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BSI Standards Publication

Railway applications — Insulation coordination

Part 1: Basic requirements — Clearances and creepage distances for all electrical and electronic equipment

National foreword

This British Standard is the UK implementation of EN 50124-1:2017. It supersedes BS EN 50124-1:2001+A2:2005 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/9, Railway Electrotechnical Applications.

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European foreword

This document (EN 50124-1:2017) has been prepared by CLC/TC 9X, “Electrical and electronic applications for railways.”

The following dates are fixed:

• latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2018–02–06
• latest date by which the national standards conflicting with this document have to be withdrawn	(dow)	2020–02–06

This document supersedes EN 50124-1:2001, EN 50124-1:2001/A1:2003 and EN 50124-1:2001/A1:2005.

EN 50124-1:2017 includes the following significant technical changes with respect to EN 50124-1:2001:

- the scope has been enlarged to include altitudes higher than 2 000 m above sea level;
- related requirements have been included, especially new subclause 5.4, Table A.9 and Table A.10.

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This document has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For the relationship with EU Directive(s) see informative Annex ZZ, which is an integral part of this document.

Introduction

Special conditions occurring in railway applications and the fact that the equipment here concerned falls into the scope of both the EN 60071 series (prepared by CLC/SR 28) and EN 60664-1 (prepared by CLC/SR 109), led to the decision to draw from these documents and from EN 60077-1 (prepared by CLC/TC 9), a single document of reference for all standards applicable to the whole railway field.

EN 50124 consists of two parts:

— EN 50124-1, *Railway applications - Insulation coordination - Part 1: Basic requirements - Clearances and creepage distances for all electrical and electronic equipment*;

— EN 50124-2, *Railway applications - Insulation coordination - Part 2: Overvoltages and related protection*.

This Part 1 allows, in conjunction with EN 50124-2, to take into account advantages resulting from the presence of overvoltage protection when dimensioning clearances.

1 Scope

This European Standard deals with insulation coordination in railways. It applies to equipment for use in signalling, rolling stock and fixed installations.

Insulation coordination is concerned with the selection, dimensioning and correlation of insulation both within and between items of equipment. In dimensioning insulation, electrical stresses and environmental conditions are taken into account. For the same conditions and stresses, these dimensions are the same.

An objective of insulation coordination is to avoid unnecessary over dimensioning of insulation.

This standard specifies:

— requirements for clearances and creepage distances for equipment;

— general requirements for tests pertaining to insulation coordination.

The term equipment relates to a section as defined in 3.3 it may apply to a system, a sub-system, an apparatus, a part of an apparatus, or a physical realization of an equipotential line.

This standard does not deal with:

— distances through solid or liquid insulation;

— distances through gases other than air;

— distances through air not at atmospheric pressure;

— equipment used under extreme conditions.

Product standards should align with this generic standard.

However, they may require, with justification, different requirements due to safety and/or reliability reasons, e.g. for signalling, and/or particular operating conditions of the equipment itself, e.g. overhead contact lines which should comply with EN 50119.

This standard also gives provisions for dielectric tests (type tests or routine tests) on equipment (see Annex B).

NOTE For safety critical systems, specific requirements are needed. These requirements are given in the product specific signalling standard EN 50129.

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.

EN 50123 (all parts), *Railway applications - Fixed installations - D.C. switchgear*

EN 50163, *Railway applications - Supply voltages of traction systems*

EN 60060-1, *High-voltage test techniques - Part 1: General definitions and test requirements (IEC 60060-1)*

EN 60071-1, *Insulation co-ordination - Part 1: Definitions, principles and rules (IEC 60071-1)*

EN 60112, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials (IEC 60112)*

EN 60587, *Electrical insulating materials used under severe ambient conditions - Test methods for evaluating resistance to tracking and erosion (IEC 60587)*

EN 60664-1:2007, *Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests (IEC 60664-1:2007)*

3 Terms and definitions

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

NOTE The definitions apply according to the following order of priority:

— the definition given here-under;

— the definition given in EN 60664–1;

— the definition given in the documents mentioned in Clause 2 other than EN 60664–1.

3.1
clearance
shortest distance in air between two conductive parts

3.2
creepage distance
shortest distance along the surface of the insulating material between two conductive parts

3.3 Sections

3.3.1
section
part of an electrical circuit having its own voltage ratings for insulation coordination

Note 1 to entry: Sections fall into two categories: earthed section and floating section.

3.3.2
earthed section
section connected to earth or to the vehicle body through a circuit for which interruption is not expected

3.3.3
floating section
section isolated from earth or from the vehicle body

Note 1 to entry: A section can be under electrical influence from adjacent sections.

Note 2 to entry: A particular point of a circuit can be considered as a section.

3.4 Voltages

3.4.1
nominal voltage
U_n
suitable approximate voltage value used to designate or identify a given supply system

3.4.2
working voltage

highest r.m.s. value of the a.c or d.c voltage which can occur between two points across any insulation, each circuit likely to influence the said r.m.s. value being supplied at its maximum permanent voltage

Note 1 to entry: Permanent means that the voltage lasts more than 5 min, as $U_{max\ 1}$ in EN 50163.

3.4.3
rated voltage

value of voltage assigned by the manufacturer to a component, device or equipment and to which operation and performance characteristics are referred

Note 1 to entry: Equipment may have more than one rated voltage value or may have a rated voltage range.

3.4.4
rated insulation voltage

U_{Nm}

r.m.s. withstand voltage value assigned by the manufacturer to the equipment or a part of it, characterising the specified permanent (over 5 min) withstand capability of its insulation

Note 1 to entry: U_{Nm} is a voltage between a live part of equipment and earth or another live part. For rolling stock, earth refers to the vehicle body.

Note 2 to entry: For circuits, systems and sub-systems in railway applications this definition is preferred to “highest voltage for equipment” which is widely used in international standards

Note 3 to entry: U_{Nm} is higher than or equal to the working voltage. As a consequence, for circuits directly connected to the contact line, U_{Nm} is equal to or higher than U_{max1} as specified in EN 50163.

Note 4 to entry: U_{Nm} is not necessarily equal to the rated voltage which is primarily related to functional performance.

3.4.5
working peak voltage

highest value of voltage which can occur in service across any particular insulation

3.4.6
recurring peak voltage

maximum peak value of periodic excursions of the voltage waveform resulting from distortions of an a.c. voltage or from a.c. components superimposed on a d.c. voltage

Note 1 to entry: Random overvoltages, for example due to occasional switching, are not considered to be recurring peak voltages.

3.4.7
rated impulse voltage

U_{Ni}

impulse voltage value assigned by the manufacturer to the equipment or a part of it, characterising the specified withstand capability of its insulation against transient overvoltages

Note 1 to entry: U_{Ni} is higher than or equal to the working peak voltage.

3.5
overvoltage

voltage having a peak value exceeding the corresponding peak value (including recurrent overvoltages) of maximum steady-state voltage at normal operating conditions

3.5.1
temporary overvoltage
overvoltage of relatively long duration due to voltage variations

Note 1 to entry: A temporary overvoltage is independent of the network load. It is characterized by a voltage/time curve.

3.5.2
transient overvoltage
short duration overvoltage of a few milliseconds or less due to current transfers

Note 1 to entry: A transient overvoltage depends on the network load. It cannot be characterized by a voltage/time curve. Basically, a transient overvoltage is the result of a current transfer from a source to the load (network).

Note 2 to entry: Two particular transient overvoltages are defined in 3.5.3 and 3.5.4.

3.5.3
switching overvoltage
transient overvoltage at any point of the system due to specific switching operation or fault

3.5.4
lightning overvoltage
transient overvoltage at any point of the system due to a specific lightning discharge

Note 1 to entry: The definitions of 3.5 are in accordance with those of EN 60664–1 and EN 50163. However, the prevalence of the nature of the cause (voltage variations or current transfer) upon time, for segregating transient overvoltages from temporary ones, is clearly stated here (whereas the nature of the cause is not considered in EN 60664–1). Long-term (typically 20 ms to typically 1 s) overvoltages defined in EN 50163, dedicated to contact line networks, are equivalent to temporary overvoltages.

3.6 Insulations

3.6.1
functional insulation
insulation between conductive parts which is necessary only for the proper functioning

3.6.2
basic insulation
insulation applied to live parts to provide basic protection against electric shock

3.6.3
supplementary insulation
independent insulation applied in addition to basic insulation, in order to provide protection against electric shock in the event of failure of basic insulation

3.6.4
double insulation
insulation comprising both basic insulation and supplementary insulation

3.6.5
reinforced insulation
single insulation system applied to live parts, which provides a degree of protection against electric shock equivalent to double insulation

Note 1 to entry: The term "single insulation system" does not imply that the insulation involves one homogeneous piece. It may involve several layers which cannot be tested singly as basic and supplementary insulation.

3.7 Contact lines

3.7.1
contact line
conductor system for supplying electric energy to vehicles through current-collecting equipment

[SOURCE: IEC 60050-811:1991, 811-33-01]

3.7.2
overhead contact line
catenary (deprecated)
contact line placed above (or beside) the upper limit of the vehicle gauge and supplying vehicles with electric energy through roof-mounted current collection equipment

[SOURCE: IEC 60050-811:1991, 811-33-02]

4 Basis for insulation coordination

4.1 Basic principles

4.1.1 General

Insulation coordination implies the selection of the electric insulation characteristic of the equipment with regard to its application and in relation to its surroundings.

Insulation coordination can only be achieved if the design of the equipment is based on the stresses to which it is likely to be subjected during its anticipated lifetime.

4.1.2 Insulation coordination with regard to voltage

4.1.2.1 General

Consideration shall be given to:

— the voltages which can appear in the system;

— the voltages generated by the equipment (which could adversely affect other equipment in the system);

— the degree of the expected availability of the equipment;

— the safety of persons and property, so that the probability of undesired incidents due to voltage stresses do not lead to an unacceptable risk of harm;

— the safety of functions for control and protection systems;

— voltages induced in track-side cables;

— the shape of insulating surfaces;

— the orientation and the location of creepage distances;

— if necessary: the altitude that applies.

4.1.2.2 Insulation coordination with regard to permanent a.c. or d.c. voltages

Insulation coordination with regard to permanent voltages is based on:

— rated voltage;

— rated insulation voltage;

— working voltage.

Unless otherwise specified in product standards, permanent voltages last more than five minutes.

4.1.2.3 Insulation coordination with regard to transient overvoltage

Insulation coordination with regard to transient overvoltage is based on controlled overvoltage conditions. There are two kinds of control:

— inherent control: the condition within an electrical system wherein the characteristics of the system can be expected to limit the prospective transient overvoltages to a defined level;

— protective control: the condition within an electrical system wherein specific overvoltage attenuating means can be expected to limit the prospective transient overvoltages to a defined level.

NOTE 1 Overvoltages in large and complex systems such as overhead contact lines subjected to multiple and variable influences can only be assessed on a statistical basis. This is particularly true for overvoltages of atmospheric origin and applies whether the controlled condition is achieved as a consequence of inherent control or by means of protective control.

A probabilistic analysis is recommended to assess whether inherent control exists or whether protective control is needed.

NOTE 2 The specific overvoltage attenuating means can be a device having means for storage or dissipation of energy and, under defined conditions, capable of harmlessly dissipating the energy of overvoltages expected at the location.

EXAMPLE of inherent control: Control ensured by flash-over across insulators or spark gap horns on overhead contact lines.

