Designation: D1868 – 20

Standard Test Method for Detection and Measurement of Partial Discharge (Corona) Pulses in Evaluation of Insulation Systems[1]

This standard is issued under the fixed designation D1868; 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 covers the detection and measurement of partial discharge (corona) pulses at the terminals of an insulation system under an applied test voltage, including the determination of partial discharge (corona) inception and extinction voltages as the test voltage is raised and lowered. This test method is also useful in determining quantities such as apparent charge and pulse repetition rate together with such integrated quantities as average current, quadratic rate, and power. This test method is useful for test voltages ranging in frequency from zero (direct voltage) to approximately 2000 Hz.

1.2 This test method is directly applicable to a simple insulation system that can be represented as a two-terminal capacitor (**1**), (**2**).[2]

1.3 This test method is also applicable to (distributed parameter) insulation systems such as high-voltage cable. Consideration must be given to attenuation and reflection phenomena in this type of system. Further information on distributed parameter systems of cables, transformers, and rotating machines will be found in Refs (**1-9**). (See AEIC CS5-87, IEEE C57 113-1991, IEEE C57 124-1991, and IEEE 1434-2005.)

1.4 This test method can be applied to multi-terminal insulation systems, but at some loss in accuracy, especially where the insulation of inductive windings is involved.

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 determine the applicability of regulatory limitations prior to use.* Specific precaution statements are given in Sections 8 and 14.

1.6 *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:*[3]

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

D2275 Test Method for Voltage Endurance of Solid Electrical Insulating Materials Subjected to Partial Discharges (Corona) on the Surface

D3382 Test Methods for Measurement of Energy and Integrated Charge Transfer Due to Partial Discharges (Corona) Using Bridge Techniques

2.2 *IEEE Standards*[4]

IEEE 48 Standard Test Procedures and Requirements for High Voltage Alternating Current Cable Terminations

IEEE 1434-2005 Guide to the Measurement of Partial Discharges in Rotating Machinery

IEEE C57 113-1991 Guide for PD Measurement in Liquid-Filled Power Transformers and Shunt Reactors

IEEE C57 124-1991 Recommended Practice for the Detection of PD and the Measurement of Apparent Charge in Dry-Type Transformers

2.3 *Other Documents:*

AEIC CS5-87 Specifications for Thermoplastic and Cross-linked Polyethlene Insulated Shielded Power Cables Rated 5 through 35 kV (9th Edition) October 1987[5]

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[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] The boldface numbers in parentheses refer to the list of references at the end of this test method.

[3] 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.

[4] Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., Piscataway, NJ 08854-4141, http://www.ieee.org.

[5] Available from Association of Edison Illuminating Companies (AEIC), P.O. Box 2641, Birmingham, AL 35291-0992, http://www.aeic.org.

***A Summary of Changes section appears at the end of this standard**

ICEA T-24-380 Guide for Partial Discharge Procedure[6]

3. Terminology

3.1 *Definitions:*

3.1.1 The following terms are presented in a developing sequence; it is best that they be read in their entirety.

3.1.2 *ionization*—the process by which electrons are lost from or transferred to neutral molecules or atoms to form positively or negatively charged particles.

3.1.3 *partial discharge (corona)*—an electrical discharge that only partially bridges the insulation between conductors. This electrical discharge, which is governed by the transient gaseous ionization process, can assume the form of either a spark characterized by a narrow discharge channel or a diffused glow having an expanded or substantially broadened discharge channel. The partial discharges occur in gas filled cavities occluded within insulating systems and are initiated whenever the voltage across the cavities changes by a value equal to their breakdown voltage (**5**).

3.1.4 *corona*—visible partial discharges in gases adjacent to a conductor. This term has also been used to refer to partial discharges in general.

3.1.5 *continuous partial discharges (continuous corona)*—discharges that recur at rather regular intervals; for example on approximately every cycle of an alternating voltage or at least once per minute for an applied direct voltage.

3.1.6 *partial discharge (corona) inception voltage (PDIV [CIV])*—the lowest voltage at which continuous partial discharges above some stated magnitude (which may define the limit of permissible background noise) occur as the applied voltage is gradually increased (Note 1). Where the applied voltage is alternating, the PDIV is expressed as 1/√2 of the peak voltage. Many test and specimen parameters can affect this value, and in some cases reproducibility may be difficult to achieve.

