Designation: D 3426 – 97

An American National Standard

Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials Using Impulse Waves[1]

This standard is issued under the fixed designation D 3426; 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 test method covers the determination of dielectric strength of solid electrical insulating materials under simulated-lightning impulse conditions.

1.2 Procedures are given for tests using standard 1.2 by 50 µs full-wave impulses.

1.3 This test method is intended for use in determining the impulse dielectric strength of insulating materials, either using simple electrodes or functional models. It is not intended for use in impulse testing of apparatus.

1.4 This test method is similar to IEC Publication 243-3. All procedures in this test method are included in IEC 243-3. Differences between this test method and IEC 243-3 are largely editorial.

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 9.

2. Referenced Documents

2.1 *ASTM Standards:*

D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies[2]

D 374 Test Methods for Thickness of Solid Electrical Insulation[2]

D 2413 Test Methods for Preparation and Electrical Testing of Insulating Paper and Board Impregnated with a Liquid Dielectric[2]

2.2 *American National Standard:*

C 68.1 Techniques for Dielectric Tests (IEEE Standard No. 4)[3]

2.3 *IEC Standard:*

Pub 243-3 Methods of Test for Electric Strength of Solid Insulating Materials—Part 3: Additional Requirements for Impulse Tests[3]

3. Terminology

3.1 *Definitions:* Reference should be made to Fig. 1 for the symbols mentioned.

3.1.1 *full-impulse-voltage wave, n*—an aperiodic transient voltage that rises rapidly to a maximum value, then falls less rapidly to zero.

3.1.2 *peak value of an impulse voltage wave, n*— the maximum value of voltage.

3.1.3 *virtual-peak value of an impulse voltage wave, n*—a value derived from a recording of an impulse wave on which high-frequency oscillations or overshoot of limited magnitude may be present. If the oscillations have a magnitude of no more than 5 % of the peak value and a frequency of at least 0.5 MHz, a mean curve may be drawn, the maximum amplitude of which is the virtual-peak value. If the oscillations are of greater magnitude, the voltage wave is not acceptable for standard tests.

3.1.4 *virtual-front time of an impulse voltage wave, n*—equal to 1.67 times the interval t_f between the instants when the voltage is 0.3 and 0.9 times the peak value (t_1, Fig. 1).

3.1.5 *virtual origin of an impulse voltage wave, n*—the point of intersection O_1 with the line of zero voltage of a line drawn through the points of 0.3 and 0.9 times the peak voltage on the front of an impulse voltage wave.

3.1.6 *virtual time to half-value of an impulse voltage wave, n*—the time interval t_2 between the virtual origin O_1 and the instant on the tail when the voltage has decreased to half the peak value.

4. Summary of Test Method

4.1 A series of sets-of-three voltage waves of a specified shape (see 5.3) is applied to the test specimen. The voltage of successive sets is increased in magnitude until breakdown of the test specimen occurs.

4.2 The procedures for sampling and specimen preparation are as specified in the material specification or other document calling for the use of this test method. The surrounding

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

[3] Available from American National Standards Institute, 11 West 42nd St., 13th Floor, New York, NY 10036.

