



Designation: ~~D2275~~—14 D2275 – 22

Standard Test Method for Voltage Endurance of Solid Electrical Insulating Materials Subjected to Partial Discharges (Corona) on the Surface¹

This standard is issued under the fixed designation D2275; 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 reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

1. Scope

1.1 This test method determines the voltage endurance of solid electrical insulating materials for use at commercial power frequencies under the action of corona (see [Note 1](#)). This test method is more meaningful for rating materials with respect to their resistance to prolonged ac stress under corona conditions for comparative evaluation between materials.

NOTE 1—The term “corona” is used almost exclusively in this test method instead of “partial discharge,” because it is a visible glow at the edge of the electrode interface that is the result of partial discharge. Corona, as defined in Terminology [D1711](#), is “visible partial discharges in gases adjacent to a conductor.”

1.2 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements, see Section 7.

1.4 *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

- [D149](#) Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
- [D618](#) Practice for Conditioning Plastics for Testing
- [D1711](#) Terminology Relating to Electrical Insulation
- [D1868](#) Test Method for Detection and Measurement of Partial Discharge (Corona) Pulses in Evaluation of Insulation Systems
- [D3382](#) Test Methods for Measurement of Energy and Integrated Charge Transfer Due to Partial Discharges (Corona) Using Bridge Techniques

2.2 Special Technical Publications:²

- Symposium on Corona, STP 198, ASTM, 1956*
- Corona Measurement and Interpretation, Engineering Dielectrics, Vol 1, STP 669, ASTM, 1979*

¹ This test method is under the jurisdiction of ASTM Committee [D09](#) on Electrical and Electronic Insulating Materials and is the direct responsibility of Subcommittee [D09.12](#) on Electrical Tests.

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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.

2.3 *International Electrotechnical Commission (IEC) Documents:*
*Documents:*³

[IEC Publication 60343 Recommended Test Methods for Determining the Relative Resistance of Insulating Materials to Breakdown by Surface Discharges](#)

[IEEE/IEC 62539-2007 – IEC 62539 Ed.1 \(IEEE Std 930™-2004\) Guide for the Statistical Analysis of Electrical Insulation Breakdown Data](#)⁴

2.4 *Institute of Electrical and Electronic Engineers (IEEE) Document:*

[IEEE 930-1987 Guide for the Statistical Analysis of Electrical Insulation Voltage Endurance Data](#)⁴

3. Terminology

3.1 *Definitions*—For definitions of other terms used in this standard, refer to Terminology [D1711](#) and Test Method [D1868](#).

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *surface corona, n*—corona that exists in the electrically stressed gas where electrodes are near insulation surfaces.

3.2.2 *threshold voltage*—that voltage below which failure will not occur under the test conditions irrespective of the duration of the test.

3.2.3 *voltage endurance, n*—the time that an insulating material can withstand a prolonged alternating voltage stress under the action of surface corona.

3.2.4 *voltage stress-time curve, n*—a plot of the logarithm of the mean or median time to failure of a material against voltage stress (or the logarithm of voltage stress) for a particular set of test conditions.

3.2.4.1 *Discussion*—

The plot is the quantitative depiction of the voltage stress endurance over a range of voltage stress for the conditions of test, and for the thickness tested. The curves of a material obtained at two thicknesses are different.

3.2.5 *volt-time curve, n*—a plot of the logarithm of the mean or median time to failure of a material against voltage (or the logarithm of voltage) for a particular set of test conditions.

3.2.5.1 *Discussion*—

The plot is the quantitative depiction of the voltage endurance over a range of voltage for the conditions of the test, which includes the particular thickness tested.

4. Summary of Test Method

4.1 In this test method, voltage sufficient to produce surface corona is applied to nine samples from the same specimen until failure occurs. The voltage endurance is the relative time to failure, determined by the voltage-time curve or Weibull Probability Plot.

4.2 When there is a large dispersion of times to failure for a given sample, it is acceptable to use the median time of nine specimens (time of fifth failure) as the failure time for the sample. This removes the necessity of waiting for the last few to fail. The mean can also be determined statistically (see [IEEE 930-1987](#)/[IEEE/IEC 62539-2007](#) for additional information).

