

Standard

Low Earth Orbit Spacecraft Charging Design Standard Requirement and Associated Handbook

American National Standard

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Low Earth Orbit Spacecraft Charging Design Standard Requirement and Associated Handbook

Sponsored by

American Institute of Aeronautics and Astronautics

Approved September 2013

American National Standards Institute

Abstract

This standard presents an overview of the current understanding of the various plasma interactions that can result when a high-voltage system is operated in the Earth's ionosphere, references common design practices that have exacerbated plasma interactions in the past, and recommends standard practices to eliminate or mitigate such reactions.

American National Standard

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Foreword

This document is based on the low Earth orbit (LEO) Spacecraft Charging Design Guidelines (Ferguson and Hillard, 2003), and the National Aeronautics and Space Administration (NASA) Low Earth Orbit Spacecraft Charging Design Standard [NASA-STD-(I)-4005 (2006) and NASA-STD-4005 and NASA-HDBK-4006 (2007)] and has the same authors, Ferguson and Hillard, as those documents. It is the first American National Standard in its subject area and thus does not cancel or replace any other American National Standard in whole or in part. Only minor technical changes and updates distinguish the present standard from NASA-STD-(I)-4005. The present standard deals only with surface charging in LEO environments. In particular, this standard is not intended to replace NASA TP-2361, which is applicable to geosynchronous Earth orbit (GEO) plasma environments, or NASA-HDBK-4002, which deals only with deep dielectric charging. NASA-HDBK-4002A, which covers only charging environments outside of equatorial LEO and deep-dielectric charging, is also not to be replaced by this document. In this document, all of the Annexes are only informative. The only requirements in this standard are in Section 5 (Requirements).

At the time of approval, the members of the AIAA Atmospheric and Space Environment Committee on Standards Working Group for Low Earth Orbit were:

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The above consensus body approved this document in July 2013.

The AIAA Standards Executive Council (VP-Standards Laura McGill, Chairperson) accepted the document for publication in August 2013.

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Introduction

The purpose of this document and information handbook is to provide design standard requirements for high-voltage space power systems (>55 V) that operate in the plasma environment associated with LEO (altitude between 200 km and 1000 km, and latitude between -50 degrees and $+50$ degrees). Such power systems, particularly solar arrays, are the proximate cause of spacecraft charging in LEO, and these systems can interact with this environment in a number of ways that are potentially destructive to themselves and to the platform or vehicle that has deployed them. This document is also applicable to satellites during the lower latitude portion of polar orbits and to GEO satellites during the initial low altitude portion of their geostationary transfer orbit.

This document represents the technical consensus of the spacecraft charging community. Systems designers need a standard to show them how to mitigate the spacecraft charging effects of using high voltages in LEO. In addition to system designers, this document should be useful to project managers, solar array designers, system engineers, etc.

This document is intended as a standard for design applications and can be used as a requirements-specification instrument.

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1 Scope

This document and information handbook presents an overview of the current understanding of the various plasma interactions that can result when a high-voltage system is operated in the Earth's ionosphere. This document is also applicable to satellites during the lower latitude portion of polar orbits and to GEO satellites during the initial low altitude portion of their geostationary transfer orbit.

It references common design practices that have exacerbated plasma interactions in the past, and recommends standard requirements and practices to eliminate or mitigate such reactions.

1.1 Purpose

The purpose of this standard is to provide the requirements for a design standard for high-voltage space power systems (>55 V) that operate in the plasma environment associated with LEO (altitude between 200 km and 1000 km and latitude between -50 degrees and +50 degrees). Such power systems, particularly solar arrays, are the proximate cause of spacecraft charging in LEO. These systems can interact with this environment in a number of ways that are potentially destructive to themselves and to the platform or vehicle that has deployed them.

High-voltage systems are used in space for two reasons. The first is to save launch weight. High-voltage systems are often used as a means to reduce mass and increase efficiencies by reducing power line I^2R losses. High-voltage systems are also used in space because some spacecraft functions require high voltages. For example, electric propulsion uses voltages from about 300 V (Hall thrusters) to about 1000 V (ion thrusters). For low-voltage power systems, conversion of substantial power to high voltages is required for these spacecraft functions to operate. The weight of the power conversion systems, power management and distribution (PMAD), can be a substantial fraction of the total power system weight in these cases. It is more efficient, and can save weight, if the high-voltage functions can be directly powered from a high-voltage solar array, for instance. If the high-voltage function is electric propulsion, then we call such a system a direct-drive electric propulsion system.