NOTE 1—Many factors may influence the value of the PDIV and PDEV including the rate at which the voltage is increased or decreased as well as the previous history of the voltage applied to the specimen. In many cases it may be difficult to obtain the same value with subsequent tests.

Moreover, the "continuous" character of the partial discharges is sometimes quite difficult to define, and an arbitrary judgment in this respect may lead to different values of the PDIV or PDEV.

3.1.7 *partial discharge (corona) extinction voltage (PDEV [CEV])*—the highest voltage at which partial discharges above some stated magnitude no longer occur as the applied voltage is gradually decreased from above the inception voltage (see Note 1). Where the applied voltage is alternating, the PDEV is expressed as 1/√2 of the peak voltage. Many test and specimen parameters can affect this value, and in some cases reproducibility may be difficult to achieve.

3.1.8 *partial discharge pulse voltage (V_t)*—the terminal pulse voltage resulting from a partial discharge represented as a voltage source suddenly applied in series with the capacitance of the insulation system under test, and that would be detected at the terminals of the system under open-circuit conditions. The shape, rise time, and magnitude of the voltage V_t of the partial discharge pulse are dependent upon the geometry of the cavity, its size, nature of its boundaries, the type of gas and the pressure within as well as the parameters of the transmission medium between the discharge site and the partial discharge pulse detector. The partial discharge pulses of the spark-type discharge will have substantially shorter rise times than those of the glow-type (**10**).

3.1.9 *partial discharge quantity (terminal corona charge) (Q_t)*—the magnitude of an individual discharge in an insulation system expressed in terms of the charge transfer measured at the system terminals. The measured charge is in general not equal to the charge transferred at the discharge site, and does have a relation to the discharge energy. For a small specimen that can be treated as a simple lumped capacitor, it is equal to the product of the capacitance of the insulation system and the partial discharge pulse voltage, that is:

$$Q_t = C_t V_t \quad (1)$$

where:

Q_t = partial discharge quantity, C,
C_t = capacitance of the specimen insulation system, F, and
V_t = peak value of the partial discharge pulse voltage appearing across C_t, V.

3.1.10 *partial discharge (corona) level*—the magnitude of the greatest recurrent discharge during an observation of continuous discharges.

3.1.11 *average discharge (corona) current (I_t)* —the sum of the absolute magnitudes of the individual discharges during a certain time interval divided by that time interval. When the discharges are measured in coulombs and the time interval in seconds, the calculated current will be in amperes.

$$I_t = \frac{\Sigma_{t_0}^{t_1} Q_1 + Q_2 + - - - - Q_n}{t_1 - t_0} \quad (2)$$

where:

I_t = average current, A,
t_0 = starting time, s,
t_1 = completion time, s, and
Q_1, Q_2, Q_n = partial discharge quantity in a corona pulse 1 through n, C.

3.1.12 *quadratic rate*—the sum of the squares of the individual discharge magnitudes during a certain time interval divided by that time interval. The quadratic rate is expressed as $(\text{coulombs})^2$ per second.

3.1.13 *partial discharge (corona) energy (W)*— the energy drawn from the test voltage source as the result of an individual discharge. It is the product of the magnitude *Q* of that discharge and the instantaneous value *V* of the voltage across the test specimen at the inception of the discharge (**11**). Thus the discharge energy of the *i*th pulse is:

$$W_i = Q_i V_i \quad (3)$$

where:

W_i = the discharge energy, W·s(= J),
Q_I = the partial discharge magnitude (see 3.1.9), and

[6] Available from The Insulated Cable Engineers Association, Inc. (ICEA), P.O. Box 2694, Alpharetta, GA 30023, http://www.icea.net.

V_i = the instantaneous value of the applied test voltage at the time of the discharge, V.

3.1.14 *partial discharge (corona) power loss (P)*—the summation of the energies drawn from the test voltage source by individual discharges occurring over a period of time, divided by that time period.

$$P = \frac{1}{T}\Sigma_{i=1}^{i=m} Q_i V_i \quad (4)$$

where:

P = the discharge power, W,
T = the time period, s,
m = the number of the final pulse during T, and
$Q_i V_I$ = the discharge energy of the ith pulse (see 3.1.13).