4.3 Under the conditions outlined in [Appendix X2](#) it is permissible for the test to be accelerated by increasing the frequency of the applied voltage. In cases agreed upon between the buyer and the seller, or required in relevant specifications to perform testing on specific specimens where a service condition is thought to alter the corona endurance, this factor shall be introduced as part of the test and reported.

4.4 It is possible to obtain additional information from the test if corona-voltage levels and corona intensity are measured at the start of the test and monitored at various stages of deterioration of the insulation. The voltage levels include corona-inception voltage, corona-extinction voltage, and corona intensity using Test Method [D1868](#).

³ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org> International Electrotechnical Commission (IEC), 3, rue de Varembe, 1st floor, P.O. Box 131, CH-1211, Geneva 20, Switzerland, <https://www.iec.ch>.

⁴ Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., P.O. Box 1331, Piscataway, NJ 08854-1331, <http://www.ieee.org>.

NOTE 2—Comparative measurements of corona power or energy by bridge and oscilloscope techniques can also be informative.

5. Significance and Use

5.1 This test method is useful in research and quality control for evaluating insulating materials and systems since they provide for the measurement of the endurance used to compare different materials to the action of corona on the external surfaces. A poor result on this test does not indicate that the material is a poor selection for use at high voltage or at high voltage stress in the absence of surface corona; surface corona is not the same as corona that occurs in internal cavities. (See Test Methods [D3382](#).)

5.2 This test method is also useful for comparison between materials of the same relative thickness. When agreed upon between the buyer and the seller, it is acceptable to express any differences in terms of relative time to failure or the magnitude of voltage stress (kV/mm or kV/in.) required to produce failure in a specified number of hours.

5.3 It is possible for this test method to also be used to examine the effects of different processing parameters on the same insulating material, such as residual strains produced by quenching, high levels of crystallinity or molding processes that control the concentration and sizes of gas-filled cavities.

5.4 The data are generated in the form of a set of values of lifetimes at a voltage. The dispersion of failure times is analyzed using one of the methods below:

5.4.1 Weibull Probability Plot.

5.4.2 Statistically (see ~~IEEE 930-1987~~[IEEE/IEC 62539-2007](#) for additional information), to yield an estimate of the central value of the distribution and its standard deviation.

5.4.3 Truncating a test at the time of the fifth failure of a set of nine and using that time as the measure of the central tendency. Two such techniques are described in [10.2](#).

5.5 This test method intensifies some of the more commonly met conditions of corona attack so that materials are able to be evaluated in a time that is relatively short compared to the life of the equipment. As with most accelerated life tests, caution is necessary in extrapolation from the indicated life to actual life under various operating conditions in the field.

5.6 The possible factors related to failures produced by corona are:

5.6.1 Corona eroding the insulation until the remaining insulation can no longer withstand the applied voltage.

5.6.2 Corona causing the insulation surface to become conducting due to carbonization, so that failure occurs quickly.

5.6.3 Forming of compounds such as oxalic acid crystals causing the surface conductance to vary with ambient humidity. It is possible conductance will be at a sufficient level to reduce the potential gradient at the electrode edge at moderate humidities, and thus cause either a reduction in the amount of corona, or its cessation, thus retarding failure.

5.6.4 Corona causing “treeing” within the insulation and consequently accelerating the time to failure.

5.6.5 Gases released within the insulation that change its physical dimensions.

5.6.6 Changes in the physical properties of an insulating material; embrittlement or cracking, for instance, causing the material to lose flexibility or crack, or both, and thus make it useless.

5.7 Tests are often made in open air, at 50 % relative humidity. In cases agreed upon between the buyer and the seller, additional information can be obtained for some materials with tests in circulating air at 20 % relative humidity or less (see [Appendix X1](#)).

5.7.1 If tests are made in an enclosure, the restriction in the flow of air can trap ozone and influence the results (see [Appendix X2](#)).

5.7.2 When tests are done outside the standard conditions, the report shall note the deviation and the alternative conditions.

5.8 The variability of the time to failure is a function of the consistency of the test parameters, such as voltage levels, which shall be monitored. The Weibull slope factor, β , is recommended as a measure of variability. β is the slope obtained when percent failure is plotted against failure time on Weibull probability paper. Such a plot is called a Weibull Probability Plot (see Fig. 1).

5.9 The shape of the Weibull Probability Plot can provide additional information. It is possible that a non-straight-line plot will indicate more than one mechanism of failure. For instance, a few unaccountably short time failures in the set indicating a small portion of defective specimens with a different failure mechanism from the rest of the lot.