These two reasons and others are causing spacecraft designers and manufacturers to use high voltages more and more. However, doing so entails risk; in particular, spacecraft charging in LEO, in contrast to that in GEO, is caused by exposed high voltages and can lead to arcing, power drains, power disruptions, and loss of spacecraft coatings. Thus, system designers need a standard to show them how to mitigate the spacecraft-charging effects of using high voltages in LEO. In addition to system designers, this document should be useful to project managers, solar array designers, system engineers, etc.

This document is intended to provide requirements and associated best practices for design applications and can be used as a requirements-specification instrument.

1.2 Applicability

The contents of this document are applicable to high-voltage space power systems that operate in the plasma environment associated with LEO. This standard is intended for space systems that spend the majority of their time at altitudes between 200 km and 1000 km (usually known as LEO applications) and at latitudes between about -50 degrees and +50 degrees—that is, space systems that do not encounter GEO charging conditions, that do not (often) encounter the auroral ovals of electron streams, and that do not fly through the Van Allen belts. For the extreme radiation protection that is necessary for orbits in the Van Allen belts, exterior spacecraft charging will likely be a secondary concern. However, internal charging will be very important. It is not in the purview of this document to deal with internal charging.

Some of the design standards for LEO are at variance with good design practice for GEO spacecraft. If your spacecraft will fly in both LEO and GEO conditions, then be careful to use design solutions that are applicable in both environmental regimes.

Table 1 (Ferguson and Brandhorst, 2012) illustrates some of the differences between good GEO and LEO design practices.

Table 1 — Differences between good GEO and LEO design practices

Good GEO Practices	Good LEO Practices
Grounded conductive coatings on solar cells.	Closely spaced cells with large coverglass overhang.
Negatively grounded power system.	Positively grounded power system.
Low inter-string voltages (< 60 V).	Low string voltages (< 100 V).
Grouting between cells of high inter-string voltage.	Encapsulation of array conductors, but beware of Paschen discharge.
Grounded conductive coatings on entire spacecraft body.	Dielectric surfaces on entire spacecraft body.
Spacecraft surfaces with high secondary electron emission and low photoemission.	Careful attention to materials thicknesses near points of high electric field.
Use a good GEO spacecraft charging code (i.e., Nascap-2K).	Use a good LEO spacecraft charging code (i.e., Nascap-2K).

2 Tailoring

When viewed from the perspective of a specific program or project context, the requirements defined in this standard may be tailored to match the actual requirements of the particular program or project. Tailoring of requirements shall be undertaken in consultation with the procuring authority where applicable.

This standard may be cited in contract, program, and other documents as a technical requirement. Mandatory requirements are indicated by the word “shall.” Tailoring of this standard for application to a specific program/project shall be approved by the technical authority for that program/project.

3 Applicable Documents

The following documents contain provisions that, through reference in this text, constitute provisions of this standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

3.1 General

The documents listed in this section contain provisions that constitute requirements of this standard as cited in the appendices. The latest issuances of cited documents shall be used unless otherwise approved by the assigned Technical Authority.

3.2 Government and International Documents

Dunbar, W. G., “Design Guide: Designing and Building High Voltage Power Supplies, Materials Laboratory,” A. F. Wright Aeronautical Laboratories, A. F. Systems Command, Wright Patterson A. F. Base, OH, AFWAL-TR-88-4143, Vol. II, August 1988.

NASA-HDBK-4001 Electrical Grounding Architecture for Unmanned Spacecraft, issued February 17, 1998.

NASA-STD-4005 Low Earth Orbit Spacecraft Charging Design Standard, issued June, 2007.

NASA-HDBK-4006 Low Earth Orbit Spacecraft Charging Design Handbook, issued June, 2007.

NASA-HDBK-4002A Mitigating In-Space Charging Effects - A Guideline, issued 2011.

ISO 11221 Space systems — Space solar panels — Spacecraft charging induced electrostatic discharge test methods, issued August, 2011.