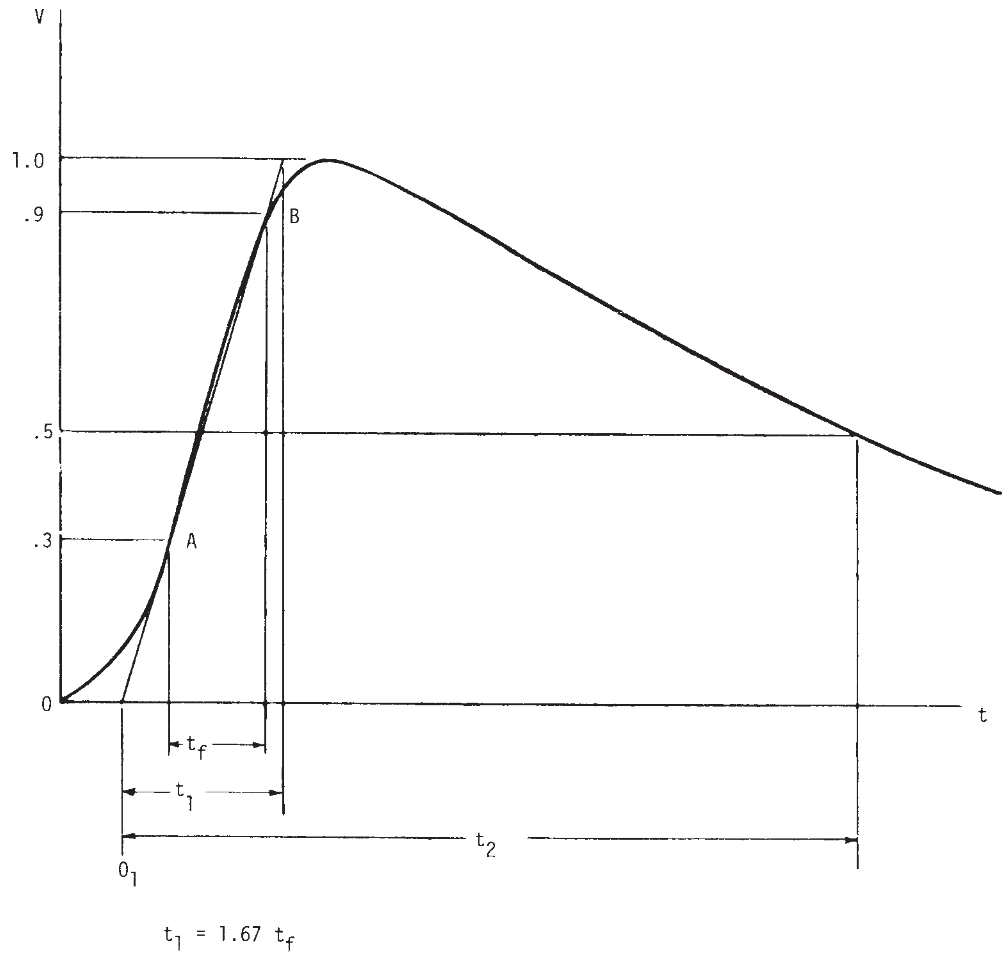

FIG. 1 Full-Impulse Voltage Wave

medium (air or other gas, or oil or other liquid) is also as specified if it differs from the medium in which the specimens are finally conditioned for test.

5. Significance and Use

5.1 Insulating materials used in high-voltage equipment may be subjected to transient voltage stresses, resulting from such causes as nearby lightning strokes. This is particularly true of apparatus such as transformers and switchgear used in electrical-power transmission and distribution systems. The ability of insulating materials to withstand these transient voltages is important in establishing the reliability of apparatus insulated with these materials.

5.2 Transient voltages caused by lightning may be of either positive or negative polarity. In a symmetrical field between identical electrodes, the polarity has no effect on the breakdown strength. However, with dissimilar electrodes there may be a pronounced polarity effect. It is common practice when using dissimilar electrodes, to make negative that electrode at which the higher gradient will appear. When asymmetrical electrodes are used for testing materials with which the tester has no previous experience or knowledge, it is recommended that he make comparative tests with positive polarity and negative polarity applied to the higher gradient, or smaller electrode, to determine which polarity produces the lower breakdown voltage.

5.3 The standard wave shape is a 1.2 by 50-µs wave, reaching peak voltage in approximately 1.2 µs and decaying to 50 % of peak voltage in approximately 50 µs after the beginning of the wave. This wave is intended to simulate a lightning stroke that may strike a system without causing failure on the system.

5.4 For most materials, the impulse dielectric strength will be higher than either its power frequency alternating voltage or its direct voltage dielectric strengths. Because of the short time involved, dielectric heating and other thermal effects are largely eliminated during impulse testing. Thus, the impulse test gives values closer to the intrinsic breakdown strength than do longer time tests. From comparisons of the impulse dielectric strength with the values obtained from longer time tests, inferences may be drawn as to the modes of failures under the various tests for a given material. Appendix X1 of Test Method D 149 should be referred to for further information on this subject.

6. Apparatus

6.1 *Impulse Generator*, capable of applying to the test specimen a standard 1.2 by 50-µs wave of either positive or negative polarity. The virtual front time shall be 1.2 µs± 30 % and the virtual time to half value 50 µs ± 20 %. The maximum voltage and the energy-storage capability must be sufficient to provide impulse waves of the proper shape to any specimen to be tested up to the breakdown voltage (or specified proof voltage) of the material. The electrical characteristics (particularly capacitance) of the test specimen may have a significant effect on the magnitude and shape of the applied voltage wave, especially when using generators having low energy-storage capability. In such cases, provisions must be made for monitoring and adjusting the voltage wave shape.

6.2 *Voltage-Measurement Equipment*, meeting the requirements of ANSI C68.1.

6.3 *Electrodes*:

6.3.1 Electrodes shall be as defined in the specification or method in which reference is made to this test method. If no electrodes are specified, one of the types listed in Table 1 of Test Method D 149 should be used when testing materials as listed in Table 1 of Test Method D 149.

6.3.2 The surfaces of the electrodes must be polished and free of projecting irregularities resulting from previous tests.

6.4 *Surrounding Medium*, as specified for the material being tested. If the surrounding medium is not specified, refer to 8.2 and 8.3 and to the section on Surrounding Medium in Test Method D 149 for guidance.

7. Sampling

7.1 Sample in accordance with the requirements given in the document in which this test method is specified.

7.2 Sample in such a manner as to permit preparation of test specimens that are representative of the lot or other unit of material being evaluated.