6. Apparatus

6.1 *Electrical Circuit:*

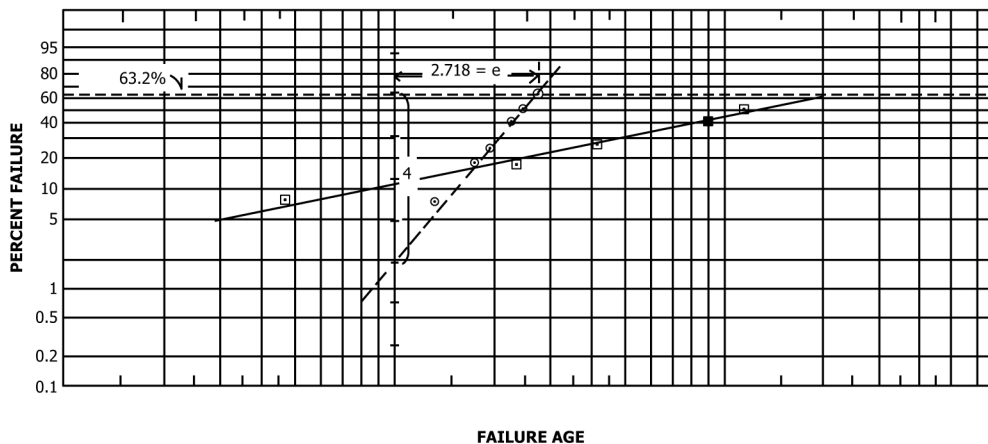
6.1.1 *High-Voltage Supply*—A high-voltage source with controls and voltage-measuring means in accordance with requirements of Test Method D149; which in addition provides a test voltage stable within $\pm 1\%$ during the test period. If necessary use a voltage stabilizer, or other suitable equipment, for this purpose.

6.1.2 It is essential to provide for safe, continuous, and reliable operation, with automatic detection of failure times and automatic removal of specimens from the test circuit when they fail. Two suitable circuits are described in detail in Appendix X3. Particular features are described as follows:

6.1.2.1 *Current Limiting Resistors*—A series of resistors in the high voltage line between the transformer and the specimen limit the current to approximately 0.05 A when a specimen fails. These resistors must have adequate voltage rating. The current limitation prevents pitting of the electrodes and minimizes surges. Since accidental grounding of the high voltage electrode will cause the resistors to become extremely hot, it is important to assure that the current goes through the interruption circuit.

6.1.2.2 *Specimen Circuit Opening*—An additional resistor of 50 k Ω ($\pm 10\%$) in series with each specimen develops a sufficient voltage across it, when a specimen fails, to operate a special high-voltage fuse system that opens a gap in series with the specimen when it fails (see Fig. X3.2). This allows the other specimens to continue on test. The failure current simultaneously operates a relay which provides a pulse of current to operate a recorder such as a recording ammeter, an event recorder, or a running time meter to indicate the time to failure. (See Fig. X3.1, for instance.)

6.1.2.3 An alternative technique has advantages for lower voltages associated with thin films and with materials of relatively low dielectric strength. In such cases, the possibility exists that the failure current will not be high enough to melt fuse wire. It also works better than the fuse wire at higher voltages where intense discharge currents flow sporadically, making the fuse wire scheme unreliable. Fig. X3.3 shows a relay-latch mechanism that has been successfully used. Specimen failure current energizes the coil of relay LM5, closes the contacts, energizes the coil of the latching relay, and releases the latch, which opens the contacts in the specimen circuit. The latch contacts are designed to open with sufficient clearance to interrupt the high-voltage arc. Auxiliary



NOTE 1—Plotting percentage are 100 times the average of $(n - \frac{1}{2})/N$ and $n/(N + 1)$. Artificial data were placed on a line (dashed) drawn to illustrate a Weibull line with a β of 4. A second line (not dashed) illustrates the distribution of failure times which are characteristic of materials with very flat volt-time curves, such as mica composites. This line has a β value of 0.7.

FIG. 1 Representative Weibull Plot Showing the First Five Failures of a Group Specimen of Nine.

contacts of relay *LM5* cause the event recorder to indicate the time of failure. The remaining specimens remain under continuous test automatically with no time lost and no need for extra attention by personnel.

