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Standard Test Method for Voltage Endurance of Solid Electrical Insulating Materials Subjected to Partial Discharges (Corona) on the Surface[1]

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 reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε1 NOTE—The units statement in subsection 1.2 was corrected and old footnote ten deleted to conform to ASTM guidelines on sole source editorially in July 2008.

1. Scope

1.1 This test method differentiates among solid electrical insulating materials for use at commercial power frequencies with respect to their voltage endurance under the action of corona (see Note 1). In general, this test method is more meaningful for rating materials with respect to their resistance to prolonged a-c stress under corona conditions than is dielectric strength.

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 smaller electrode. This is a difference in location, not in kind. Partial discharges also occur at the edges of electrodes, and in general corona describes an electrical discharge irrespective of its location.

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 and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements, see Section 7.

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

D1711 Terminology Relating to Electrical Insulation

D1868 Test Method for Detection and Measurement of Partial Discharge (Corona) Pulses in Evaluation of Insulation Systems

D5032 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Glycerin Solutions

D6054 Practice for Conditioning Electrical Insulating Materials for Testing (Withdrawn 2012)[3]

E41 Terminology Relating To Conditioning

E104 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions

E171 Practice for Conditioning and Testing Flexible Barrier Packaging

2.2 *Special Technical Publications:*

Symposium on Corona, STP 198, ASTM, 1956.[2]

Corona Measurement and Interpretation, Engineering Dielectrics, Vol 1, STP 669, ASTM, 1979.[2]

2.3 *International Electrotechnical Commission (IEC) Documents:*

IEC Publication 60343 Recommended test methods for determining the relative resistance of insulating materials to breakdown by surface discharges[4]

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

IEEE SS 11205-TBR Guide for the Statistical Analysis of Electrical Insulation Voltage Endurance Data, 1987[5]

3. Terminology

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

[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.

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

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[5] 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.

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3.2.1.1 *Discussion*—Demonstration of a threshold is difficult when the slope of a volt-time curve is small, and failure times are long. High frequency tests are often an aid in demonstration, by reducing the time required to reach a necessary number of voltage cycles.

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

3.2.3 *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.

3.2.3.1 *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.

3.2.4 *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.

3.2.4.1 *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 corona is applied to the specimen until failure occurs. Comparative voltage endurance is the relative time to failure of two different materials of the same thickness when tested with similar electrodes at the same voltage. Comparison is also possible in terms of the magnitude of voltage stress (kV/mm or kV/in.) required to produce failure in a specified number of hours.

4.2 Surface corona exists in the electrically stressed gas where electrodes are near insulation surfaces.

4.3 As with most tests at constant stress, there may be a large dispersion of times to failure for a given sample. The median time of nine specimens (time of fifth failure) may be used as the failure time for the sample. This removes the necessity of waiting for the last few to fail. The mean may also be determined statistically (see IEEE SS 11205-TBR for additional information).

4.4 Under the proper conditions, the test may be accelerated by increasing the frequency of the applied voltage (see Appendix X1).

4.5 Standardized test conditions and conditioning prior to testing are important. In particular, tests with specified air flow at both low and moderate humidities may be informative. In special cases, where a service condition is thought to alter the corona endurance, this factor should be introduced as part of the test and reported. Such conditions might include elongation, elevated temperature, high humidity, other gases besides air, pollution, etc.

4.6 Additional information from the test may be obtained 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. Also, comparative measurements of corona power or energy by bridge and oscilloscope techniques can be informative (see ASTM STP 198 and STP 669).

4.7 If elevated frequencies are used to accelerate the test, it is recommended that the corona-discharge pulse heights and energy per cycle at the test frequency be compared with these values at rated power frequency. If the energy per cycle is the same, it can be concluded that failure time is inversely proportional to frequency.

5. Significance and Use

5.1 This test method is used to compare the endurance of 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 should be distinguished from corona that occurs in internal cavities for which no standardized test has been developed. Evaluation of endurance by comparison of data on specimens of different thickness is not valid.

5.2 The processing of the material may affect the results obtained. For instance, residual strains produced by quenching, or high levels of crystallinity caused by slow cooling may affect the result. Also, the type of molding process, injection or compression, may be important especially if the mixing of fillers or the concentration and sizes of gas-filled cavities are controlled in any degree by the process. Indeed, this test method may be used to examine the effects of processing.

5.3 The data are generated in the form of a set of values of lifetimes at a voltage. The dispersion of failure times can be analyzed using Weibull or extreme value statistics to yield an estimate of the central value of the distribution and its standard deviation. This is particularly recommended when the dispersion of failure times is large, and a comparison of lifetimes of two materials must be made at a specified level of confidence.

5.4 This test is often used to demonstrate the differences between different classes of materials, and to illustrate the importance of eliminating corona in any application of a particular material. When the test is used for such purposes or other similar ones, the need for precision is reduced, and certain time saving techniques, such as 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, are recommended. Two such techniques are described in 10.2. Both techniques remove the necessity of testing beyond median failure, and reduce the required testing time to approximately half of that required to obtain failures on all specimens.

