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TECHNICAL REPORT

RAPPORT TECHNIQUE

Electrostatics –
Part 1: Electrostatic phenomena – Principles and measurements

Electrostatique –
Partie 1: Phénomènes électrostatiques – Principes et mesures

IEC/TR 61340-1:2012

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ELECTROSTATICS –

Part 1: Electrostatic phenomena – Principles and measurements

FOREWORD

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IEC/TR 61340-1, which is a technical report, has been prepared by IEC technical committee 101: Electrostatics.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
101/344/DTR	101/355/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all the parts in the IEC 61340 series, published under the general title *Electrostatics,* can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

The contents of the corrigenda 1 (March 2013) and 2 (December 2017) have been included in this copy.

INTRODUCTION

Static electricity has been known for around 2 500 years but until recently had little impact on humankind. More recently in the last century the nature of static electricity became better understood and the principles of charge separation and accumulation could be described. Despite this improved understanding, it remains difficult to predict with certainty the polarity and magnitude of charges built up in any situation due to the many factors involved, and to, many electrostatics remains a “black art” rather than a science.

The development of modern materials, especially polymers, and their nearly ubiquitous application in fields such as floor materials, furnishings, clothing and engineering materials, has made static electricity an everyday phenomenon. In some industries, such as electronics manufacture and processes using flammable materials, unintended and invisible electrostatic discharges can lead to substantial component damage or unreliability, or fires or explosions. In everyday life, experience of electrostatic shocks to personnel has become commonplace. This has led to increasing need to understand such phenomena, and to specify materials, equipment and procedures for use in preventing and controlling electrostatic problems in the human environment.

This technical report gives an overview of the field of electrostatics and has been prepared to give the user a view of the background, principles, methods of measurement and industrial applications prepared in conformity with IEC TC101 publications.

ELECTROSTATICS –

Part 1: Electrostatic phenomena – Principles and measurements

1 Scope

This part of IEC 61340, which is a technical report, describes the fundamental principles of electrostatic phenomena including charge generation, retention and dissipation and electrostatic discharges.

Methods for measuring electrostatic phenomena and related properties of materials are described in a general way.

Hazards and problems associated with electrostatic phenomena and principles of their control are outlined.

Useful applications of electrostatic effects are summarized.

The purpose of this technical report is to serve as a reference for the development of electrostatics related standards, and to provide guidance for their end-users.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60079-10-1, *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*

IEC 60079-10-2, *Explosive atmospheres – Part 10-2: Classification of areas – Combustible dust atmospheres*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61340-5-1, *Electrostatics – Part 5-1: Protection of electronic devices from electrostatic phenomena – General requirements*

IEC 61340-5-2, *Electrostatics – Part 5-2: Protection of electronic devices from electrostatic phenomena – User guide*

IEC 60243-1, *Electrical strength of insulating materials – Test methods – Part 1: Tests at power frequencies*

IEC 60243-2, *Electric strength of insulating materials – Test methods – Part 2: Additional requirements for tests using direct voltage*

IEC 61241-2-3, *Electrical apparatus for use in the presence of combustible dust – Part 2: Test methods – Section 3: Method for determining minimum ignition energy of dust/air mixtures*

BS EN 13821, *Potentially explosive atmospheres. Explosion prevention and protection. Determination of minimum ignition energy of dust/air mixtures*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
antistatic additive
antistatic filler, antistatic treatment
substance added to, or process applied to a liquid or solid in order to reduce its tendency to acquire a charge by contact and rubbing, or to promote more rapid charge migration and so to reduce its ability to retain significant charge when in contact with earth

3.2
antistatic
refers to the property of a material that inhibits or limits triboelectric charging

3.3
bonding
electrical connection between two or more conducting objects that reduces the potential difference between them to an insignificant level

3.4
breakdown
failure, at least temporarily, of the insulating properties of an insulating medium under electric stress

3.5
breakdown voltage
voltage at which breakdown occurs, under prescribed conditions of test or use

3.6
charge decay
neutralization or migration of charge across or through a material leading to a reduction of charge density or surface potential at the point where the charge is deposited

3.7
charge decay time
charge relaxation time
time taken for charge to decay from a specified value to a specified lower value

Note 1 to entry: The specified lower value is commonly one tenth or 1/e of the starting value (e = 2,718).

3.8
conductivity
ability of the substance to conduct electrical current expressed as $S \times m^{-1}$

3.9
conductor or conductive material
object or material providing a sufficiently high conductivity so that potential differences over any parts of it are not sufficiently large as to be of practical significance

Note 1 to entry: In general this is a material having a resistance below about $_{10}{}^{5}\Omega$ but different standards may define different resistance ranges for this term.

3.10
dissipative material
material which allows charge to migrate over its surface and/or through its volume in a time that is short compared to the timescale of the actions creating the charge or that will cause an electrostatic problem

Note 1 to entry: In general a material having a resistance approximately 10^5 Ω and below approximately 10^{11} Ω is considered to be dissipative. Different standards may disagree on the exact values of the limits.

3.11
earth, earthing, grounding
ground
electrical connection (bonding) of a conductor to the main body of the earth to ensure that it is at earth potential

3.12
electrostatic discharge
ESD
transfer of charge by direct contact or by breakdown from a material or object at a different electrical potential to its immediate surroundings

3.13
explosion groups
flammable gaseous atmospheres subdivided into explosion groups I, IIA, IIB and IIC to define their inflammability

Note 1 to entry: The most sensitive explosion group is Group IIC.