3.3 Nongovernment Documents

ASTM D257-61 Standard Test Methods for DC Resistance or Conductance of Insulating Materials, issued October 10, 1999. This standard is not widely used in the spacecraft charging community, as it employs a 60-second measurement time, which is inadequate for the large resistances typical of spacecraft dielectric materials, and is inadequate for use for space materials because it performs measurements in Earth-atmosphere ambient conditions (temperature and humidity). The annex to ASTM D257-61 indicates how humidity variations can affect measured resistivity by orders of magnitude. The major area of concern for terrestrial electronics is high-humidity/high-leakage conductance, whereas the major area of concern for space operation is zero humidity and outgassed dielectrics, with their possible much higher resistivity.

3.4 Order of Precedence

In the case of conflict, the technical requirements of this standard take precedence over the technical requirements cited in the applicable documents or referenced guidance documents.

4 Vocabulary

4.1 Acronyms and Abbreviated Terms

AC	alternating current
AIAA	American Institute of Aeronautics and Astronautics
AO	atomic oxygen
ANSI	American National Standards Institute
APSA	Advanced Photovoltaic Solar Array
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing and Materials
BSR	Bureau of Safety and Regulation
CHAWS	Charging Hazards and Wake Studies
DC	direct current
EMI	electromagnetic interference
EMU	Extra-vehicular Maneuvering Unit (spacesuit)
EOS-AM1	Earth Observing System—Morningside 1 (now named Terra)
ESA	European Space Agency
ESD	electrostatic discharge
EURECA	European Retrievable Carrier
EUV	extreme ultraviolet
EVA	Extra-vehicular Activity (spacewalk)
EWB	Environments WorkBench

FEF	field enhancement factor
FPP	floating potential probe
GEO	geosynchronous Earth orbit
GRC	Glenn Research Center
IRI	International Reference Ionosphere
ISS	International Space Station
ITAR	International Traffic-in-Arms Regulations
JAXA	Japan Aerospace Exploration Agency
LEO	low Earth orbit (for the purposes of this document, between 200 km and 1000 km altitude and between –50 degrees and +50 degrees latitude)
LeRC	Lewis Research Center (now GRC)
MET	Marshall Engineering Thermosphere
MSFC	Marshall Space Flight Center
MSIS Model	mass spectrometer incoherent scatter model
NASA	National Aeronautics and Space Administration
NASCAP	NASA/Air Force Spacecraft Charging Analyzer Program
Nascap-2k	Most up-to-date version of NASCAP
PAS-6	Commercial communications satellite owned by PamAmSat (now part of Intelsat), designed and built by Space Systems/Loral
PASP Plus	Photovoltaic Array Space Power Plus Diagnostics
PC	personal computer
PCU	plasma contactor unit
PIX-II	Plasma Interactions Experiment-II
PMAD	power management and distribution
PMG	Plasma Motor Generator
ProSEDS	Propulsive Small Expendable Deployer System
RCS	Reaction Control System (attitude thrusters)
RTV	Room Temperature Vulcanized-rubber
SAIC	Science Applications International Corporation
SAMPIE	Solar Array Module Plasma Interactions Experiment
SPENVIS	Space Environment Information System
TSS-1R	Tethered Satellite System—first reflight
UV	ultraviolet

4.2 Terms and Definitions

For the purposes of this document, the following terms and definitions apply (they are based largely on AFWAL-TR-88-4143, Volume II):

Aging

change in properties of a material with time under specific conditions

Anode

electrode through which a positive direct current (DC) enters the liquid, gas, or other discrete part of an electrical circuit; the positively charged pole of an electrochemical cell

Arc

a low voltage, self-sustaining discharge between cathode and anode surfaces

Arc-site

the place where an arc initiates or is presently located

Arc-over voltage

minimum voltage required to create an arc between electrodes separated by an insulating medium under specified conditions

Blowoff current

the release of charge and/or charged material having the net effect of neutralizing a spacecraft to the surrounding plasma potential (see Flashover)

Breakdown (puncture)

disruptive discharge through an insulating medium

Breakdown voltage

voltage at which the insulation between two conductors fails

Capacitance (capacity)

that property of a system of conductors and dielectrics that permits the storage of electricity when potential difference exists between the conductors; the ratio of the charge on one of the conductors of a capacitor to the potential difference between the conductors.

NOTE: There will be an equal and opposite charge on the other conductor.

