

Methods for

Measurements in electrostatics —

Part 1: Guide to basic electrostatics

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Committees responsible for this British Standard

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- British Floor Covering Manufacturers' Association
- British Plastics Federation
- British Rubber Manufacturers' Association Ltd.
- ERA Technology Ltd.
- Electrical and Electronic Insulation Association (BEAMA Ltd.)
- European Electrostatic Discharge Association
- Federation of the Electronics Industry
- Federation of Resin Formulators and Applicators Ltd.
- Health and Safety Executive
- Ministry of Defence
- RAPRA Technology Ltd.
- Tyre Manufacturers' Conference (Service Committee)

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Foreword

This Part of BS 7506 was prepared by Technical Committee PRI/25.

This Part is related to BS 5958 and BS EN 100015 which are codes of practice concerned with hazards arising from electrostatic phenomena.

Electrostatic problems are experienced in a wide spectrum of industry and measurements are made by technologists who are not necessarily experts in electrostatics. Part 2 of this British Standard describes methods for measuring electrostatic effects and quantifying the relevant properties of materials and gives guidance on implementation of the methods.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 20, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This Part of BS 7506 provides information and guidance on methods for making reliable measurements of electrostatic phenomena and the relevant properties of materials.

This Part comprises the following:

- review of basic electrostatics;
- outline of the range of problems caused by static;
- consideration of the role of materials and description of methods to minimize charge generation and achieve safe dissipation of static charge;
- consideration of electrostatic applications;
- recommendations for the control of the test environment conditions;
- general consideration of the basic recommendations for reliable measurement of electrostatic parameters.

2 References

2.1 Normative references

This British Standard incorporates, by reference, provisions from specific editions of other publications. These normative references are cited at the appropriate points in the text and the publications are listed on the inside back cover. Subsequent amendments to, or revisions of, any of these publications apply to this British Standard only when incorporated in it by updating or revision.

2.2 Informative references

This British Standard refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of this standard are listed on the inside back cover, but reference should be made to the latest editions.

3 Definitions

For the purposes of this British Standard the following definitions apply.

3.1

antistatic material or treatment

a material or treatment which allows easy migration of charge so that when bonded to earth the material does not retain static charge or one which does not easily acquire charge by contact

NOTE An antistatic material will satisfy the quantitative requirements of either a dissipative or an astatic material (see 3.12 and 3.3).

3.2

antistatic additive or filler

a substance added to a liquid or a solid in order to promote more rapid charge migration and so reduce its ability to retain significant electrostatic charge when in contact with earth

3.3

astatic material

a material with low tendency for charge separation by contact or by rubbing against other materials

NOTE As a means to control static risks it is essential that the maximum surface charge generated in an approved test procedure should remain below the relevant hazard threshold value.

3.4

bonding

the use of an additional independent connection between conductors to provide electrical continuity when this cannot otherwise be ensured

3.5

breakdown

the annihilation, at least temporary, of the insulating properties of an insulating medium under electric stress

3.6

breakdown voltage

the voltage at which breakdown occurs, under prescribed conditions of test or use

3.7

charge decay

the migration of charge across or through a material leading to a reduction of charge density or surface potential at the point where the charge was deposited

NOTE It is usually measured by observation of the timescale for decay of surface voltage.

3.8

charge decay time constant

the time required for the local charge density or surface potential to fall to $1/e$ of its initial value

NOTE For characterizing materials the initial value should be the relevant hazard threshold value.