7.3 Handle and store the samples (and specimens prepared from the samples) in a manner to prevent alteration of the properties of the material due to such handling and storage.

8. Test Specimens

8.1 Prepare specimens of sufficient number and size to permit making five valid tests (see 9.2.4).

8.2 Prepare the specimens for test using procedures as specified in the material specification. (In general, materials should be tested in the medium in which they are to be used, after conditioning in a manner representative of the manufacturing methods to which they will be subjected.)

8.3 When testing specimens in a surrounding medium other than air, do not remove them from that surrounding medium subsequent to final conditioning for test until after completion of the test. As a specific example, when conditioning specimens for testing in oil by vacuum-impregnation with oil do not remove the specimen from oil even momentarily prior to testing.

9. Procedure

9.1 **Warning—** *Lethal voltages are a potential hazard during the performance of 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. Solidly ground all electrically conductive parts which it is possible for a person to contact 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 or have the potential for acquiring an induced charge during the test or retaining a charge even after disconnection of the voltage source. Thoroughly instruct all operators as to the correct procedures for performing tests safely. When making high voltage tests, particularly in compressed gas or in oil, it is possible for the energy released at breakdown to 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. If the potential for fire exists, have fire suppression equipment available.*

9.2 *Voltage Application*:

9.2.1 Place the specimen between the electrodes and apply waves of the polarity specified. The initial peak voltage shall be approximately 70 % of the expected breakdown voltage.

9.2.2 Apply the impulse waves in sets of three waves, each set at successively increasing voltage levels until breakdown occurs. Each level of peak voltage shall be higher than the preceding level by from 5 to 10 % of the crest voltage of the initial level.

9.2.3 The minimum time between successive voltage applications is dependent upon the charging time-constant of the generator and should be three times the time constant.

9.2.4 A valid test is one in which impulse waves are applied for at least two levels without breakdown before breakdown occurs at the third or some higher voltage level.

9.3 *Criteria of Breakdown*:

9.3.1 Observation of actual rupture, either visually or audibly, may be the most immediate indication of failure. For some specimen configurations, observation of the impulse wave on an oscilloscope may be the most sensitive indication. A collapse of the voltage wave at any point is an indication of failure either by puncture or surface creepage.

9.3.2 The impulse dielectric breakdown voltage is the peak voltage that the wave causing breakdown would have reached had breakdown not occurred.

9.4 *Thickness*— Measure the average thickness of the specimen in the area between the electrodes, using procedures given in Test Methods D 374 for the material being tested.

10. Calculation

10.1 Calculate the impulse-withstand strength using the specimen thickness and the value for the maximum level of impulse voltage that did not cause failure of the specimen.

10.2 Calculate the impulse-breakdown dielectric strength using the specimen thickness and the value for impulse dielectric breakdown voltage.

11. Report

11.1 Report the following:

11.1.1 Identification of test sample,

11.1.2 For each specimen:

11.1.2.1 Average thickness,

11.1.2.2 Maximum impulse-withstand voltage,

11.1.2.3 Impulse dielectric breakdown voltage,

NOTE 1—It may in some cases be desirable to report which of the three impulse waves at the breakdown level resulted in failure.

11.1.2.4 Impulse-withstand strength,

11.1.3 For each sample:

11.1.3.1 Average impulse-withstand strength,

11.1.3.2 Average impulse dielectric breakdown strength,

11.1.3.3 Indication of variability, preferably the standard deviation, from the average dielectric strengths,

11.1.4 Conditioning or specimen preparation,

11.1.5 Ambient atmospheric temperature,

11.1.6 Surrounding medium,

11.1.7 Test temperature,

11.1.8 Impulse wave polarity,

11.1.9 Initial voltage level and magnitude of voltage steps, and

11.1.10 Date of test.

12. Precision and Bias

12.1 The precision and bias for this test method have not been established.

12.2 Tests made by one operator in a single laboratory, using one test set over a period of 18 months, on 15 sets of 5 randomized specimens from a single reference sample, resulted in a repeatability within ± 5 %. The sample was 0.002-in (50-µm) thick high-density capacitor tissue. The specimens were made up of three layers and were impregnated with oil prior to test in accordance with Test Methods D 2413. The specimens were tested under oil, using Type 1 electrodes. The average impulse breakdown strength for the 15 sets of specimens ranged from 4200 to 4600 V/mil (165 to 181 kV/mm).

13. Keywords

13.1 dielectric breakdown; dielectric breakdown criteria; dielectric breakdown voltage; dielectric strength; full-impulse-voltage wave; impulse dielectric strength; impulse generator; impulse waves; lightning strokes; peak value; simulated-lightning impulse; solid insulating material; virtual front time; virtual origin; virtual peak value; virtual time to half-value