Capacitor (condenser)

device whose primary purpose is to introduce capacitance into an electric circuit

Cathode

electrode through which an electric current leaves a liquid, gas, or other discrete part of an electric circuit; the negatively charged pole of an electrochemical cell

Cell

single unit capable of serving as a DC voltage source by transfer of ions in the course of a chemical reaction

Charge

in electrostatics, the amount of electricity (coulombs) present upon any substance that has accumulated electric energy

Conductance

reciprocal of resistance; the ratio of current passing through a material to the potential difference at its ends

Conductivity

reciprocal of resistivity

Conductor

electrical path that offers comparatively little resistance; a wire or combination of wires that are not insulated from each other and that are suitable for carrying a single electric current

Contaminant

impurity or foreign substance present in or on a material and affecting one or more properties of the material

Corona

non-self-sustaining discharge (sometimes visible) due to ionization of the gas surrounding a conductor in the presence of a voltage gradient exceeding a certain critical value for a gaseous medium

Corona resistance

time that insulation will withstand a specified level of field-intensified ionization that does not result in the immediate complete breakdown of the insulation

Coverglass or coverslide

layer (usually of glass) that covers a semiconductor solar cell or array to prevent radiation damage

Critical voltage (of gas)

voltage at which a gas ionizes and corona occurs, preliminary to dielectric breakdown of the gas

Debye Length

the distance over which electrons and ions may separate in a thermal plasma. For $T_e \gg T_i$, the Debye length is given by

$$\lambda_D = (kT_e/4\pi n e^2)^{1/2} = 7.43 \times 10^2 (T_e/n)^{1/2} \text{ cm},$$

where k is the Boltzmann constant, T_e is the electron temperature in eV, n is the electron density in cm^{-3} , and e is the charge of the electron.

Dielectric

non-conducting material

Dielectric breakdown

electrical discharge within a dielectric due to an applied electric field in excess of the dielectric strength of the material

Dielectric constant (relative permittivity)

property of a dielectric that determines the electrostatic energy stored per unit volume for unit potential gradient; the total permittivity is the product of a dielectric constant and the permittivity of free space (see Permittivity)

Dielectric loss

time rate at which electric energy is transformed into heat in a dielectric when it is subjected to a changing electric field

Dielectric strength

maximum electrical potential gradient (electric field) that an insulating material can withstand without rupture, usually expressed in volts per mm of thickness

Dielectric tests

tests that consist of applying a voltage higher than the rated voltage for a specified time in order to determine the adequacy against breakdown of insulating materials and spacings under normal conditions

Electric field intensity

force exerted on a stationary positive charge per unit charge at a point in an electric field; designated by E ; also known as electric field strength and electric field vector; for a point charge in space, it is given by

$$E = \frac{Q}{4\pi\epsilon r^2}$$

where ϵ is the dielectric constant and r is the distance from the charge Q

Electrode

conductor, not necessarily metal, through which a current enters or leaves an electrolytic cell, arc, furnace, vacuum tube, gaseous discharge tube, or any conductor of the non-metallic class

Electron

stable elementary, negatively charged particle that may be found surrounding the center or nucleus in an atom

Electrostatic discharge (ESD)

sudden release of pent-up electrical energy through generation of a plasma and a resultant spark

Encapsulating

enclosing an article in an envelope of plastic or other sealant

Epoxy Resins

straight-chain thermoplastics and thermosetting resins based on ethylene oxide, its derivatives, or homologs

Flashover

disruptive electrical discharge around or over the surface of a solid or liquid insulator; flashover generally neutralizes local charge, but does not change the total charge state of a spacecraft (see Blowoff current)

Floating potential

potential that a spacecraft comes to under current balance with the surrounding plasma

Frequency

number of complete cycles or vibrations per unit of time

Glow discharge

nearby luminous neutral plasma of high charge density; a cathode will have a surface glow at low pressure and higher fields, owing to the excitation of the incoming positive ions and neutralization at the surface

Graded insulation

combination insulations, some portions of which are arranged to improve the distribution of the electric field to which the insulation combination is subjected

Gradient

rate of increase or decrease of a variable parameter

Grounded parts

parts that are so connected that, when the installation is complete, they are substantially at the same potential as the spacecraft ground

Ground insulation

major insulation used between a winding and the magnetic core or other structural parts, usually at ground potential

Hollow cathode

efficient plasma-emitting device that flows gas through a hollow orifice

Hygroscopic

tending to absorb moisture

Impedance

total opposition that a circuit offers to the flow of alternating current (AC) or any other time-varying current at a particular frequency; it is a combination of resistance R and reactance X , measured in ohms, and designated by $Z = (R^2 + X^2)^{1/2}$