When partial discharge pulse-height analysis is performed over a one-second interval, then the power dissapated, P, can be determined from:

$$P = \Sigma_{j=1}^{t} n_j Q_j V_j \quad (5)$$

where:

P = pulse discharge power loss, W,
n_j = recurrence rate of the jth discharge pulse in pulses/second,
Q_j = the corresponding value of the partial discharge quantity in coulombs for the particular pulse, and
V_j = instantaneous value of the applied voltage in volts at which the jth discharge pulse takes place (**6**).

If the assumption (**12**) is made that $V_j \Delta C_j \simeq C_t \Delta V_j$ (where ΔC_j is incremental capacitance rise in C_t due to the drop ΔV_j in V_j as a result of the *j*th discharge), then the above summation must be multiplied by 1/2. However, this assumption is not usually borne out in practice.

3.1.15 *partial discharge apparent power loss (P_a)*—the summation over a period of time of all corona pulse amplitudes multiplied by the rms test voltage.

$$P_a = I_t V_t \quad (6)$$

where:

P_a = apparent power loss in time interval $(t_1 - t_0)$, W,
I_t = average corona current, A, and
V_s = applied rms test voltage, V.

3.1.16 *partial discharge (corona) pulse rate (n)*—the average number of discharge pulses that occur per second or in some other specified time interval. The pulse count may be restricted to pulses above a preset threshold magnitude, or to those between stated lower and upper magnitude limits.

3.1.17 *partial discharge pulse*—a voltage or current pulse that occurs at some designated location in a circuit as a result of a partial discharge.

4. Summary of Test Method

4.1 A specimen insulation system is energized in a test circuit by a high-voltage source. A partial discharge (corona) in the specimen will cause a sudden charge transfer and a resulting voltage pulse at the specimen terminals. Calibrate a measuring instrument coupled to the terminals to respond to the voltage pulse in terms of the charge transferred at the terminals.

5. Significance and Use

5.1 The presence of partial discharges (corona) at operating voltage in an insulation system has the potential to result in a significant reduction in the life of the insulating material. Some materials are more susceptible to such discharge damage than others. This characteristic can be investigated using Test Method D2275.

5.2 The presence of partial discharges (corona) in an apparently solid insulation is a potential indication of the existence of internal cavities. Partial discharge tests have been useful in the design and inspection of molded, laminated, and composite insulation, as well as specimens in the form of cables, capacitors, transformers, bushings, stator bars, and rotating machines (**1-9**), (**13**), (**12**). See also AEIC CS5-87, ICEA T-24-380, IEEE 48, IEEE C57 113-1991, IEEE C57 124-1991, and IEEE 1434-2005.

5.3 Partial discharge (corona) inception and extinction voltages are used in the determination of the limiting voltage at which an insulation system will operate free of such discharges. The extinction voltage is often substantially lower than the inception voltage. Where the operating voltage is below the inception voltage but above the extinction voltage, it is possible that a transient over-voltage will initiate discharges which then continue until the voltage is lowered below the extinction voltage. Inception and extinction voltages depend upon many factors, including temperature and the rate at which the voltage is changed. After a time at a voltage, it is possible that discharges will start and stop in a nonuniform and unpredictable fashion, especially for discharges within cavities in certain materials, in particular if the discharge degradation products formed are conductive (**1**), (**5**).

5.4 The magnitude (pulse height) of a partial discharge is an indication of the amount of energy that it dissipates in the insulation system. Partial discharge magnitude and pulse rate are useful in estimating the rate, or change of rate, at which deterioration is produced.

5.5 In general, the occurrence of partial discharges is not directly related to the basic properties of a solid insulating material, but usually results from overstressing of gaseous occlusions or similar imperfections or discontinuities in an insulating system. It is possible that partial discharges will originate at locations such as on the leads or terminals without resulting in any hazard within the main part of the insulation system.

6. Interference

6.1 It is possible that radiated or conducted electrical disturbances from sources other than the test specimen will interfere with the measurement of partial discharges. The magnitude of disturbances reaching the measuring instrument must be kept small relative to the most sensitive measurements to be made.