3.9

conductive material

a material of relatively high conductivity or charge carrier mobility. Materials of surface resistivity below $10^6 \Omega$ or volume resistivity below $10^7 \Omega \text{ m}$ are usually implied

3.10

conductivity

the reciprocal of resistivity (Sm^{-1} , equal to $(\Omega \text{ m})^{-1}$)

**3.11
conductor**

a material providing a sufficiently high conductivity that all parts of it are always at the same potential

**3.12
dissipative material**

a material which allows charge to migrate over its surface and/or through its volume in a time which is short compared to the timescale of the actions creating the charge or the time within which this charge will cause a problem. For normal applications the decay time constant for a patch of deposited charge downwards from the hazard threshold value should be within the range 0.01 s to 0.5 s

**3.13
earth/earthing**

electrical connection (bonding) of a conductor to the main body of the earth to ensure that it is at earth potential

**3.14
earth bonding point**

a dedicated point for connecting equipment and people to earth

**3.15
electrostatic discharge (ESD)**

the sudden transfer of electrostatic charge between bodies at different electrostatic potentials by direct contact or by breakdown

**3.16
electrostatic discharge sensitive device (ESDS)**

a discrete device, semiconductor, integrated circuit or other assembly that can be damaged by an electrostatic discharge directly to the device or nearby

**3.17
ESD common earth bonding point**

a common connection point to which all items in an ESD protected area are connected

**3.18
ESD protected area (EPA)**

an area with a defined boundary within which an ESDS can be handled without risk of damage from electrostatic discharges or fields

**3.19
ESDS voltage sensitivity**

the maximum voltage at which the ESDS does not suffer any ESD damage

**3.20
ESDS voltage sensitivity of an assembly**

the ESDS voltage sensitivity of the most sensitive device in an assembly will determine the sensitivity of the assembly

**3.21
field work**

handling ESDS within a temporary EPA with controlled boundaries

**3.22
flammable material**

a gas, vapour, liquid, dust or solid that can react continuously with atmospheric oxygen and that may, therefore, sustain fire or explosion when such reaction is initiated by a suitable spark, flame or hot surface

NOTE In normal usage gas and vapour are synonymous.

**3.23
flammable mixture**

a mixture of a gas, mist or suspension of dust with air (or air enriched with oxygen) in which combustion will propagate

**3.24
flammable range**

the range of concentrations in air of a flammable material within which combustion can occur

**3.25
garment**

a coat, jacket, smock, hood, trousers, overall or cap

**3.26
ground**

this is synonymous with earth

**3.27
ground cord**

a flexible electrical connection between the earth bonding point and the ESD earth facility

**3.28
hazard threshold voltage**

the minimum capacitively stored voltage at which an electrostatic hazard or risk will exist

**3.29
hazardous area**

an area in which flammable or explosive gas-air mixtures are, or may be expected to be, present in quantities such as to require special precautions against ignition

**3.30
incendive**

capable of igniting a prescribed flammable mixture

3.31 insulator

a material with very low mobility of charge so that any charge on the surface will remain there for a long time

NOTE The charge decay time constant is generally greater than 10 s.

3.32 ion

an atomic or molecular particle carrying electrical charge

3.33 mass charge density

the net quantity of charge carried by unit mass of a material (C kg^{-1})

3.34 minimum ignition energy

the smallest amount of energy released in a spark that can ignite a mixture of a specified flammable material with air or oxygen, measured by a standard procedure

3.35 packaging material

any material in which ESDS are packed in intimate contact or close proximity for transportation or storage; including bags, boxes, crates, wraps, magazines, cushioning, foams, loose fill, etc

3.36 relaxation

the migration of charge over and/or through a solid, liquid or gaseous material causing a reduction in surface charge density and potential

3.37 relaxation time constant

charge decay time constant

3.38 shielding material

a material which when formed into an enclosure provides strong attenuation of fast electric field transients associated with spark discharges to, or in the vicinity of, the outside of the enclosure

3.39 shielding bag/container

a bag or container made from shielding material which provides protection for the storage or transport of ESDS

NOTE For normal applications it is necessary to provide 1 000 : 1 voltage attenuation ratio over the frequency range 10 Hz to 1 GHz between the inside and outside region. This may be affected by both the material and the construction.