EXAMPLE of protective control: Control ensured by the filter of a locomotive on the downstream circuit, provided that no switching overvoltage source is likely to perturb the said circuit.

Insulation coordination uses a preferred series of values of rated impulse voltage: it consists of the values listed in the first column of Table A.3.

4.1.2.4 Insulation coordination with regard to recurring peak voltage

Consideration shall be given to the extent partial discharges can occur in solid insulation or along surfaces of insulation.

4.1.3 Insulation coordination with regard to environmental conditions

The micro-environmental conditions for the insulation shall be taken into account as classified by the pollution degree.

The micro-environmental conditions depend primarily on the macro-environmental conditions in which the equipment is located and in many cases the environments are identical. However, the micro-environment can be better or worse than the macro-environment where, for example, enclosures, heating, ventilation or dust influence the micro-environment.

NOTE Protection by enclosures provided according to classes specified in EN 60529 does not necessarily improve the micro-environment with regard to pollution.

4.2 Voltages and voltage ratings

4.2.1 General

For determining the working voltage of a floating section, it is considered that a connection is made to earth or to another section, so as to produce the worst case.

It is recommended to avoid floating sections in high voltage systems.

The voltages in 4.2 are “required voltages” that would be specified for a particular application. These are different from rated voltages that are stated by a manufacturer for a product.

Rated voltages are defined for each section of a circuit.

4.2.2 Rated insulation voltage U_{Nm}

The minimum value of the rated insulation voltage of a section shall be higher or equal to the highest working voltage appearing within the section, or produced by adjacent sections.

Stresses shorter than 5 min (e.g U_{max2} as defined in EN 50163) may be taken into account case by case, considering in particular the interval between such stresses.

4.2.3 Rated impulse voltage U_{Ni}

4.2.3.1 General

The minimum value of rated impulse voltage of a section shall be determined either by method 1 or by method 2.

In inherent control, method 1 should be used.

In protective control, method 1 and method 2 may be used.

4.2.3.2 Method 1

Method 1 is based on rated insulation voltages and overvoltage categories.

The relation between rated insulation voltages and nominal voltages commonly used in railway applications is given in Table D.1 of Annex D.

Method 1 uses four overvoltage categories to characterize the exposure of the equipment to overvoltages.

- OV1: Circuits which are protected against external and internal overvoltages and in which only very low overvoltages can occur because:
  - they are not directly connected to the contact line;
  - they are being operated indoor;
  - they are within an equipment or device;
- OV2: The same as OV1, but with harsher overvoltage conditions and/or higher requirements concerning safety and reliability;
- OV3: The same as OV4, but with less harsh overvoltage conditions and/or lower requirements concerning safety and reliability;
- OV4: Circuits which are not protected against external or internal overvoltages (e.g. directly connected to the contact or outside lines) and which can be endangered by lightning or switching overvoltages.

Further details for specific applications are given in Clause 8.

In method 1, the minimum value of rated impulse voltage of a section shall be determined as follows:

— For low voltage circuits not powered directly by the contact line, the rated impulse voltage is given by Table A.1;

— For circuits powered by the contact line and for traction power circuits in thermo-electric driven vehicles the rated impulse voltage is given by Table A.2.

When a specific protection against overvoltages is involved, the choice of the overvoltage category is linked to the characteristics of this protective device.

4.2.3.3 Method 2

In method 2, the minimum value of rated impulse voltage of a section shall be higher or equal to the working peak voltage appearing within the section, or produced by adjacent sections.

4.2.3.4 Contingency

Contingency need not be applied to the rated impulse voltage, whatever the method.

4.3 Time under voltage stress

With regard to creepage distances, the time under voltage stress influences the number of drying-out incidents capable of causing surface electrical discharge with energy high enough to entail tracking. The number of drying-out incidents is considered to be sufficiently large to cause tracking:

— in equipment intended for continuous use and not generating in its interior sufficient heat for drying-out;

— in equipment on the input side of a switch and between the line and load (input and output) terminals of a switch supplied directly from the low-voltage mains;

— in equipment subject to condensation for long periods and frequently switched on and off.

The creepage distances shown in Tables A.5, A.6 and A.7 have been determined for insulation intended to be under continuous voltage stress for a long time.

4.4 Pollution

The micro-environment determines the effect of pollution on the insulation. The macro-environment, however, shall be taken into account when considering the micro-environment.

Means may be provided to reduce pollution at the insulation under consideration by effective use of enclosures, encapsulation or hermetic sealing. Such means to reduce pollution may not be effective when the equipment is subject to condensation or if, in normal operation, it generates pollutants itself.

Small clearances can be bridged completely by solid particles, dust and water and therefore minimum clearances are specified where pollution can be present in the micro-environment.

NOTE 1 Pollution will become conductive in the presence of humidity. Pollution caused by contaminated water, soot, metal or carbon dust is inherently conductive.

NOTE 2 Conductive pollution by ionized gases and metallic deposits occurs only on specific instances, for example in arc chambers of switchgear or controlgear, and is not covered by this standard.

For the purpose of evaluating creepage distances and clearances, seven degrees of pollution PD1, PD2....PD4B are established according to Table A.4.

NOTE 3 The seven pollution degrees were derived from EN 60664–1, IEC/TR 60815:1986 and EN 60077–1, but some definitions are not identical. The main reason is that PD4 of EN 60664–1 and EN 60077–1 had to be broken down into PD3A, PD4, PD4A and PD4B of this standard to cover railway applications and experience. Nevertheless, the definitions given in this standard are consistent with those of EN 60077–1 when the pollution degree is strictly identical.

The classification considers micro-environmental conditions only. However, macro-environmental conditions should not be ignored. Annex E gives some guidance when trying to define the relevant PD to be applied to a practical case.

4.5 Insulating material

4.5.1 General

External high voltage insulators shall comply with their relevant product standards. Additional compliance to this standard is not required.

4.5.2 Comparative tracking index (CTI)

4.5.2.1 Insulating materials can be roughly characterized according to the damage they suffer from concentrated release of energy during electrical discharge when a surface leakage current is interrupted due to drying of the contaminated surface. The following behaviour of insulating materials in the presence of electrical discharge can occur:

— decomposition of the insulating material;

— the wearing away of the insulating material by action of electrical discharges (electrical erosion);

— the progressive formation of conductive paths which are produced on the surface of solid insulating material due to the combined effects of electric stress and electrolytic contamination on the surface (tracking).

NOTE Tracking or erosion will occur when:

— a liquid film carrying the surface leakage current breaks, and

— the applied voltage is sufficient to break down the small gap formed when the film breaks, and

— the current is above a limiting value which is necessary to provide sufficient energy locally to thermally decompose the insulating material beneath the film.

Deterioration increases with the time for which the current flows.

4.5.2.2 A method of classification for insulating materials according to 4.5.2.1 does not exist. The behaviour of the insulating material under various contaminants and voltages is extremely complex. Under these conditions many of the materials can exhibit two, or even three of the characteristics stated. A direct correlation with the material groups of 4.5.2.3 is not practical. However, it has been found by experience and tests that insulating materials having a higher relative performance also have approximately the same relative ranking according to the comparative tracking index (CTI). Therefore, this standard uses the CTI values to categorize insulation materials.

4.5.2.3 Materials are separated into four groups according to either their CTI values as defined in EN 60112 or their class as determined by EN 60587 tests.

Material Group I	600 ≤ CTI	or	class 1A4.5
Material Group II	400 ≤ CTI < 600	or	class 1A3.5
Material Group IIIa	175 ≤ CTI < 400	or	class 1A2.5
Material Group IIIb	100 ≤ CTI < 175	or	class 1A0

The CTI values above refer to values obtained, in accordance with EN 60112, on samples specifically made for the purpose and tested with solution A.

NOTE 1 The proof-tracking index (PTI) is also used to identify the tracking characteristics of materials. A material may be included in one of the four groups given above on the basis that its PTI, established by the method of EN 60112 using solution A, is equal to or greater than the lower value specified for the group.

NOTE 2 Equivalence between CTI and classes has not been demonstrated.

5 Requirements and dimensioning rules for clearances

5.1 General

Clearances shall be dimensioned to withstand the voltages referred to in 5.2, taking into account all the parameters affecting breakdown of insulation during the whole life of the equipment.

For correct measurement of clearances, the requirements of Clause 7 apply.

The clearances given in Table A.3 apply to altitudes up to 2 000 m above sea level. For higher altitudes, correction methods are given in 5.4.

5.2 Minimum clearances

5.2.1 Functional insulation

Minimum clearances for functional insulation are based on the rated impulse voltage, according to Table A.3, for altitudes higher than 2 000 m clearances shall be increased in accordance with 5.4.

A smaller value may be adopted, in particular in case of homogeneous fields. The decreased distance shall withstand the required rated impulse voltage U_{Ni}. Its compliance shall be verified by test. The test voltage is the value of U_i, U_{ac} or U_{dc} of Table A.8 for a distance equal to the minimum clearance according to Table A.3.

5.2.2 Basic and supplementary insulation

Minimum clearances for basic and supplementary insulation are based on the rated impulse voltage, according to Table A.3, for altitudes higher than 2 000 m clearances shall be increased in accordance with 5.4.

Smaller values are not allowed.

5.2.3 Reinforced insulation

When dimensioning reinforced insulation, 5.2.2 applies with the following modification: the rated impulse voltage shall be 160 % of the rated impulse voltage required for basic insulation.

Smaller values are not allowed.

5.3 Contingency

Attention is drawn to the fact that a higher value of U_{Ni} may be determined by electromagnetic compatibility test requirements as those given in the EN 50121 series.

In addition, applications may require larger clearances in order to take account of the following:

— atmospheric conditions, special pollution risks, high humidity;

— ionized environment;

— installation conditions;

— connections;

— human safety;

— variations in production, in maintenance;

— ageing in service;

— failure situations and other exceptional cases;

— kinematic conditions, electromechanical forces;

— bacteria, biological and chemical substances;

— whiskers (hair shaped metal bodies growing from the metal surface);

— etc.

5.4 Clearances for altitudes higher than 2 000 m

The clearances given in Table A.3 apply for use up to 2 000 m above sea level. For altitudes higher than 2 000 m the clearances given in Table A.3 shall be increased.

For circuits with rated impulse voltage U_{Ni} up to and including 60 kV the clearances given in Table A.3 shall be multiplied by the altitude correction factor k_d given in Table A.9.

For circuits with rated impulse voltage U_{Ni} higher than 60 kV the clearances given in Table A.3 shall be multiplied by the altitude correction factor k_d given in Table A.10.

6 Dimensioning rules for creepage distances

6.1 General

Creepage distances shall be dimensioned to withstand the voltages referred to in 6.2, taking into account all the parameters affecting long-term insulation during the entire life of the equipment.

Information on influencing factors is provided in Clause 4.

Voltages induced in track-side cables by rolling stock currents are to be added to influencing factors.

For correct measurement of creepage distances, the requirements of Clause 7 apply.

The minimum creepage distance shall be at least equal to the minimum clearance given by Table A.3.

The values of Tables A.5 and A.6 do not apply for the combination of various insulating materials within the insulation distance. Where there exists a combination of an insufficient clearance in series with an insufficient creepage distance, one of them shall be increased to comply with the requirements of 5.2 or 6.2.

Insulation material surfaces may be provided with ribs or slots to interrupt conductive paths. Ribs, slots, sheds or shield parts of an insulation surface can protect from pollution and precipitation. Joints, slots or scratches vertical to conductive parts (electrodes) should be avoided, since dirt can collect therein or water can collect due to capillary action.