Impregnate

fill the voids and interstices of a material with a compound

Impulse

unidirectional surge generated by the release of electric energy into an impedance network

Impulse ratio

ratio of the flashover, sparkover, or breakdown voltage of an impulse to the crest value of the power-frequency flashover, sparkover, or breakdown voltage

Insulation

material having a high resistance to the flow of electric current to prevent leakage of current from a conductor

Insulation resistance

ratio of the applied voltage to the total current between two electrodes in contact with a specific insulator

Insulation system

all the materials used to insulate a particular electrical or electronic product

Insulator

material of such low electrical conductivity that the flow of current through it can usually be neglected

Inverted gradient

the result of differential charging where the insulating surface or dielectric reaches a positive potential with respect to the neighboring conducting surface or metal

Ion

electrified portion of matter of sub-atomic, atomic, or molecular dimensions such as is formed when a molecule of gas loses an electron (when the gas is stressed electrically beyond the critical voltage) or when a neutral atom or group of atoms in a fluid loses or gains one or more electrons

Ionization

generally, the dissociation of an atom or molecule into positive or negative ions or electrons; restrictively, the state of an insulator whereby it facilitates the passage of current due to the presence of charged particles (usually induced artificially)

Normal gradient

the result of differential charging where the insulating surface or dielectric reaches a negative potential with respect to the neighboring conducting surface or metal

Over potential

voltage above the normal operating voltage of a device or circuit

Partial discharge

electric discharge that only partially bridges the insulation system between conductors when the voltage stress exceeds a critical value (these partial discharges can occur adjacent to a conductor, or elsewhere); often referred to as "corona," but the term "corona" is preferably reserved for localized discharges in cases around a conductor, bare or insulated, remote from any other solid insulation

Partial discharge pulse

voltage or current pulse that occurs at some designated location in the test circuit as a result of a partial discharge

Partial discharge pulse charge

quantity of charge supplied to the test specimen's terminals from the applied voltage source after a partial discharge pulse has occurred; the pulse charge is related but not necessarily equal to the quantity of charge flowing in the localized discharge; often referred to as apparent charge or terminal charge

Partial discharge pulse energy

energy dissipated during one individual partial discharge

Partial discharge pulse repetition rate

number of partial discharge pulses of specified magnitude per unit time

Partial discharge pulse voltage

peak value of the voltage pulse that, if inserted in the test circuit at a terminal of the test specimen, would produce a response in the circuit equivalent to that resulting from a partial discharge pulse within the specimen; also referred to as terminal corona pulse voltage

Particulates (space particulate debris)

sources of space particulate debris are Earth, spacecraft, and space environments (Earth particulate is mostly dust, sand, and solids in rocket exhaust; sources are materials spalled by cosmic dust impacts on materials and the solar array, outgassing products, and slip rings; space environment particulate consists of residues that form the space plasma, cosmic dust of masses less than one gram, micrometeoroids, and meteoroids)

Paschen discharge

breakdown of neutral gas in a high electric field

Permittivity

The dielectric constant of a material multiplied by the permittivity of empty space, where the permittivity of empty space, ϵ_0 , is a constant appearing in Coulomb's law (see Dielectric constant)

Plasma

gaseous body of ions and electrons of sufficiently low density that considerable charge separation is possible (because of the mobility of charge, a plasma is normally neutral and free of an electric field in its interior, just like a metallic conductor)

Plasma arcing

electrical discharges that are a consequence of the presence of a plasma at the site of the discharge

Plasma ground

see "Plasma potential"

Plasma potential

the potential as it exists on average in the space between charged particles, independent of the question of how it can be measured

Plasma temperature

kinetic temperature of a thermal plasma in eV or Kelvins. The ion temperature (T_i) in a plasma need not be the same as the electron temperature (T_e). The plasma temperature describes the average thermal energy of an ion or electron in the plasma

Plastic

high polymeric substances (including both natural and synthetic products, but excluding rubber products) that are capable of flowing under heat and pressure at one time or another

Polarization

state of a dielectric material such that the bulk orientation yields a net electric field. An electret is an example of a polarized material (see also Dielectric absorption)

Polyimide

polymer often used for spacecraft thermal control multilayer insulation blankets because of its radiation resistance; very thermally stable, this polymer is often also used for flexible solar array blankets (Kapton® is a polyimide)