Note 2 to entry: See [9] to [11][1] for definitions of classification method.

3.14
flammable substance
substance in the form of gas, liquid, solid or mixture of these, capable of propagating combustion when subjected to a sufficiently strong ignition source

3.15
hazard threshold voltage
minimum electrical potential of capacitive stored charge that may give rise to an electrostatic hazard

3.16
hazardous area
area in which flammable substance is, or may be expected to be, present in quantities such as to require special precautions against ignition

Note 1 to entry: Hazardous area zones are defined in IEC 60079-10-1 and IEC 60079-10-2.

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1 References in square brackets refer to the bibliography.

3.17
insulator
insulative material
material with very low mobility of charge so that any charge on the surface will remain there for long time

Note 1 to entry: Connecting an insulator to earth does not help charge migration.

3.18
minimum ignition energy
MIE
smallest amount of energy released in a capacitive electrical spark that can ignite a mixture of a specified flammable material with air or oxygen, according to a defined procedure

3.19
relaxation of charge
migration or neutralization of charge over and/or through a solid, liquid or gaseous material causing a reduction in surface charge density and energy

Note 1 to entry: If the potential of a surface is defined then this is also reduced.

3.20
surface charge density
σ_s
net quantity of charge per unit area of surface of a solid or liquid

3.21
surface resistivity
Ω
resistance between opposing sides of a square on the surface of a material

3.22
triboelectric charging
electrical charging process in which charge is generated by the contact and separation of two surfaces which may be solid, liquid or particle-carrying gases

3.23
volume charge density
σ_v
net quantity of charge per unit volume of a solid, liquid or gas

3.24
volume resistivity
Ω×m
resistance between opposing sides of 1 m^3 of the material

4 Fundamentals of static electricity

4.1 General

Generally, electrostatic charge on a material, product or object is the result of:

- contact and rubbing;
- charge transfer;
- induction in an electric field;

- effect of polarization;
- photoelectric effect;
- pyroelectric effect;
- piezoelectric effect;
- ionization and ions adsorption;
- electrochemical processes.

However, the primary source of electrostatic charge is triboelectric charging. If two previously uncharged substances come into contact, charge transfer will, in general, occur at their common boundary. If a gas containing solid particles or liquid droplets in suspension becomes charged by contact and separation, then the gas can be seen as carrying an electrostatic charge. On separation, each surface will carry an additional charge of equal magnitude but of opposite polarity. Conducting or dissipative objects can become charged by induction if they reside in an electric field produced by other charged objects or conductors at high potential in their vicinity. Any object can become charged if charged particles or molecules accumulate on it.

It is very important to have some appreciation of these phenomena in order to enable the proper implementation of test procedures and unambiguous interpretation of the resultant data. It is also important with regard to choice of electrodes, protection of current measuring devices from the initial capacitive surge and the time at which the value is recorded. The latter should, of course, be appropriate to meet the practical circumstance for which the data are required. Further comments are included in this technical report with the descriptions of the individual test methods, where considered necessary.

4.2 Contact electrification

Contact electrification can occur at solid/solid, liquid/liquid or solid/liquid interfaces. Clean gases cannot charge materials 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 solids of different materials, initially uncharged and normally at earth potential, charge is transferred from one material to the other when they make contact. When they separate, a net positive charge remains on the one surface and a net negative charge on the other surface. The quantity of charge is increased by the size of the contact areas and the size is affected by the contact pressure. Additional rubbing also increases the effective contact area.

The relative amounts and polarity of charge transferred between materials can be presented as a list, referred to as the triboelectric series. A material is expected to charge positively against materials lower in the series, and negatively against materials higher in the series. It should be noted that the position of a material in the triboelectric series is an approximation, dependent on test conditions, and that two samples of the same material rubbed against each other can result in quite strong charging.

Examples of triboelectric series are shown in Table 1.

Table 1 – Example of triboelectric series

Item	Charge
Rabbit fur	Positive
Glass	
Human hair	
Polyamide (nylon)	
Wool	
Fur	
Silk	
Aluminum	
Paper	
Cotton	
Steel	
Wood	
Rubber	Negative
Acetate rayon	
Polyethylene (PE) and polypropylene (PP)	
PET	
PVC	
Polyurethane	
PTFE	

The two materials are oppositely charged and consequently there is an electric field between them. If the materials are then separated, measures shall be taken to overcome the attraction between the opposing charges and the potential difference between them 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. Realistic surfaces are usually rough and so the charging is enhanced if the contact and separation involves rubbing and/or pressure, since the area of real contact is increased by these actions. Note that the real area of contact can be quite different in size from the appearing area of contact. They can differ by a magnitude or more.

Contact electrification in liquids is essentially the same process but it can depend on the presence of ions or sub-microscopic charged particles (the latter are usually less important). Ions (or particles) of one polarity may be absorbed at the interface and they then attract ions of opposite polarity which form 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.

4.3 Charging by induction

There is an electric field around any charged object. A conductor or dissipative material introduced into this field changes the distribution of electric field in its vicinity and at the same time there is a redistribution of charges in the material under the influence of the field (see