NOTE For distances up to 2 mm stressed by voltage peaks under moist conditions, see EN 60664–5.

6.2 Minimum creepage distances

6.2.1 Functional, basic and supplementary insulations

Minimum creepage distances are based on the rated insulation voltage (U_{Nm}) according to Tables A.5, A.6 and A.7.

6.2.2 Reinforced insulation

When dimensioning reinforced insulation, twice the creepage distance for basic insulation applies.

NOTE The requirement has changed compared to the previous version of the standard by replacing “two times the rated insulation voltage” by “twice the creepage distance”. The change has been introduced by applying the requirement of the basic safety standard EN 60664–1. It is well known that according to Table A.6 this can cause significant changes to systems with a rated insulation voltage below 160 V.

7 Tests and measurements

7.1 General

This clause deals only with verification of the requirements of Clauses 5 and 6.

Type and routine tests for equipment are treated in Annex B.

If required, clearances and creepage distances shall be measured on a representative item in accordance with 7.2.

If clearances of functional insulation are actually smaller than those specified in Clause 5, or impossible to measure, a dielectric test instead of measurement of the clearances shall be carried out on the electrical parts involved, on a clean representative item. This dielectric test shall be performed according to 7.3, 7.4 or 7.5.

The electric test shall be carried out according to values of Table A.8 based on distances which are required in Table A.3.

The preferred dielectric test is an impulse voltage test in accordance with 7.3.

Alternatively, clearances may be verified by a power frequency voltage test in accordance with 7.4, or a d.c. voltage test in accordance with 7.5.

The d.c. voltage test is preferred when clearances are bridged by capacitances.

Because the voltage application lasts much longer than the duration of an impulse voltage, a.c. or d.c. voltages more highly stress solid insulations. Insulations can be damaged by the test. Product standards should take this into account when requiring high a.c. or d.c. test voltages.

For equipment with a surge suppressor, withstand voltage tests should be conducted with the surge suppressor separated from the circuit as necessary. If it cannot be separated, the test method should be agreed between supplier and purchaser.

The test voltage, when applicable, shall be applied only to the section in which the clearance is to be verified.

Only those sections which have the same voltage and pollution requirements may remain connected to the test voltage sources.

Creepage distances can only be verified by measurement.

7.2 Measurement of creepage distances and clearances

7.2.1 Method and values

Clearances are defined in Clause 5 and creepage distances in Clause 6.

The methods of measuring creepage distances and clearances are indicated in Annex C.

7.2.2 Acceptance criteria

Smaller values than those specified in Clauses 5 and 6 shall not be allowed.

7.3 Verification of clearances by impulse test

7.3.1 Method and values

The 1,2/50 μs impulse test voltage shall be applied three times for each polarity at intervals of 1 s minimum.

The test voltage shall be the value U_i given in Table A.8, based on a distance determined according to Clause 5.

Depending on the atmospheric conditions and the altitude at the location of testing the impulse test voltages U_i given in Table A.8 shall be corrected according to EN 60664-1 for circuits with rated impulse voltage U_{Ni} up to and including 60 kV and according to EN 60060-1 for circuits with rated impulse voltage U_{Ni} higher than 60 kV.

NOTE This standard does not consider the distinction between self restoring and non self restoring insulation, which is to be found rather in product standards (insulators etc.).

7.3.2 Test acceptance criteria

The test is successful if the test voltage does not collapse.

7.4 Verification of clearances by power-frequency test

7.4.1 Method and values

The test shall be carried out in accordance with EN 60060-1 or EN 60664-1.

The test voltage shall be the value U_{ac} given in Table A.8, based on a distance determined according to Clause 5.

Depending on the atmospheric conditions and the altitude at the location of testing the test voltages U_{ac} given in Table A.8 shall be corrected according to EN 60664-1 for circuits with rated impulse voltage U_{Ni} up to and including 60 kV and according to EN 60060-1 for circuits with rated impulse voltage U_{Ni} higher than 60 kV.

The test frequency is 50 Hz ± 10 % or 60 Hz ± 10 %.

The test value shall be reached in 5 s and be kept for 5 s.

7.4.2 Test acceptance criteria

The test is successful if the test voltage does not collapse.

7.5 Verification of clearances by d.c. voltage test

7.5.1 Method and values

The test voltage shall be the value U_{dc} given in Table A.8, based on a distance determined according to Clause 5.

Depending on the atmospheric conditions and the altitude at the location of testing the test voltages U_{dc} given in Table A.8 shall be corrected according to EN 60664-1 for circuits with rated impulse voltage U_{Ni} up to and including 60 kV and according to EN 60060-1 for circuits with rated impulse voltage U_{Ni} higher than 60 kV.

The test value shall be reached in 5 s and be kept for 5 s.

The ripple factor shall not exceed that one given by a three phase bridge (4,2 %).

7.5.2 Test acceptance criteria

The test is successful if the test voltage does not collapse.

8 Specific requirements for applications in the railway field

8.1 General

It is acknowledged that some requirements may be more specific than, or even may not use the set of common requirements stated in Clauses 4, 5, 6, and 7, provided that they apply to limited areas and are supported by technical or economic reasons.

8.2 Specific requirements for signalling

8.2.1 Overvoltage categories

In addition to the overvoltage provisions given in 4.2.3.2, the following may serve as a guideline when defining overvoltage categories in signalling:

— OV1:

— EXAMPLES:

— data lines;

— circuits not connected to a power distribution system;

— screened circuits;

— circuits being operated indoors.

— OV2:

Circuits with normal transient overvoltages, or circuits with normal availability requirements.

EXAMPLES:

— 230 V a.c. primary circuits of equipment;

— indoor supply circuits.

— OV3:

Circuits with enhanced availability requirements.

EXAMPLES:

— Power distribution systems in installations;

— Lines outside of buildings protected by additional provisions for protection.

— OV4:

EXAMPLE:

— Lines outside buildings protected only by inherent protection.

8.2.2 Rated impulse voltages

8.2.2.1 General

In the absence of any specific information of rated impulse voltages, clearances shall be determined according to 8.2.2.2 and 8.2.2.3.

NOTE The value of 8.2.2.2 is higher than that of 8.2.2.3 for reliability reasons: it is more difficult to detect a failed remote equipment.

8.2.2.2 Equipment for outdoor use

Clearances of basic insulation in circuits without additional overvoltage protection, which are installed in earth, or close to earth, beside the track shall be dimensioned for U_{Ni} = 3 100 V.

8.2.2.3 Equipment for indoor use

Clearances of basic insulation in circuits without additional overvoltage protection which are not separated galvanically from outdoor circuits shall be dimensioned for U_{Ni} = 2 200 V.

8.2.3 Induced voltages

In track-side cables along electrified tracks, voltages are induced e.g. by traction currents or short circuits of the catenary. These voltages affect the insulation and therefore they shall be taken into account when dimensioning clearances and creepage distances. Railway operators or network operators shall specify the maximum voltages, frequencies, durations and shapeforms of voltages expected within their systems.

For dimensioning insulation of circuits which are connected galvanically with outdoor circuits and which are installed beside electrified tracks supplied by a.c. systems, a permanent voltage of 250 V between live parts and earth shall be taken into account unless otherwise specified. This induced voltage has the frequency of the a.c. supply system.

8.2.4 Installation instructions

The manufacturer shall state, in the installation instructions, the operating conditions for interfaces of equipment as follows:

— rated voltage(s) or rated voltage range(s);

— rated impulse voltage(s) or overvoltage category;

— withstand capability against induced voltages caused by traction currents.

8.2.5 Pollution degrees

Insulation of equipment which is operated indoors should be dimensioned for PD1.

Insulation of equipment which is operated outdoors should be dimensioned for PD3.

If the equipment is operated in an environment described by PD3 or better, insulation inside an enclosure which fulfils the requirements for IP51 (according to EN 60529) or better may be dimensioned for PD1.

Insulation inside an enclosure which fulfils the requirements for IP65 (according to EN 60529) or better may be dimensioned for PD1.

8.3 Specific requirements for rolling stock

8.3.1 Determination of the rated impulse voltage U_{Ni} by method 1

In addition to the overvoltage provisions given in 4.2.3.2, the following may serve as a guideline when defining overvoltage categories in rolling stock:

— OV2: Circuits which are not directly connected to the contact line and which are protected against overvoltages;

— OV3: Circuits which are directly connected to the contact line but with overvoltage protection and are not exposed to atmospheric overvoltages;

— the power traction circuits without further protective components other than the protective device, which could reduce overvoltages, are subject to OV3 conditions;

— the power traction circuits protected additionally by filter or inherently protected by components (e.g. semiconductors) are subject to OV2 conditions, unless the surge level is well known;

— OV1 may be used for low voltage circuits isolated from high power circuits, either by galvanic isolation, or several successive filters, or components as such.

NOTE Rolling stock is generally equipped with a surge protective device which gives a protection level the value of which is known according to its characteristics and used as U_{Ni}.

8.3.2 Creepage distances

Only PD1 to PD4 are to be considered on rolling stock equipment.

Values of minimum creepage distances for U_{Nm} above 1 000 V may be limited to 20 mm/kV if mitigating measures such as greasing or cleaning of the insulation surfaces are envisaged.

8.3.3 Roof installations

Unless otherwise specified in relevant product standards, compliance to this standard is required.

Distances may be increased due to specific needs generated by accumulation of pollution on a large conductive horizontal plan.

8.4 Specific requirements for fixed installations

8.4.1 Determination of the rated impulse voltage U_{Ni} by method 1

8.4.1.1 General

In addition to the overvoltage provisions given in 4.2.3.2, the following may serve as a guideline when defining overvoltage categories in fixed installations:

8.4.1.2 Definition of OV2 and OV3 and PD choice

OV2 and OV3 are referred to the following situation: Equipment in direct contact with the contact line such as line circuit breaker and disconnectors, with medium lightning risk or some protection (inherent or not).

For devices located in outdoor or indoor substations in exposed conditions, PD4 may be required or stated in product standards.

The rated impulse voltage U_{Ni} shall be increased by 10 % to 25 % in case a switching device is intended to provide, for safety reasons, an isolating distance between its open contacts (EN 50123-1:2003, 3.1.4). The minimum clearance between the open contacts shall be increased accordingly.

8.4.1.3 Overhead contact lines

Overhead contact lines are considered a case of inherent control. The rated insulation level is based on statistical and risk considerations.

Therefore the rated impulse voltage U_{Ni} shall be chosen among the values given in Table A.2, but irrespective of the correspondence with the insulation voltages and of the overvoltage levels stated in Table A.2.

Table A.3 is based on the worst dielectric conditions of electrodes. In overhead contact lines different conditions are present and by consequence different clearances may be given in EN 50119 for values of U_{Ni} = 95 kV and upwards.

8.4.2 Distances of outdoor insulators

The following exceptions shall be considered for outdoor insulators in fixed installations, the insulation properties of which can be influenced by surrounding atmospheric conditions. Dimensioning of creepage distance versus rated insulation voltage is as follows:

— normal operating conditions: 24 to 33 mm/kV;

— unfavourable operating conditions: 36 to 40 mm/kV;

— extremely unfavourable operating conditions: > 48 mm/kV.

NOTE 1 Normal operating conditions exist when there is low industrial pollution, a low population density and no thermal engines.