5.5 Insulating materials operating in a gaseous medium are subjected to corona attack at operating voltage on some types of electrical apparatus in those regions where the voltage gradient in the gas exceeds the corona inception level. On other types of equipment, where detectable corona is absent initially, it may appear later due to transient over-voltages or changes in insulation properties attending aging. Certain inorganic materials can tolerate corona for a long time. Many organic materials are damaged quickly by corona, and for these, operation with no detectable corona is important. This test

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method intensifies some of the more commonly met conditions of corona attack so that materials may 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 failure produced by corona may be due to one of several possible factors. The corona may erode the insulation until the remaining insulation can no longer withstand the applied voltage. The corona may cause the insulation surface to become conducting. For instance, carbonization may occur, so that failure occurs quickly. On the other hand, compounds such as oxalic acid crystals may be formed, as with polyethylene, in which case the surface conductance will vary with ambient humidity, and at moderate humidities the conductance may be at the proper level to reduce the potential gradient at the electrode edge, and thus cause either a reduction in the amount of corona, or its cessation, thus retarding failure. The corona may cause a "treeing" within the insulation, which may progress to failure. It may release gases within the insulation that change its physical dimensions. It may change the physical properties of an insulating material; for instance, it may cause the material to embrittle or crack, and thus make it useless.

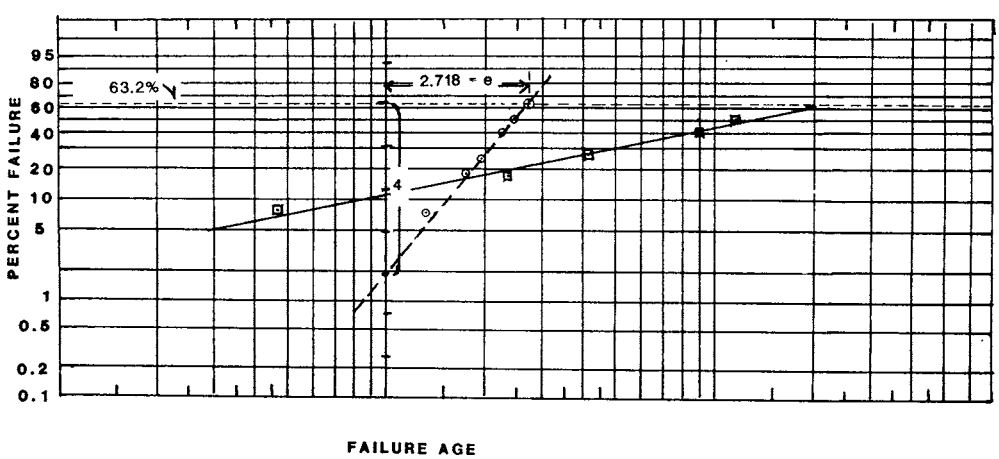
5.7 Tests are often made in open air, at 50 % relative humidity. It may be important for some materials to make tests in circulating air at 20 % relative humidity or less (see Appendix X1). If tests are made in an enclosure, the restriction in the flow of air or other gas may influence the results (see Appendix X2).

5.8 The shape of the (voltage stress)-(time-to-failure) curve is sometimes useful as an indicator of the useable electric strength of a material in an application involving surface corona and its variation with time of application of voltage, though such comparisons are risky. (Specimen thickness, electrode system, the presence of more than one mechanism of failure, and the details of the ambient, including the nature of the surface corona, all have significant effects.) For instance, on log-log paper, the volt-time curve often obtained by the procedures of this test for void-free materials such as polyethylene sheet generally has a continuous curvature that is slightly concave upward. The low voltage end of the curve tends toward the horizontal and approaches a threshold voltage below which the curve does not go. A similar threshold would be expected for many materials in an application involving surface corona. Moreover, if the material possesses a low electric strength (as measured by Test Method D149), or especially if in service there is another mechanism of failure in the short time range of this test, the shape of the left hand end of the curve would be affected and would not reach the same high levels of stress as are exhibited by polyethylene either on this test or in many service applications, including surface corona. In summary, voltage stress-time curves are useful tools for examining modes and mechanisms of failure, but must be used with care.

5.9 For materials that possess a basic resistance to corona, such as mica, or, to a smaller degree, silicone rubber, the time required for the curve to reach the threshold produced by corona may be greater by many orders of magnitude than the time required for materials such as polyethylene, polyethylene terephthalate, or polytetrafluoroethylene.

5.10 The variability of the time to failure is a function of the constancy of the parameters of the test, such as the test voltages, which should be monitored. It is also a significant material property. 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).

5.11 The shape of the Weibull probability plot can provide additional information. A non-straight-line plot may indicate more than one mechanism of failure. For instance, a few unaccountably short time failures in the set could indicate a small portion of defective specimens with a different failure mechanism from the rest of the lot.



NOTE 1—Plotting percentage are 100 times the average of (n – ½)/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 5 Failures of a Group Specimen of 9

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