6.1.2.4 *Circuit Protection*—An automatic circuit breaking device protects the entire circuit by opening when 0.05 A of secondary current is drawn for more than 15 s. (See Fig. X3.1, for instance.)

6.2 It is imperative to electrically interlock the test chamber, and:

6.2.1 A grounded metal base is recommended to be installed under the specimens and under any high voltage bus structure, so that any free lead will contact ground and operate the breaker (see 7.2).

6.2.2 An isolation transformer with a grounded shield to provide power to relay circuits, and event recorders (see 7.2).

6.2.3 A smoke detector in the roof of the chamber (see 7.1).

6.2.4 A means of test chamber ventilation (see 7.3 and 7.4).

6.2.5 Equipment for control of ambient conditions (see Appendix X1).

6.3 *Electrodes*:

6.3.1 The upper electrodes shall be:

6.3.1.1 *Cylinders*, 12.7 mm (½ in.) in diameter, 13 mm high, with edges rounded to a radius of 1.6 mm (0.0625 in.), loaded to give a total weight of at least 90 g, and made self-aligning to conform to the surface of the specimen, or

6.3.1.2 *Steel Spheres*, 12.7 mm (½ in.) in diameter, loaded to give a total weight of at least 50 g. The steel balls used in ball bearings make satisfactory electrodes, or

6.3.1.3 *Cylinders*, ~~6.06.0 mm ± 0.3 mm~~ 0.3 mm (¼ in.) in diameter, with edges rounded to a radius of 1 mm (0.04 in.) and weight of approximately 30 g, and made self-aligning to conform to the surface of the specimen. This is the IEC standard electrode.

6.3.2 The lower electrodes shall extend beyond the upper electrodes by a minimum ~~12.7 mm~~ 12.7 mm (½ in.) and so that the lower electrode centers are separated by at least ~~51 mm~~ 51 mm (2.0 in.). The simplest design is to make the lower electrode one common plate, if that meets the needs of the electrical circuit.

6.3.3 The standard electrode material is stainless steel Type 309 or 310. The surface finish shall be 0.4 µm (16 µin.).

6.4 The test chamber provides for control of the ambient conditions by supplying a constant flow of a chosen atmosphere, or by preventing flow if that is desired. When flow is desired, there are two acceptable methods to introduce the atmosphere: by controlled draft (as in a hood in a controlled atmosphere laboratory), or by means of a manifold directing the flow to nozzles which terminate at a distance of ~~13 mm~~ ± 1 mm from the edge of the top electrode of the specimen. The chamber must be connected to a vent to remove ozone and other gasses (see also 9.1 and Appendix X1).

7. Hazards

7.1 **Warning**—Provide adequate protection against fire. Avoid the use of panels and enclosures made of flammable materials such as transparent plastics. Electrical design features related to this risk are given in 6.2.1 and 6.4.

7.2 **Warning**—Lethal voltages are present during this test. It is essential that the test apparatus, and all associated equipment electrically connected to it, be properly designed and installed for safe operation.

7.2.1 *Solidly ground all electrically conductive parts that any person might come in contact with during the test.*

7.2.2 *At the completion of any test, provide means to ground any parts which possibly acquired an induced charge during the test and retained even after disconnection of the voltage source.*

7.2.3 Thoroughly instruct all operators in the proper way to conduct the test safely. When making high voltage tests, particularly in compressed gas or in oil, the energy released at breakdown has the potential to be sufficient enough 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.

7.3 **Warning**—The tests of this test method generate ozone and other potentially hazardous gasses. This is not a problem if the tests are made in chambers vented to the outside. If the tests are not safely vented, it is important to note that:

7.3.1 *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 Industrial Hygienists.⁵ 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.*

7.4 **Warning**—Oxides of Nitrogen are also hazardous and are generated by this test.

8. Test Specimens

8.1 *Thick Materials (1.4 mm (0.062 in.) and Over)*—Nine specimens with a thickness of $1.4 \text{ mm} \pm 0.1 \text{ mm}$ (~~$0.06 \pm 0.06 \text{ in.} \pm 0.004 \text{ in.}$~~) are required for each test voltage. For thicker specimens, reduce the thickness to this value and place the small electrode against the original surface. The size of the specimens shall be sufficient to prevent flashover.