NOTE 2 Unfavourable operating conditions exist when there is high industrial pollution and industrial gases, a high population density, mixed railway operation, road traffic and frequent fog.

NOTE 3 Extremely unfavourable operating conditions exist when large power plants, chemical industry or smelting works are near the ocean and there is frequent fog.

NOTE 4 Clearances and creepage distances can be reduced by agreement between purchaser and supplier or in product standards.

Annex A
(normative)

Tables

Table A.1 is not to be used in Method 2.

Table A.1 — Rated impulse voltage U_{Ni} for low voltage circuits not powered directly by the contact line

Nominal voltage of the supply system U_n V		Rated insulation voltage U_{Nm} a.c. or d.c. V	Rated impulse voltage U_{Ni} kV			
3-phase	**1-phase**		**OV1**	**OV2**	**OV3**	**OV4**
		up to 50	0,33	0,5	0,8	1,5
		up to 100	0,5	0,8	1,5	2,5
	120 – 240	up to 150	0,8	1,5	2,5	4,0
230/400 277/480		up to 300	1,5	2,5	4,0	6,0
400/690		up to 600	2,5	4,0	6,0	8,0
1 000		up to 1 000	4,0	6,0	8,0	12,0

NOTE 1 The mark / in the first column indicates a four-wire three-phase distribution system. The lower voltage is the voltage line-to-neutral, while the higher is the voltage line-to-line. Where only one value is indicated, it refers to line-to-line voltage for three-phase systems or to single-phase systems.

NOTE 2 The mark - in the second column indicates a single-phase three-wire distribution system. The lower voltage is the voltage line-to-neutral, while the higher is the voltage line-to-line. Where only one value is indicated, it refers to single-phase two-wire and specifies the value line-to-line.

NOTE 3 For three-phase equipment, the rated insulation voltage refers to the voltage line-to-neutral.

NOTE 4 National regulations can impose a minimum U_{Ni}.

NOTE 5 This table is cited in 4.2.3.2.

Table A.2 is not to be used in Method 2.

Table A.2 — Rated impulse voltages (U_{Ni}) for circuits powered by the contact line and for traction power circuits in thermo-electric driven vehicles

Rated insulation voltage a.c. or d.c. U_{Nm} kV	**Rated impulse voltage U_{Ni} kV**			
Up to (≤)	**OV1**	**OV2**	**OV3**	**OV4**
0,9	4	5	6	8
1,2	5	6	8	12
1,8	6	8	10	15
2,3	8	10	12	18
3	10	12	15	20
3,7 [a] / 3,6 [b]	12	15	20 [a] / 25 [b]	30
4,8	15	18	25 [a] / 30 [b]	40
6,5	20	25	30 [a] / 40 [b]	50
8,3	25	30	35 [a] / 45 [b]	60 a
10	30	35		
17,25 [a]			75	95
17,25 [a,c]			95	125
17,25 [b]			95	125
17,25 [b,c]			145	170
27,5 [a]			125	170
27,5 [b]			170	200
27,5 [b,c]			200 / 250	250 / 325

If equipment for standardized three-phase a. c. systems according to EN 60071–1 is used (e.g. 24/36/52 kV), devices shall be selected in accordance with U_{Ni} and U_a - relevant for fixed installation only (see Table B.1).

NOTE 1 This table is cited in 4.2.3.2 and 8.4.1.3.

NOTE 2 For the correlation between U_n and U_{Nm}, see Table D.1.

[a] For rolling stock only.

[b] For fixed installations only.

[c] Higher values for special cases of switching arrangements, see F.2.9, or when specified by purchaser prior to order.

Table A.3 — Minimum clearances in air for the standard altitude ranges based on the rated impulse voltage U_{Ni}

U_{Ni} kV	Minimum clearances in air for the standard altitude ranges						
	PD1 mm	PD2 mm	PD3 mm	PD3A mm	PD4 mm	PD4A mm	PD4B mm
0,33	0,01	0,20	0,80	1,60	5,50		
0,5	0,04	0,20	0,80	1,60	5,50		
0,8	0,10	0,20	0,80	1,60	5,50		
1,5	0,50	0,50	0,80	1,60	5,50		
2,5	1,50	1,50	1,50	1,60	5,50		
3	2,0				5,5		
3,5	2,5				6,2		
4	3,0				7,0		
4,5	3,5				8,0		
5	4,0				8,5		
6	5,5				10	18	20
8	8,0				14	21	23
10	11				18	23	26
12	14				22	27	30
15	18				27	33	37
18	22				32	39	43
20	25				36	43	48
25	33				45	53	58
30	40				54	63	68
40	60				72	82	87
50	75				91	101	106
60	90				110	120	125
75	120				135	145	150
95	160				175	180	185
125	210				230	235	235
145	260				265	270	270
170	310				310	310	310
200	370				370	370	370
250	480				480	480	480
325	600				600	600	600

Interpolation between adjacent values of the table is permitted, but the values of the first column are preferred values (see 4.1.2.3).

NOTE 1 For contact lines, see 8.4.1.3

NOTE 2 For definition of U_{Ni}, see 3.4.7. For definition of PD1...PD4B, see 4.4, Table A.4, Annex E.

NOTE 3 If this table is applied to roof installations in rolling stock, see 8.3.3.

NOTE 4 This table is cited in 4.1.2.3, 5.1, 5.2.1, 5.2.2, 5.4, 6.1, 7.1, 8.4.1.3, Table A.7, B.2.2, F.2.4, Table F.1 and F.4.1.

Table A.4 — Definition of pollution degrees

	Dust deposit	Humidity
PD1	– no pollution – non–conductive – well protected	– dry – no condensation
PD2	– non–conductive – protected – temporary conductivity caused by condensation	– rare, short temporary condensation
PD3	– low conductivity (caused by condensation)	– frequent condensation
PD3A	– low conductivity	– damp – long time condensation
PD4	– occasionally conductive with periodic cleaning	– rain, snow, ice, fog
PD4A [a]	– occasionally conductive coming from heavy pollution	– rain, snow, ice, fog
PD4B [b]	– occasionally conductive coming from very heavy pollution	– rain, snow, ice, fog

[a] Fixed installations and track side equipment e.g. for signalling

[b] Fixed installations only

NOTE This table is cited in 4.4 and Table A.3

Table A.5 — Minimum creepage distances based on rated insulation voltage U_{Nm} up to 1 000 V for printed wiring material and associated components

U_{Nm} V	PD1 Material Groups I-II-IIIa-IIIb mm	PD2 Material Groups I-II-IIIa mm
Up to 50	0,025	0,040
63	0,040	0,063
80	0,063	0,100
100	0,10	0,16
125	0,16	0,25
160	0,25	0,40
200	0,40	0,63
250	0,56	1,00
320	0,75	1,60
400	1,00	2,00
500	1,30	2,50
630	1,80	3,20
800	2,40	4,00
1 000	3,20	5,00

Interpolation between adjacent values of the table is permitted.

NOTE 1 For definition of U_{Nm} see 3.4.4.

NOTE 2 This table is cited in 4.3, 6.1 and 6.2.1.

Table A.6 — Minimum creepage distances for low values of rated insulation voltage U_{Nm} for materials other than printed wiring material

U_{Nm}	PD1	PD2			PD3			PD3A and PD4		
	Material Groups	Material Group			Material Group			Material Group		
	I-II-IIIa-IIIb	I	II	III	I	II	III	I	II	III
V	mm	mm			mm			mm		
10	0,080	0,40			1,0			1,6		
12,5	0,090	0,42			1,05			1,6		
16	0,100	0,45			1,1			1,6		
20	0,110	0,48			1,2			1,6		
25	0,125	0,50			1,25			1,7		
32	0,140	0,53			1,3			1,8		
40	0,16	0,56	0,8	1,1	1,4	1,6	1,8	1,9	2,4	3,0
50	0,18	0,6	0,85	1,2	1,5	1,7	1,9	2,0	2,5	3,2
63	0,20	0,63	0,9	1,25	1,6	1,8	2,0	2,1	2,6	3,4
80	0,22	0,67	0,95	1,3	1,7	1,9	2,1	2,2	2,8	3,6
100	0,25	0,71	1,0	1,4	1,8	2,0	2,2	2,4	3,0	3,8
125	0,28	0,75	1,05	1,5	1,9	2,1	2,4	2,5	3,2	4,0
160	0,32	0,8	1,1	1,6	2,0	2,2	2,5	3,2	4,0	5,0
200	0,42	1,0	1,4	2,0	2,5	2,8	3,2	4,0	5,0	6,3
250	0,56	1,25	1,8	2,5	3,2	3,6	4,0	5,0	6,3	8,0
320	0,75	1,6	2,2	3,2	4,0	4,5	5,0	6,3	8,0	10
400	1,0	2,0	2,8	4,0	5,0	5,6	6,3	8,0	10	12,5
500	1,3	2,5	3,6	5,0	6,3	7,1	8,0	10	12,5	16
630	1,8	3,2	4,5	6,3	8,0	9,0	10	12,5	16	20
800	2,4	4,0	5,6	8,0	10	11	12,5	16	20	25
1 000	3,2	5,0	7,1	10	12,5	14	16	20	25	32
Interpolation between adjacent values of the table is permitted.										
NOTE 1 This table is cited in 4.3, 6.1 and 6.2.1.										

Table A.7 — Minimum creepage distances (in mm/kV) for high values of rated insulation voltage U_{Nm}

Material Groups	Above 1 000 V					Above 500 V	
	PD1	PD2	PD3	PD3A	PD4	PD4A	PD4B
I	3,2	5	12,5	20	25	30	40
II	4	7,1	14	25	30	40	50
III A	6	10	16	32	Not recommended		
III B	Not recommended						
The minimum creepage distance shall be at least equal to the minimum clearance given by Table A.3.							
NOTE 1 For rolling stock, see 8.3.2 and 8.3.3. NOTE 2 This table is cited in 4.3 and 6.2.1.							

Table A.8 — Test voltages for verifying clearances at atmospheric and altitude reference conditions, not to be used for routine dielectric tests

Distance mm	U_i kV	U_{ac} kV	U_{dc} kV
0,01	0,33	0,23	0,33
0,04	0,52	0,37	0,52
0,1	0,81	0,50	0,70
0,5	1,55	0,84	1,19
1,0	1,95	1,06	1,50
1,5	2,56	1,39	1,97
2,0	3,09	1,68	2,38
2,5	3,60	1,96	2,77
3,0	4,07	2,21	3,13
3,5	4,51	2,45	3,47
4,0	4,93	2,68	3,79
5,5	6,10	3,32	4,69
8	7,84	4,26	6,03
10	9,10	4,95	7,00
11	9,86	5,37	7,59
14	12,1	6,60	9,33
18	15,0	8,20	11,6
22	17,8	9,70	13,7
25	19,9	10,8	15,3
32	24,6	13,4	18,9
40	29,8	16,2	22,9
60	42,0	22,9	32,3
90	59,4	32,3	45,7
100	65,0	35,4	50,0
120	74,6	40,5	57,2
160	95,0	51,5	72,9
260	143	77,6	110
310	166	90,0	127
370	193	104	148
480	240	130	184
600	289	157	222
Interpolation between adjacent values of the table is permitted (linear interpolation of the logarithm of the test voltage as a function of the logarithm of the clearance).			
NOTE 1 U_i is the amplitude of the 1,2/50 impulse test voltage; U_{ac} is the peak value of the power frequency test voltage divided by √2; U_{dc} is the value of the d.c. test voltage. NOTE 2 This table is cited in 5.2.1, 4.1, 7.3.1, 7.4.1, 7.5.1. NOTE 3 This table is derived from EN 60664–1:2007 Table A.1 which is for an altitude of 2000 m			

Table A.9 — Altitude correction factors for clearances in circuits with U_{Ni} up to and including 60 kV when equipment is intended to be used above 2 000 m

Altitude (above sea level) m	Altitude correction factor k_d
≤ 2 000	1,00
2 500	1,07
3 000	1,14
3 500	1,21
4 000	1,29
4 500	1,38
5 000	1,48
For altitudes in between or above, linear interpolation is allowed.	
NOTE 1 The altitude correction factors are determined in accordance with Table A.2 of EN 60664–1:2007. NOTE 2 This table is cited in 5.4.	