3.40 surface charge density

the net quantity of charge per unit area of surface of a solid or liquid (C m^{-2})

3.41 surface resistivity

the resistance between opposing sides of a square on the surface of a material with account taken of all current flow paths

3.42 triboelectric charging

the separation of charge occurring at relative contact movement between two surfaces

3.43 volume charge density

the net quantity of charge per unit volume of a solid, liquid or gas (C m^{-3})

3.44 volume resistivity

the resistance between opposing sides of a cube of the material with account taken of fringing field effects

3.45 permittivity (absolute)

the quantity whose product by the electric field strength is the electric flux density or surface charge density

3.46 electric constant ϵ_0

the value of the permittivity in a vacuum, sometimes referred to as the permittivity of free space

3.47 relative permittivity

the ratio of the absolute permittivity to the electric constant. The permittivity is often taken to mean relative permittivity. It is also the ratio of the capacitance of an electrode system filled with a dielectric to that where the interelectrode space is free of all material (i.e. in a vacuum)

4 List of symbols

The following symbols are used in this standard:

Quantity	Symbol	Unit or value
Area	A	m^2
Capacitance	C	F
Charge	Q	C
Charge density	σ	Cm^{-2}
Conductivity	γ	$\Omega^{-1}\text{m}^{-1}$
Current	I	A
Electric field	E	V/m
Energy, potential energy	W	J
Ionic charge	ϵ	C
Ionic mobility	μ	$\text{m}^2\text{V}^{-1}\text{s}^{-1}$
Linear dimension (thickness, diameter)	d	m
Permittivity, relative	ϵ	1
Potential	V	V
Probability	P	1
Resistance	R	Ω
Temperature (Kelvin)	T	K
Time	t	s
Electric constant	ϵ_0	$8.85 \times 10^{-12} \text{ Fm}^{-1}$
Base of natural logarithms	e	2.718282
Boltzmann's constant	k	$1.3804 \times 10^{-23} \text{ J/K}$

5 Fundamentals of static electricity

5.1 General

The most common cause of electrostatic charge is contact electrification. Conducting objects can become charged by induction if they reside in an electric field produced by other charged objects or conductors at high potential in the vicinity. Any object can become charged if charged particles or ionized molecules accumulate on it.

5.2 Contact electrification

Contact electrification can occur at solid/solid, liquid/liquid or solid/liquid interfaces. Clean gases cannot be charged in this way. If a gas contains solid particles or liquid droplets in suspension, however, these may be charged by contact so that such a gas can carry an electrostatic charge by virtue of these particles.

In the case of dissimilar solids, initially uncharged and normally at earth potential, a small amount of charge is transferred from one material to the other when they make contact. The two materials are, therefore, oppositely charged and consequently there is an electric field between them. If the materials are then separated, work has to be done to overcome the attraction between the opposing charges and the potential difference between them, therefore, increases linearly with distance. This higher potential difference tends to drive charge back to any point of residual contact. In the case of two conductors the recombination of charges is virtually complete and no significant amount of charge remains on either material after separation. If one material, or both, is a non-conductor, the recombination cannot take place completely and the separating materials retain part of their charge. There may only be a small amount of charge involved but, because the distance between the charges when the surfaces are in contact is extremely small, the potential generated on separation can easily reach many kilovolts. In practice, surfaces are usually rough and so the charging is enhanced if the contact and separation involves rubbing since the area of real contact is increased.

Contact electrification in liquids is essentially the same process but it can depend on the presence of ions or sub-microscopic charged particles. Ions (or particles) of one polarity may be adsorbed at the interface and they then attract ions of opposite polarity forming a diffuse layer of charge in the liquid, close to the surface. If the liquid is then moved relative to the interface, it carries away some of this diffuse layer, thereby bringing about separation of the opposing charges. As in the case of solids a high voltage is generated because of the work done to bring about separation, provided that the liquid is sufficiently non-conducting to prevent recombination. Such processes can occur at both solid/liquid and liquid/liquid interfaces.