8.2 *Thin Materials (Under 1.4 mm (0.062 in.))*—Use sheets of sufficient size to extend under all nine electrodes with an adequate margin to prevent flashover.

9. Conditioning

9.1 Products of corona, in combination with moisture from the atmosphere, often tend to inhibit the corona discharge so as to influence the time to failure. This makes it necessary to clean and condition the specimens prior to testing and to use conditioned air throughout the life test (see X1.2) with a minimum flow rate of 0.5 L/min per test electrode. Unless otherwise specified, the conditions given in 9.1.1 shall be considered standard for these tests, with designations and standard tolerances in accordance Practice D618, condition 40/23/5: T-23/5 (low humidity), or

9.1.1 Condition 40/23/50: T-23/50 (standard laboratory atmosphere).

10. Procedure

10.1 Apply a voltage to the set of test specimens that is higher than the corona inception voltage (see Test Method D1868), but below the level at which failures will be expected to occur in less than 1 day. Select a voltage high enough that some failures occur in <30 days (at 60 Hz). A good starting point is usually 20 kV/mm (500 V/mil).

10.2 It is convenient to truncate the test at the time of median failure to save testing time. When nine specimens are used and the scatter is such that the median failure time is not more than twice the time to first failure, report the median failure time as the time to failure. If the scatter is greater than this, draw a straight line through the failure time data plotted on Weibull probability paper. Report the time at 50 % failure as the failure time.

10.3 Using the experience of each test to determine the next lower test voltage, obtain data at three or more voltage levels for a curve of voltage stress versus failure time. Continue the tests until a stress of 4 kV/mm (100 V/mil) or a voltage 40 % above the corona-starting voltage, whichever is higher, is reached. Plot the stress in kV/mm (or V/mil) versus the logarithm of the failure time in hours.

⁵ Information may be obtained from American Conference of Governmental Industrial Hygienists, Inc. (ACGIH), 1330 Kemper Meadow Dr., Cincinnati, OH 45240, <http://www.acgih.org>.

10.4 An optional method for the more corona-resistant materials is to accelerate the test by increasing the frequency. Life for some materials is a function of the total number of cycles and not the frequency that produced those cycles (see [Appendix X1](#)). Tests at elevated frequency shall be made to overlap the voltage range of the ~~60-Hz~~60 Hz tests to confirm there is a constancy with the number of cycles to failure. This check is effective because departures from constancy are more likely to occur at high stress than low.

11. Report

11.1 Report the following information:

11.1.1 Material, type designation, conditions of fabrication (if known),

11.1.2 Conditioning prior to test (temperature, humidity, and time),

11.1.3 Test conditions (temperature, humidity, and rate of air flow),

11.1.4 Specimen thickness, maximum, minimum, and average values,

11.1.5 Electrode shape and material,

11.1.6 Frequencies used,

11.1.7 Any corona quantities measured (for example, corona-inception voltage, charge, energy, and so forth),

11.1.8 Curve of stress versus logarithm of failure times, and

11.1.9 All failure times for all tests at all voltages, together with all Weibull plots.

12. Precision and Bias

12.1 This test method is used to rate materials in a comparative way with respect to their resistance to prolonged exposure to partial discharge conditions. A precision and bias statement is nonapplicable to this test method.

13. Keywords

13.1 partial discharge; surface discharge; threshold voltage; voltage ~~insurance~~endurance; voltage stress-time curve; volt-time curve

APPENDIXES

(Nonmandatory Information)

X1. ACCELERATED TESTING BY INCREASING THE TEST FREQUENCY

X1.1 Voltage endurance of solid electrical insulating materials under corona attack may be determined in a shorter length of time if test frequencies higher than 60 Hz are used. The rate of insulation deterioration per cycle is nearly constant on some materials under certain humidity conditions, providing frequency is not raised excessively to the level where dielectric heating begins to shorten insulation life. Frequencies above ~~22 kHz~~ or ~~3 kHz~~ 3 kHz are seldom used if the results are to be correlated with those at power frequency.

X1.2 Life measurements on many hydrocarbon plastics have shown a strong dependence on humidity. A linear relationship between life and reciprocal frequency appears to exist when tests are run in a dry (5 % relative humidity) atmosphere compared to an almost exponential relationship at 50 % relative humidity or higher. Fluorocarbon compounds, on the other hand, show a