

# What is Partial-Discharge Resistance?

**P**article discharge (PD) is defined by IEEE as an electrical discharge that only partially bridges the insulation between conductors and that may or may not occur adjacent to a conductor. Partial discharges occur when the local electrical field intensity exceeds the dielectric strength of the dielectric involved, resulting in localized ionization and breakdown. Depending on the intensity, PDs are often accompanied by emissions of light, heat, sound, and radio influence voltage (with a wide frequency range).

When voids are present in solid dielectrics and the electrical field is sufficiently high, air (or other gas) inside the voids ionizes and creates breakdown pulses across the voids. These pulses are referred to as discharges. Most solid-dielectric insulations degrade under the presence of partial discharge and lead to premature failure of the insulation. However, some dielectric materials are relatively insensitive to PD activities. The ability of solid dielectrics to withstand voltage under the presence of partial discharge is called partial-discharge resistance.

## Why is Partial-Discharge Resistance Important?

In today's triple-extrusion/dry-curing technology or with the PD factory test one may tend to believe that discharge resistance is not necessary for new cable. While it is true that today's cables contain fewer apparent PD activities than their predecessors, there is no assurance that they are completely free of partial discharge. As stated in the Association of Edison Illuminating Companies (AEIC) specifications CS5-97, CS6-87, and CS7-93, the pass/fail criterion for the factory PD test is 5-pC (picocoulomb). A single 5-pC signal requires at least three 10-mil voids, nine 5-mil voids, 100 1-mil voids, or other equivalent void combinations to simultaneously discharge.

Higher test voltages enable smaller voids to discharge but do not necessarily increase the magnitude of PD. Regardless of how high the test voltage is, there is always probability that some voids in cable insulation will escape the detection of factory PD testing. These voids can discharge under normal lightning/switching surges.



*by Ralph Patterson  
Power Products  
& Solutions, Inc.*

---

## Factory Partial-Discharge Test Procedure

Since the gaseous by-product of curing takes time to diffuse out of the cable, the voids are pressurized for a period of time after cable extrusion. The detectability of partial discharge is decreased due to the gas pressure. In accordance with Insulated Cable Engineers Association (ICEA) publication T-24-380, the manufacturer shall perform a partial discharge test prior to shipment. The manufacturer shall wait a minimum of 20 days after the insulation extrusion process before the test is performed. The 20 day waiting period may be reduced by mutual agreement between the purchaser and manufacturer when effective degassing procedures are used.

**Table 1**  
**Partial-Discharge Requirements**

V <sub>t</sub> /V <sub>g</sub> ratio	1.0	1.5	2.0	2.5
pC - Limit	5	5	5	10

ICEA S 108-720-2002

V<sub>t</sub> = Test Voltage, V<sub>g</sub> = Cable Line-to-Ground Rated Voltage

**Table 2**  
**Test Voltages for Partial-Discharge Measurements**

Cable Voltage Rating (kV)	Test Voltages (V <sub>t</sub> ) in KV Corresponding to V <sub>t</sub> /V <sub>g</sub> Ratio			
	1.0	1.5	2.0	2.5
69	40	60	80	100
115	65	100	135	160
120	70	105	140	175
138	80	120	160	200
161	95	140	185	230
230*	135	200	265	N/A

\* 230 kV class cables are partial discharge tested up to 2.0 V<sub>g</sub> only.

ICEA S 108-720-2002

Each shipping length of completed cable shall be subjected to a partial discharge test. The partial discharge shall not exceed the values in Table 1. The test voltages for partial discharge measurements are listed in Table 2.

Theoretically, spaces originally filled by water and/or water soluble materials also may become sites for PD if water diffuses away, leaving a gas-filled pocket, and the void shape is maintained. These spaces are not detectable in factory PD tests since there is no air or gas at the time of measurement.

### Field Testing:

Discharge sites also may be introduced at splices or terminations during installation. The discharge may affect the surface of cable insulation in contact with the devices and cause failure in the termination or splice.

A shielded power cable is composed of a conductor, conductor screen, insulation, insulation screen, a coaxial insulation shield, and a jacket. The coaxial shield causes the electrical field within the cable to be equally distributed between the conductor and the shield so that the insulation is equally stressed, thus allowing the minimum insulation thickness.

When a cable ends, the shield must be separated from the core by a sufficient distance to reduce the electrical interaction between the two. Unfortunately, when the shield is ended abruptly, a destructively high electrical field is generated at the terminus. This stress must be relieved to insure the life of the installation.


The surface of the insulation that lies between the conductor and the shield terminus is under an electrical stress and is susceptible to electrical discharge that causes erosion and chemical decomposition. This vulnerable area can be fortified by the choice of materials and/or the geometry.

Cable preparation is extremely important to the reliable performance of any termination. When preparing the cable for the termination as per the manufacturer's instructions, extreme care must be taken when removing the insulation semiconducting shield. The underlying insulation must not be nicked or cut and the semiconductive layer that remains on the cable must not be lifted up on the end. These occurrences introduce air voids into the system, which will cause premature failure. If the cable preparation is done correctly and the termination is installed as per the manufacturer's instructions, the termination will perform.

If testing in-service cables installed before the mid 1980s a PD occurrence may not necessarily indicate that the PD is from service aging. During the last 15 years cable has been manufactured with less than 5 pC discharge magnitudes. This was not always the case, as we evolved over the last 30 years to this plateau. In 1976 the AEIC cable committees introduced this standard. This prompted the triple extrusion process which was needed to meet this stringent requirement.

Of additional importance is the newly-discovered relationship between partial-discharge activity and the water-treeing phenomenon, a degradation mechanism recognized as the main reason for many premature cable failures in extruded dielectric cables. Discharge activity may develop during the service life of cables regardless of the discharge-free design of cables.

## In Conclusion:

Since discharge activities may exist in today's cable as it is produced, installed, terminated, and aged in service, it is beneficial to consider partial-discharge resistance as a very important property for overall cable performance. 

---

## References:

AEIC CS5-94, *Specifications for Cross-Linked Polyethylene Insulated Shielded Power Cables Rated Through 46 kV*

AEIC CS6-87, *Specifications for Ethylene Propylene Rubber Insulated Shielded Power Cables Rated Through 69 kV*

AEIC CS7-93, *Specifications for Cross-Linked Polyethylene Insulated Shielded Power Cables Rated Through 138 kV*

Insulated Conductors Committee, 117<sup>th</sup> Meeting  
Spring 2005

ICEA S-108-720, *Extruded Insulation Power Cable Rated Above 46 Through 230 kV*

ICEA Publication T-24-380-1994, *Guide for Partial-Discharge test procedure*

---

Ralph Patterson is President of Power Products and Solutions, located in Charlotte NC. His professional background includes working as a design engineer of transformers and as a specifying engineer of insulated conductors. He has more than 25 years in power engineering particularly in insulation diagnosis and evaluation of electrical distribution equipment. He serves on the NETA Standards Review Council and Board of Directors, is the NETA liaison for the IEEE Insulated Conductor Committees working groups and received NETA's 2001 Outstanding Achievement Award.

---

Article available for reprint with permission from NETA. Please inquire at [neta@netaworld.org](mailto:neta@netaworld.org).

---