Polymer

compound formed by polymerization that results in the chemical union of monomers or the continued reaction between lower molecular weight polymers

Polymerize

chemically unite two or more monomers or polymers of the same kind to form a molecule with higher molecular weight

Potential

work per unit charge required to bring any charge to the point from an infinite distance

Potting

similar to encapsulating, except that steps are taken to ensure complete absence of all voids in the object before the resin polymerizes

Power

time rate at which work is done; power is obtained in watts if work is expressed in joules and time is in seconds

Pressure

force per unit area; absolute pressure is measured with respect to zero pressure whereas gauge pressure is measured with respect to atmospheric pressure

Primary arc

trigger arc; an initial electrical discharge that may or may not trigger another type of discharge

Proton

elementary particle that is the positively charged constituent of ordinary matter and, together with the neutron, is a building stone of all atomic nuclei

Pulse

wave that departs from a first nominal state attains a second nominal state, and ultimately returns to the first nominal state

RC time constant

time constant obtained by multiplying resistance by capacitance

Relative humidity

ratio of the quantity of water vapor present in the air to the quantity that would saturate the air at any given temperature

Resistance

property of a conductor that determines the current produced by a given difference of potential; the ohm is the practical unit of resistance

Resistivity (specific insulation resistance)

electrical resistance between opposite faces of a 1-cm cube of an insulating material, commonly expressed in ohm-centimeters; sometimes called volume resistivity

Secondary arc

sustained electrical discharge resulting from an ESD or primary arc at a nearby location

Semiconductor

solid crystalline material whose electrical conductivity is intermediate between that of insulators and conductors, and is usually applied field and temperature dependent

Shelf life

length of time under specified conditions that a material retains its usability. Also called storage life

Silicone

polymeric materials in which the recurring chemical group contains silicon and oxygen atoms as links in the main molecular chain backbone, with recurring methyl and/or phenyl side groups; the high flexibility of the Si-O backbone gives this class of materials a low glass transition temperature, preferable for external surfaces like solar arrays.

Sizzle arc

sustained electric discharge due to dielectric breakdown

Snapover

phenomenon caused by secondary electron emission that can lead to electron collection on insulating surfaces in an electric field

Solar array

solar cells connected in series and/or parallel to generate power; often the sole power source for a spacecraft

Solar cell

photovoltaic device used to convert the energy in light to electrical energy

Sparkover (spark)

short-duration electric discharge due to a sudden breakdown of air or some other dielectric material separating two terminals, accompanied by a momentary flash of light; also known as electric spark and spark discharge

Storage life

period of time a liquid resin or adhesive can be stored and remain suitable for use; also called shelf life

String voltage

voltage of a single series-connected solar array segment near the maximum power point; often, this is the power system voltage

Surface creepage voltage

see "Creepage"

Surface flashover

see “Flashover”

Surface leakage

passage of current over the boundary surface of an insulator as distinguished from passage through its volume

Surface resistivity

resistance of a material between two opposite sides of a unit square of its surface; surface resistivity can vary widely with the conditions of measurement; often expressed as ohms per square, although a dimensional analysis yields units of ohms

Surge

transient variation in the current and/or potential at a point in the circuit

Sustained arc

electrical discharge that lasts much longer than the usual capacitance-discharging arc (on the order of 1 millisecond or longer)

Thermal conductivity

ability of a material to transport thermal energy

Tracking

scintillation of the surface of an insulator; can produce enough heat to leave a degraded track of carbon

Transient

that part of the change in a variable that disappears during transition from one steady state operating condition to another

Trigger arc

electrical discharge of one type that triggers a discharge of another type (see Primary arc)

Triple-point (triple-junction)

point where a plasma, a high-voltage conductor, and an insulator come together; at such a point, the electric field is often at a maximum, and plasma-arcing is more likely

Void

small enclosed cavity within an insulation system; can be centrally located or next to an electrode surface

Voltage

term most often used in place of electromotive force, potential difference, or voltage drop to designate electric pressure that exists between two points and is capable of producing a flow of current when a closed circuit is connected between the two points

Wire

metallic conductor of round, square, or rectangular cross-section that can be either bare or insulated

Working life

period of time a liquid resin or adhesive remains usable after mixing with catalyst solvent or other compounding ingredients