and repeat the measurements for C_{x2} and $\tan \delta_2$. Calculate the power loss, ΔP , in watts due to discharges at voltage V_2 as follows:

$$\Delta P = \omega V_2^2 [C_{x2} \tan \delta_2 - C_{x1} \tan \delta_1] \quad (1)$$

$$= P_2 - (P_1 V_2^2 / V_1^2) \quad (2)$$

8.3 The increment of dissipation factor $\tan \delta_2 - \tan \delta_1$, called delta tan delta, and written $\Delta \tan \delta$, is often used as an index of discharge intensity.

⁴ 1330 Kemper Meadow Drive, Suite 600, Cincinnati, OH 45200.

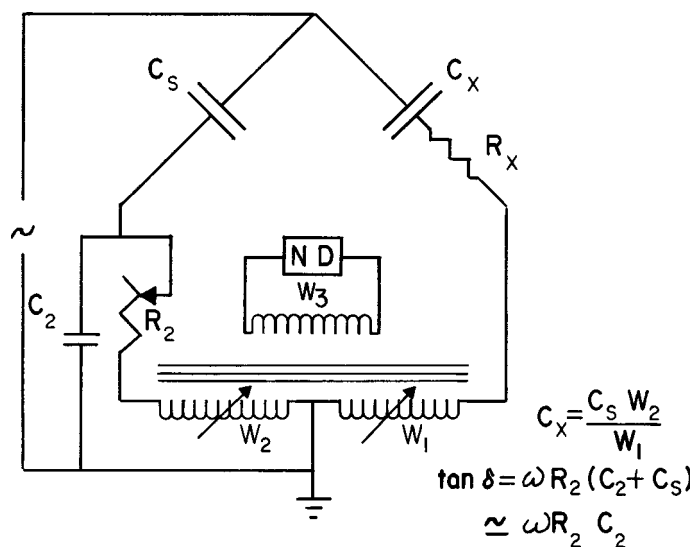


FIG. 1 Typical Transformer-Ratio-Arm Bridge (Method A)

9. Precision and Bias

9.1 This test method has been in use for many years, but no statement for precision has been made and no activity is planned to develop such a statement.

9.2 A statement of bias is not possible due to the lack of a standard reference material.

10. Interferences

10.1 *Harmonics*—The test voltage must be reasonably free of harmonics in order to produce the required horizontal line below the inception voltage. Harmonics will produce a wavy rather than a flat line. If the waviness is too severe, the voltage source may have to be filtered to remove the harmonics. The removal of harmonics is more important when the quantities to be measured are small.

TEST METHOD B

11. Procedure

11.1 The test method requires the placing of the test specimen, considered essentially as a high-voltage capacitor, in series with a low-voltage capacitor, across a sinusoidal test-voltage source. See Fig. 2. Two other bridge arms provide a voltage for balancing, at an applied voltage level below inception of partial discharges, the sinusoidal voltage across the low-voltage capacitor. Any partial discharges that occur at higher applied voltages in the specimen will be integrated by the low-voltage capacitor to produce an unbalanced voltage. The unbalanced voltage controls the vertical deflection of an oscilloscope beam, while a voltage proportional to, and in phase with, the test voltage controls the horizontal deflection. A description of a suitable circuit for this test method is detailed in Annex A2.

11.2 The oscilloscope display is simply a horizontal line below the discharge inception voltage where no unbalanced voltages occur. Above the discharge inception voltage the display opens into an approximate parallelogram. The height of the parallelogram represents the sum of the partial discharges per half cycle, and the area represents the energy dissipated per cycle by the discharges. See Fig. 3.

11.3 If the parallelogram has been tilted or distorted by the increase in voltage, a small adjustment in the capacitance and resistance balance can be made to make the top and bottom of the parallelogram horizontal. This will compensate for some changes in capacitance and $\tan \delta$ due to effects other than partial discharges.

12. Calibration of Oscilloscope Coefficients

12.1 In order to evaluate the parallelogram, it is necessary to determine the deflection sensitivities of the oscilloscope. See Fig. 3. The horizontal-deflection sensitivity, S_x , in volts per centimetre, is found from observing the horizontal deflection, D_{xi} or D_{xa} , in centimetres, to a test voltage having a peak-to-peak value of V_c or V_a as measured by accurate independent means.

$$S_x = V_c / D_{xi} = V_a / D_{xa} \quad (3)$$

12.2 The vertical-deflection sensitivity, S_y , in coulombs per centimetre, may be found from observing the vertical deflection, D_y , in centimetres, to a known charge Q_c in coulombs.