Table A.10 — Altitude correction factors for clearances in circuits with U_{Ni} higher than 60 kV when equipment is intended to be used above 2 000 m

Altitude (above sea level) m	Altitude correction factor k_d
2 000	1,000
2 500	1,145
3 000	1,217
3 500	1,294
4 000	1,376
4 500	1,465
5 000	1,555
For altitudes in between or above, linear interpolation is allowed.	
NOTE 1 The altitude correction factors above 2 000 m are determined in accordance with EN 60071–2:1997, 4.2.2 basing on an altitude of 1 400 m and exponent m = 1. NOTE 2 This table is cited in 5.4.	

Annex B
(normative)

Provisions for type and routine dielectric tests for equipment

NOTE This annex is cited in Clause 1 and Clause 7.

B.1 General

Unless other applicable product standards state otherwise, the following tests apply.

The dielectric tests, when required by product standards, are different and not alternative to those required in Clause 7. The product standard shall take into account pollution conditions if any. Otherwise, reference may be made to EN 60507 for a.c. and IEC 61245 for d.c.

B.2 Tests

B.2.1 General

Unless otherwise stated or agreed, the tests specified hereinafter are considered to be carried out on new equipment under clean conditions.

Tests specified in product standards may be more specific than those specified here, and may in particular specify tests under pollution.

Tests specified in B.2.3 and B.2.4 are alternatives.

The test is performed by applying the required test voltage between the circuit (or live part) and other circuits, earth, metallic non live-parts and metalwork, which for convenience may all be connected for the test.

When the test is carried out at the external terminals of the equipment, the test value is that of the overall insulation of the equipment seen from an external source.

The test shall be carried out

— for circuits with rated impulse voltage U_{Ni} up to and including 60 kV in accordance with Clause 6 of EN 60664-1;

— for circuits with rated impulse voltage U_{Ni} higher than 60 kV in accordance with EN 60060-1

During the test, no flashover, breakdown of insulation either internally (puncture) or externally (tracking) or any other manifestation of disruptive discharge shall occur. Any glow discharge shall be ignored.

B.2.2 Impulse test

The impulse test is generally a type test.

The test voltage shall be equal to the rated impulse voltage U_{Ni} as determined in Clause 4, and shall fall into the series of preferred values that are listed in the first column of Table A.3.

B.2.3 Power-frequency test

The power-frequency test is generally a routine test.

The test voltage value U_a is derived from U_{Ni} according to Table B.1.

NOTE To derive U_a from U_{Ni} instead of U_{Nm} is justified by the fact that most often the presence in the railway field of high overvoltages imposes dielectric test values that have no relation to U_{Nm}.

The test voltage shall be reached in 5 s and be kept for a minimum of 10 s, unless otherwise specified in a product standard.

B.2.4 DC test

The d.c. test is as for the power-frequency test, the peak value of the test voltage (taking into account ripple) being equal to the peak value of the respective a.c. voltage.

Table B.1 — Dielectric test for equipment - Short-duration power-frequency (a.c.) test levels U_a (kV) based on the rated impulse voltage U_{Ni} (kV)

Rated impulse voltage U_{Ni} kV	Test voltage U_a kV
0,33	0,2
0,5	0,3
0,8	0,42
1,5	0,7
2,5	1,2
3,0	1,4
3,5	1,6
4,0	1,9
4,5	2,0
5,0	2,3
6,0	2,8
8,0	3,6
10	4,6
12	5,5
15	6,9
18	8,3
20	9,2
25	11,5
30	14
35	17
40	18,5
50	23
60	27,5
75	34,5
95	44
125	50
145	70
170	80
200	95
250	95
325	140

Annex C
(normative)

Methods of measuring creepage distances and clearances

NOTE This annex is cited in 7.2.1.

The methods of measuring creepage distances and clearances are indicated in the following Figures C.1 to C.11. These cases do not distinguish between gaps and grooves or between types of insulation.

The above-mentioned examples show a dimension X of grooves which is a function of the pollution degree according to Table C.1

Table C.1 — Minimum dimensions of grooves

Pollution degree	Width X of grooves: Minimum values **mm**
PD1	0,25
PD2	1,0
PD3	1,5
PD3A	2,5
PD4	4
PD4A	7
PD4B	10

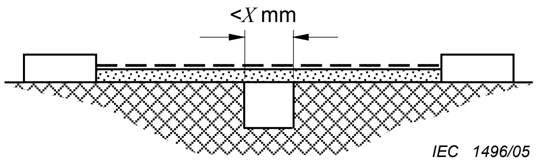
If the associated clearance is less than 3 mm, the minimum groove width may be reduced to one-third of this clearance.

The following assumptions are made:

— any recess is assumed to be bridged with an insulating link having a length equal to the specified width X and being placed in the most unfavourable position (see example 3);

— where a distance across a groove is equal to or larger than the specified width *X*, the creepage distance is measured along the contours of the groove (see example 2);

— creepage distances and clearances measured between parts which can assume different positions in relation to each other, are measured when these parts are in their most unfavourable position.



Condition: Path under consideration includes a parallel- or converging-sided groove of any depth with a width less than X mm.

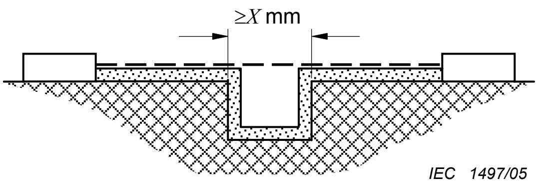
Rule: Creepage distance and clearance are measured directly across the groove as shown.

Key

– – – – – Clearance

Creepage distance

Figure C.1 — Example 1



Condition: Path under consideration includes a parallel-sided groove of any depth and width equal to or more than X mm.

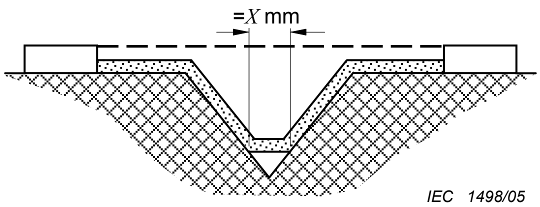
Rule: Clearance is the “line of sight” distance. Creepage path follows the contour of the groove.

Key

– – – – – Clearance

Creepage distance

Figure C.2 — Example 2



Condition: Path under consideration includes a V-shaped groove with a width greater than X mm.

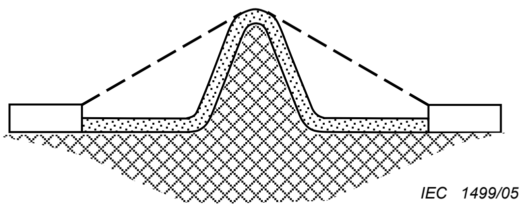
Rule: Clearance is the “line of sight” distance. Creepage path follows the contour of the groove but “short-circuits” the bottom of the groove by X mm link.

Key

– – – – – Clearance

Creepage distance

Figure C.3 — Example 3



Condition: Path under consideration includes a rib.

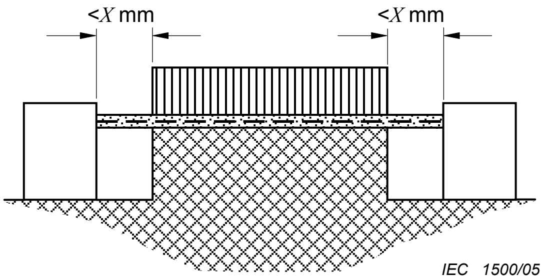
Rule: Clearance is the shortest direct air path over the top of the rib. Creepage path follows the contour of the rib.

Key

– – – – – Clearance

Creepage distance

Figure C.4 — Example 4



Condition: Path under consideration includes an uncemented joint with grooves less than X mm wide on each side.

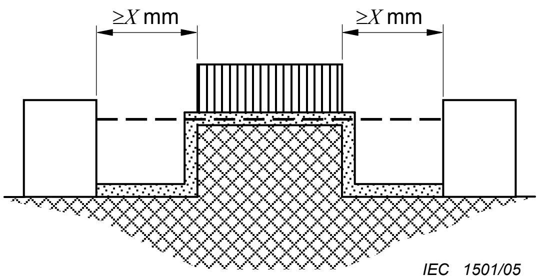
Rule: Creepage and clearance path is the "line of sight" distance shown.

Key

– – – – – Clearance

Creepage distance

Figure C.5 — Example 5



Condition: Path under consideration includes an uncemented joint with grooves equal to or more than X mm on each side.

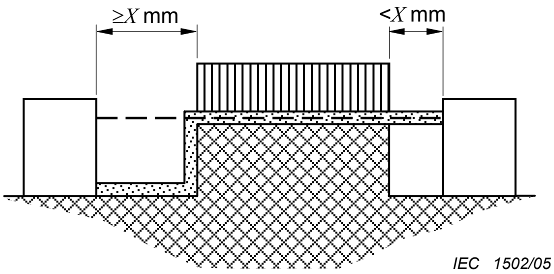
Rule: Clearance is the "line of sight" distance. Creepage path follows the contour of the grooves.

Key

– – – – – Clearance

Creepage distance

Figure C.6 — Example 6



Condition: Path under consideration includes an uncemented joint with a groove on one side less than X mm wide and the groove on the other side equal to or more than X mm wide.

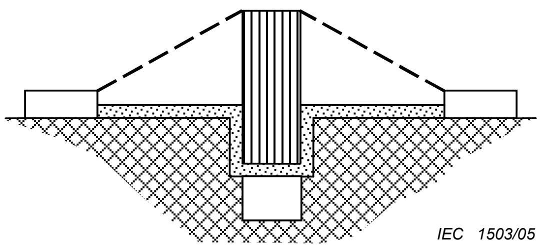
Rule: Clearance and creepage paths are as shown.

Key

– – – – – Clearance

Creepage distance

Figure C.7 — Example 7



Condition: Creepage distance through uncemented joint is less than creepage distance over barrier.

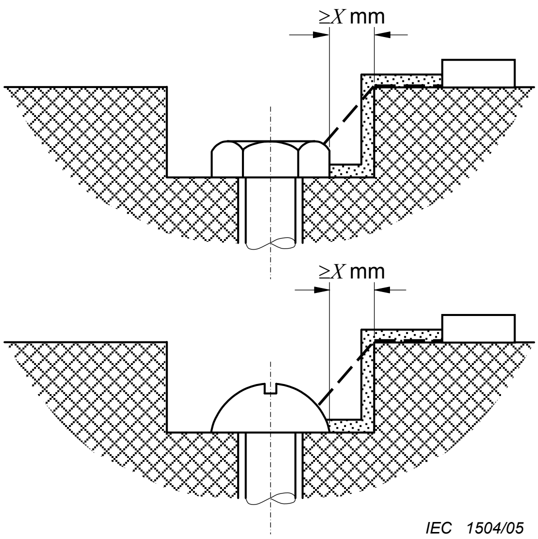
Rule: Clearance is the shortest direct air path over the top of the barrier.

Key

– – – – – Clearance

Creepage distance

Figure C.8 — Example 8



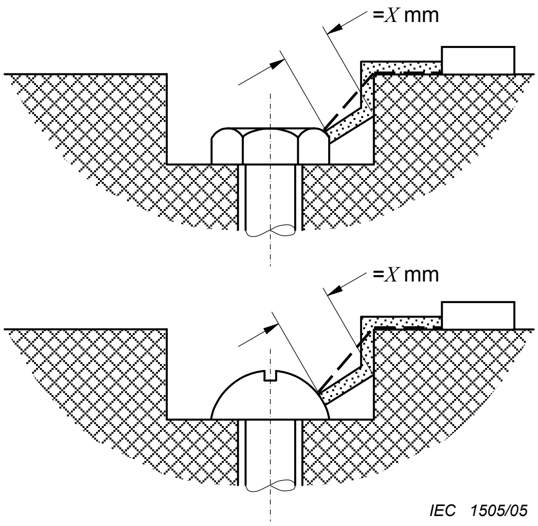
Gap between head of screw and wall of recess wide enough to be taken into account

Key

— — — — — Clearance

Creepage distance

Figure C.9 — Example 9



Gap between head of screw and wall of recess too narrow to be taken into account

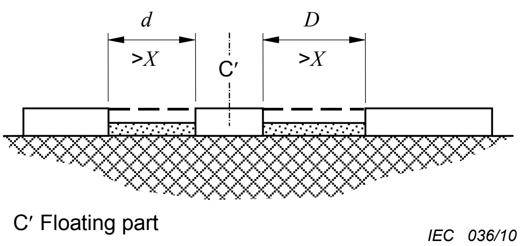
Measurement of creepage distance is from screw to wall when the distance is equal to *X* mm.

Key

– – – – – Clearance

Creepage distance

Figure C.10 — Example 10



Clearance is the distance = $d + D$

Creepage distance is also = $d + D$

Key

– – – – – Clearance

Creepage distance

Figure C.11 — Example 11

Annex D
(normative)

Correlation between U_n and U_{Nm}

Table D.1 — Correlation between nominal voltages of the railway power distribution system and the required insulation voltages for circuits of equipment which are intended to be connected to these systems

Nominal voltage U_n			Minimum values of the rated insulation voltage U_{Nm} kV
Power supply systems according to EN 50163		Battery supply systems V	
d.c. kV	a.c. kV		
		24 / 36	0,05
		48 / 72	0,1
		110 / 120	0,15
0,6			0,72
0,75			0,9
1,5			1,8
3,0			3,6
	15		17,25
	25		27,5 (36 [a] / 52 [a])
Note This table is cited in 4.2.3.2			
[a] For fixed installations only. For 25 kV a. c. traction supply systems, the choice (by purchaser or by agreement) of the different values of U_{Nm} for the same U_n depends upon the maximum non-permanent or transient voltages actually appearing in the system and upon the special circuital configuration used.			

Annex E
(informative)

Macro-environmental conditions

NOTE This annex is cited in 4.4 and Table A.3

Table E.1 — Correlation between pollution degrees and macro-environmental conditions

	Location	Ventilation	Examples
PD1	– hermetically sealed; – inside movable equipment; – well cared–for indoor location; – location with air–conditioning.	– no ventilation; – natural ventilation; – forced ventilation with air from indoors.	– room for the signalman; – living room; office; – computer room of the signal box.
PD2	– indoor location; – limited heated location; – inside movable equipment	– natural ventilation; – forced ventilation with air from indoors.	– control cabinet in the driver cabin and the passenger compartment; – store; stairway
PD3	– indoor location; – outdoor location protected from weather conditions.	– natural ventilation; – forced ventilation with clean (filtered) air from outdoors.	– transformer station – driver cabin; – passenger compartment; – machinery compartment; – station hall.
PD3A	– indoor location; – outdoor sheltered protected from weather conditions	– forced ventilation with air from outdoors – no filters	– machinery compartment; – cable manhole; – aerial mast – inside substations – insulators in light pollution level areas [a]
PD4	– outdoor location; – underfloor of vehicle; – roof of vehicle		– pantograph, shoe gear – covered platform – insulators in medium pollution level areas [a]
PD4A	– unprotected outdoor locations		– insulators in heavy pollution level areas [a]
PD4B	– unprotected outdoor locations		– insulators in very heavy pollution level areas [a]
[a] According to IEC/TR 60815:1986.			

Annex F
(informative)

Application guide

F.1 Introduction

The term “insulation co-ordination” explains the process for co-ordinating the constituents of an electrical insulation, i.e. solid/liquid insulation, clearances and creepage distances.

NOTE The dimensioning of insulation thicknesses performed by solid insulation and insulation distances performed by liquid insulation materials is not covered by this standard.

However, the use of this standard for the determination of clearances and creepage distances needs some additional explanations: The values of the tables of Annex A are based on EN 60664-1 and EN 60071-1 taking into account the severe electrical and mechanical situation of insulations in railway systems and their expected reliability and long life time.

For example, the values for clearances are selected for inhomogeneous fields and, for locations with typical railway pollutions are supplemented by safety margins. Thus, it is not necessary to perform a high voltage test, when clearances required by this standard are achieved.

Where product standards for railway applications specify test voltages and clearances, the use of these values is recommended. According to Clause 1 it can be assumed that the insulation values in the product standards were derived in accordance with this International Standard.

F.2 Determination of minimum clearances and creepage distances

F.2.1 Sections

For practical use when determining insulation values it is necessary to consider the following factors when dividing into sections:

— is the considered part of the circuit exposed to the same electrical climate? (working voltage, overvoltage category);

— are the location criteria of the considered part of circuit the same? (pollution degree, indoors/outdoors);

— for economical reasons it may be useful to subdivide sections (e.g. for lower insulation values in areas with lower voltage stress);

— for reliability or safety reasons it may be useful to increase insulation values in endangered areas, i.e. by introducing a separate section.

For floating sections consideration should be given to capacitive effects for defining the dimensioning parameters of an insulation. Due to the actual or parasitic capacitances between the considered section and adjacent sections, creepage distances and clearances can be stressed by continuous voltages greater than the nominal voltage of the circuit. The correct selection of U_{Nm} and U_{Ni} should take that effect into account.

F.2.2 Use of method 1 and 2 for determining U_{Ni}

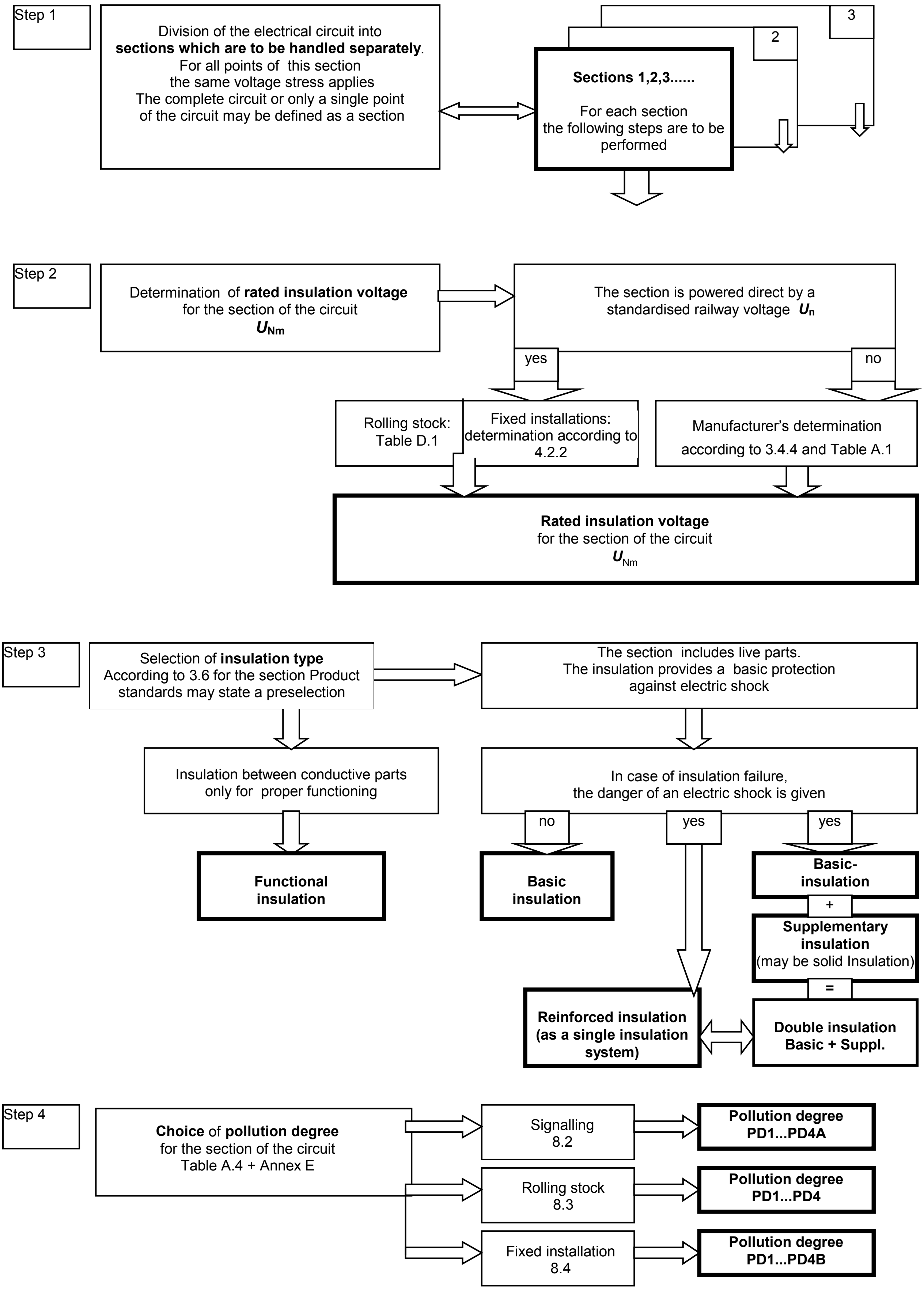
Methods 1 and 2 are considered as equivalent for dimensioning clearances because both methods lead to reliable distances.

Method 2 is a physical method to determine an insulation value taking into account the voltage stress occurring across the regarded insulation but it can only be used if the expected overvoltages are well known.

If the overvoltages are not known, method 1 should be used.

F.2.3 How to determine minimum clearances and creepage distances

The flowchart of Figure F.1 displays the procedure for determining the minimum clearances and creepage distances by taking into account the relevant electrical, environmental and operating conditions.


Step 1
Division of the electrical circuit into sections which are to be handled separately. For all points of this section the same voltage stress applies The complete circuit or only a single point of the circuit may be defined as a section
Sections 1,2,3......
For each section the following steps are to be performed
2
3
Step 2
Determination of rated insulation voltage for the section of the circuit U_{Nm}
The section is powered direct by a standardised railway voltage U_n
yes
no
Rolling stock: Table D.1
Fixed installations: determination according to 4.2.2
Manufacturer's determination according to 3.4.4 and Table A.1
Rated insulation voltage for the section of the circuit U_{Nm}
Step 3
Selection of insulation type According to 3.6 for the section Product standards may state a preselection
The section includes live parts. The insulation provides a basic protection against electric shock
Insulation between conductive parts only for proper functioning
In case of insulation failure, the danger of an electric shock is given
no
yes
yes
Functional insulation
Basic insulation
Basic-insulation
+
Supplementary insulation (may be solid Insulation)
=
Reinforced insulation (as a single insulation system)
Double insulation Basic + Suppl.
Step 4
Choice of pollution degree for the section of the circuit Table A.4 + Annex E
Signalling 8.2
Rolling stock 8.3
Fixed installation 8.4
Pollution degree PD1...PD4A
Pollution degree PD1...PD4
Pollution degree PD1...PD4B

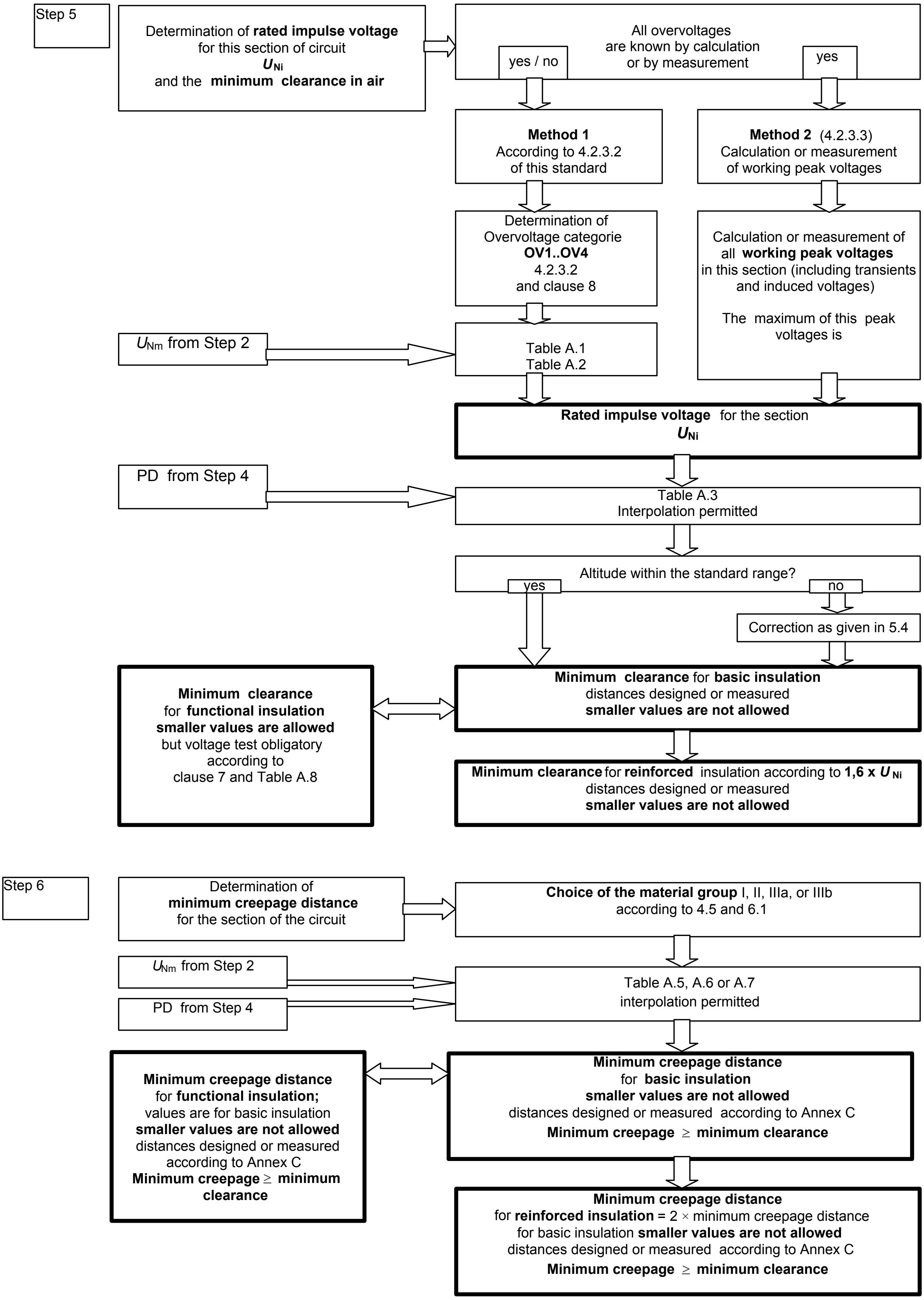


Figure F.1 — Determination of minimum clearances and creepage distances

F.2.4 Pollution

Table A.4 and Annex E may be used to identify the pollution degree applicable. A definition of a pollution degree with numerical values is not practicable.

There is no direct relation between the protection level given by IP classes of EN 60529 and the pollution to be expected. The IP classes are related to the protection against the ingress of solid objects including dust and against the ingress of water (e.g. spraying, splashing, water jets, immersion, etc.). Protection according to IP classes cannot prevent pollution created by the equipment itself.

The pollution degree PD1 may be used in areas of fixed installations and of signalling equipment where the temperature and the humidity are permanently controlled. These conditions are normally not given in rolling stock.

Table A.3 shows that for indoor locations (PD1 to PD3A) the pollution has no additional influence on clearances above 1,6 mm. On the contrary, for PD4 in rolling stock outdoor installations and for PD4A and PD4B in fixed installations, the pollution has a significant influence on clearances throughout the whole voltage range. Therefore these clearances are derived from the size of solid particles and the accumulation of pollutants likely to reduce the clearances.

For outdoor fixed installations special conditions (PD4A and PD4B) apply. It is because the pollution at any particular area is always present for that particular area and may be very severe. Rolling stock may operate in areas where the levels will be different and then the average level of pollution and time of application should be considered. Also fixed installations may be cleaned less frequently.

For further guidance in selecting PD4A and PD4B the following, which is based on IEC/TR 60815:1986, should be noted:

PD4A “heavy conditions”

— Areas with high density of industries and suburbs of large cities with high density of heating plants producing pollution;

— Areas close to the sea or in any area exposed to relatively strong winds from the sea.

PD4B “very heavy conditions”

— Areas generally of moderate extent, subjected to conductive dusts and to industrial smoke producing particular thick conductive deposits;

— Areas generally of moderate extent, very close to the coast and exposed to sea spray or to very strong and polluting winds from the sea;

— Desert areas, characterized by no rain for long periods, exposed to strong winds carrying sand and salt, and subjected to regular condensation.

F.2.5 Creepage distances

For creepage distances, the required distances increase with voltage for all pollution degrees. Values are given in Tables A.5, A.6 and A.7 based on the rated insulation voltage U_{Nm}.

Creepage distances cannot be validated by voltage tests because, among other reasons, the influence of pollution cannot be simulated. Product standards will address for tests taking into account pollution, if existing. Reduction of creepage distances is not allowed for either functional or basic insulation.

F.2.6 Insulations

F.2.6.1 Types of insulation

Figure F.2 gives an example of types of insulation.

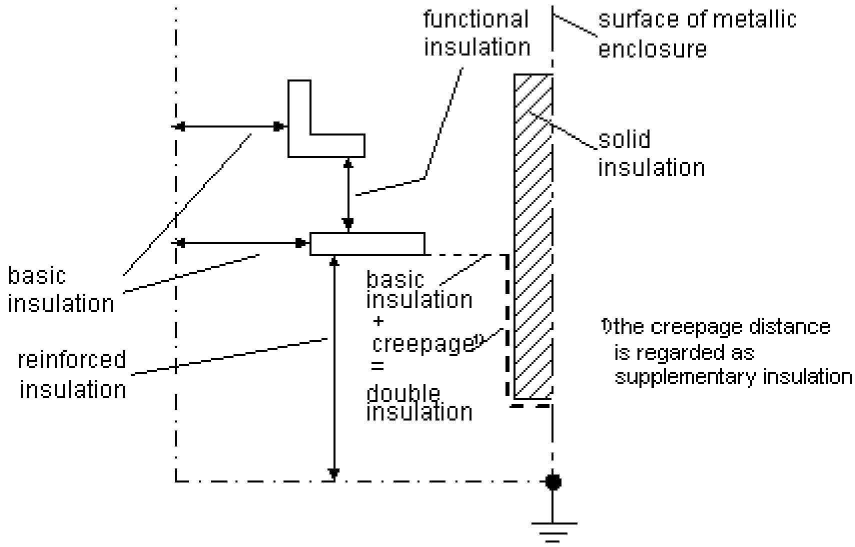


Figure F.2 — Example for types of insulation

F.2.6.2 Supplementary insulation

A supplementary insulation (see definition 3.6.3) is an additional independent insulation which is intended to protect users from electric shock in the case of breakdown of basic insulation. The electric stress of supplementary insulation in case of a failure can be different from the stress of basic insulation under normal operating conditions.

The Supplementary insulation may be performed as a layer of solid insulation.

NOTE Partial discharge may occur in the case of a combination of insufficient clearance and well-dimensioned solid insulation.

Sometimes additional insulation is provided in addition to basic insulation for mechanical protection only, not to protect against electric shock. This additional insulation is not supplementary insulation in the sense of 3.6.3, e.g. in the case of the outer sheath of a cable.

Supplementary insulation can be used for increasing the reliability of an insulation.

F.2.6.3 Double insulation

An insulation system where a layer of a basic insulation is combined with a layer of a supplementary insulation is called “double insulation”. However, the combination of two functional insulations is not a double insulation.

NOTE In braking resistors, the combination of a basic insulation with a functional insulation is sometimes termed “double insulation” but does not fulfil the requirements as defined in this standard.

F.2.6.4 Reinforced insulation

A reinforced insulation is equivalent to a double insulation, when it is not possible to identify the layers of basic and supplementary.

NOTE A typical example of the use of reinforced insulation is for safety transformers in accordance with the EN 61558 series.

F.2.7 Use of minimum distances for clearances and creepage distances

These distances are values which experience has found to be satisfactory in normal railway operation with a good reliability of equipment.

All clearance and creepage distances dimensioned according to this standard are minimum distances. The designer of an equipment is free to use larger distances.

NOTE Minimum values of clearances and creepage distances may be increased by the designer for specific requirements and service conditions in order to increase reliability.

F.2.8 Roof equipment for rolling stock

The roof of a vehicle is considered as a "closed electrical operating area" in accordance with EN 50153. In this special case, the insulation of the roof equipment may be considered as functional insulation. If agreed between purchaser and supplier, the clearances may be reduced accordingly.

It is recommended, however, to use higher values for creepage distances on the roof due to the level of pollution likely to be expected in that area.

F.2.9 Special cases of switching arrangements in fixed installations (see Table A.2, footnote c)

Table A.2 gives values for U_{Ni} for normal requirements and higher values for special requirements.

Switchgear intended to fulfil those special requirements are used for example in substations where they are connected to two phases of a three-phase network with a nominal voltage exceeding 25 kV. In such cases the switching device shall be dimensioned for a higher voltage. The next standardized value is then 52 kV in accordance with EN 60071-1.

In all other cases the relevant value of U_{Nm} is 27,5 kV for a U_n of 25 kV.

F.2.10 Insulation conditions in fixed installations (see 8.4.1.2)

Switching devices intended to isolate discrete sections of the contact line from the power source are provided with an increased value for the rated impulse voltage U_{Ni} (up to 25 %).

Detailed values for rated impulse voltages across isolating distances of switching devices are specified in the relevant product standards; for d.c. switching devices in the EN 50123 series, for a.c. switching devices in the EN 50152 series.

F.3 Examples

Figure F.3 gives an example for sections. The diagram shows a monitoring circuit for the supply voltage of a locomotive.

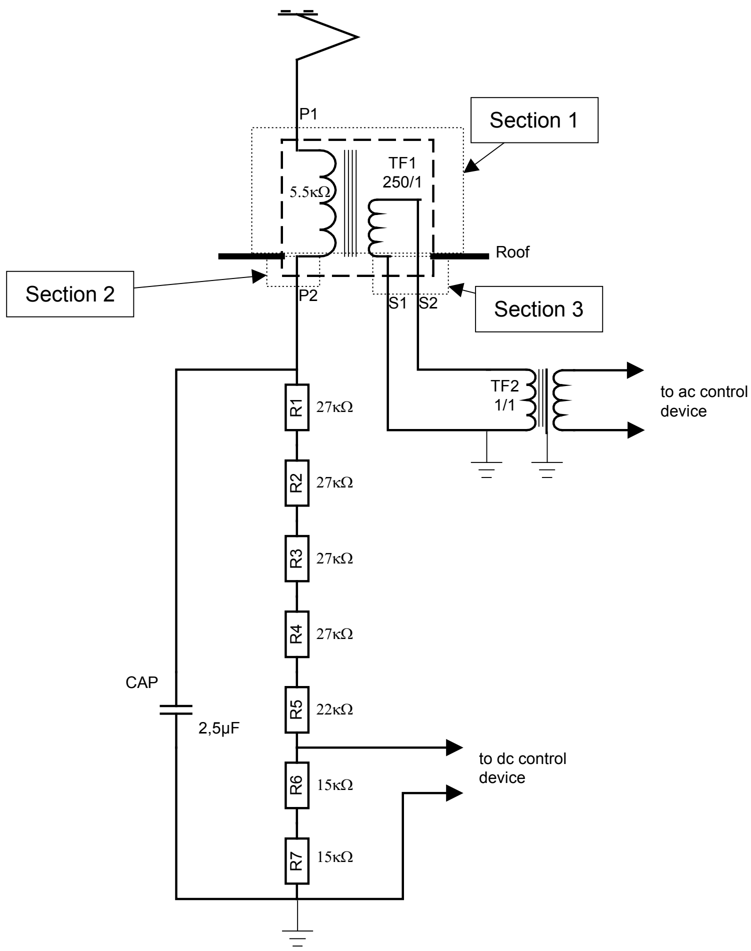


Figure F.3 — Monitoring circuit showing examples of sections

Figure F.4 shows a drawing of a monitoring device used as an example for determining clearance and creepage distances related to the monitoring circuit of Figure F.3.

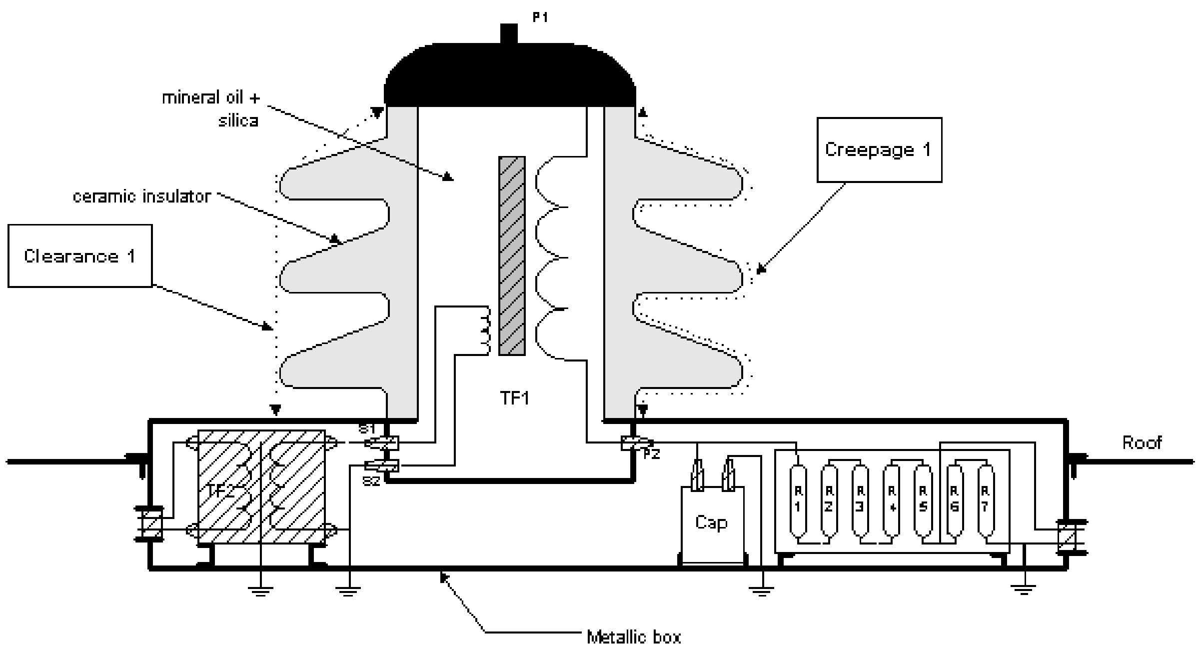


Figure F.4 — Drawing of monitoring device

Device located on the locomotive roof supplied at two supply voltages:

— 25 kV a.c.

— 1,5 kV d.c.

Determination of minimum clearances and creepage distances of the stepdown transformer TF1 in Figure F.3 (see Table F.1).

Table F.1 — Example for the determination of clearances and creepage distances

Step 1 (see diagram in Figure F.1)	Section 1	Section 2	Section 3
Step 2	Directly connected to the contact line U_{Nm} = 27,5 kV	Not directly connected to the contact line Calculation with primary voltage 1,5 kV d.c. U_{Nm} = 1,74 kV	Not directly connected to the contact line Calculation with primary voltage 25 kV a.c. U_{Nm} = 0,11 kV
Step 3	Basic insulation	Functional insulation	Functional insulation
Step 4	Pollution degree PD4	Pollution degree PD2	Pollution degree PD2
Step 5	Method 1 Table A.2 – OV4 (no surge diverter) U_{Ni} = 170 kV Table A.3 Minimum clearance = 310 mm	Method 1 Table A.2 – OV2 U_{Ni} = 8 kV Table A.3 Minimum clearance = 8,0 mm	Method 1 Table A.1 – OV3 U_{Ni} = 2,5 kV Table A.3 Minimum clearance = 1,5 mm
Step 6	Material group I Table A.7 → 25 mm/kV Minimum creepage distance = 687 mm	Material group II Table A.7 → 7,1 mm/kV Minimum creepage distance = 12,4 mm	Material group III Table A.6 – U_{Nm} = 125 V – PD2 Minimum creepage distance = 1,5 mm

F.4 Tests

F.4.1 Measuring

To demonstrate the compliance of the equipment with the insulation requirements, it is necessary to measure the clearance and creepage distances.

In order to limit the amount of measurements, it is recommended to identify where the minimum clearances and creepage distances occur. If measurement is difficult on the complete item, it is recommended to do this on a relevant subassembly.

If the measurement of clearances is not possible, a voltage test is performed in accordance with 7.3, 7.4 or 7.5 on a subassembly to avoid overstressing of the equipment.

If the clearances for functional insulation are smaller than those specified in Table A.3, a voltage test is mandatory.

For measuring of creepage distances refer to Annex C.

F.4.2 Testing

Two kinds of voltage tests are given in this standard:

a) Tests for verification of clearances (see Clause 7 and Table A.8)

This test is a type test. Where a relevant product standard specifies requirements for such a test, the test should be performed in accordance with the product standard. In all other cases Clause 7 applies.

In the case of functional insulation when the clearance has been reduced, the voltage test is carried out at the value for the unreduced clearance. When carrying out the test to verify clearances, it is good practice to test only the parts under consideration. It is acceptable to use a representative subassembly.

b) Dielectric test voltages for equipment (see Annex B, Table B.1)

This routine test is only valid for items of equipment when there is no relevant product standard.

The test voltages for dielectric testing are based on the rated impulse voltage U_{Ni} taking into account the overvoltage categories. Test voltages in most product standards, however, are conventionally based on the nominal voltage or the rated insulation voltage of the equipment.

The test voltages of Table B.1 are not used for checking clearances.

Annex ZZ
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 2008/57/EC

This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association and within its scope the standard covers all relevant essential requirements as given in Annex III of the EC Directive 2008/57/EC (also named as New Approach Directive 2008/57/EC Rail Systems: Interoperability).

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard given in Table ZZ.1 for "Locomotives and Passenger Rolling Stock", Table ZZ.2 for "Energy" confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

Table ZZ.1 — Correspondence between this European Standard, the TSI "Locomotives and Passenger Rolling Stock" (REGULATION (EU) No 1302/2014 of 18 November 2014) and Directive 2008/57/EC

Clauses of this European Standard	Chapter / § / points of LOC and PAS RST TSI	Essential Requirements (ER) of Directive 2008/57/EC	Comments
The whole standard is applicable. (To be applied together with EN 50124–2)	4.2.8.2. Power supply 4.2.8.2.9 Requirements linked to pantograph 4.2.8.2.9.9 Insulation of pantograph from the vehicle (RST level) 4.2.8.4. Protection against electrical hazards	1. General Requirements 1.5 Technical compatibility 2. Requirements specific to each sub-subsystem 2.4. Rolling Stock 2.4.1 Safety 2.4.3. Technical compatibility	

Table ZZ.2 — Correspondence between this European Standard, the TSI "Energy" (REGULATION (EU) No 1301/2014 of 18 November 2014) and Directive 2008/57/EC

Clauses of this European Standard	Chapter / § / points of ENE TSI	Essential Requirements (ER) of Directive 2008/57/EC	Comments
The whole standard is applicable. (To be applied together with EN 50124–2)	4.2.18. Protective provisions against electric shock	1. General Requirements 1.1 Safety 1.5 Technical compatibility 2. Requirements specific to each sub-subsystem 2.2 Energy 2.2.1 Safety	

WARNING: Other requirements and other EU Directives may be applicable to the products falling within the scope of this standard.

Bibliography

EN 50121 (all parts), *Railway applications - Electromagnetic compatibility (EMC)*

EN 50125 (all parts), *Railway applications - Environmental conditions for equipment*

EN 50129, *Railway applications - Communication, signalling and processing systems - Safety related electronic systems for signalling*

EN 50152 (all parts), *Railway applications - Fixed installations - Particular requirements for a.c. switchgear*

EN 50153, *Railway applications - Rolling stock - Protective provisions relating to electrical hazards*

EN 60071-2, *Insulation co-ordination - Part 2: Application guide (IEC 60071-2)*

EN 60077-1, *Railway applications - Electric equipment for rolling stock - Part 1: General service conditions and general rules (IEC 60077 1)*

EN 60099-1, *Surge arresters - Part 1: Non linear resistor type gapped surge arresters for a.c. systems (IEC 60099-1)*

EN 60099-4, *Surge arresters - Part 4: Metal-oxide surge arresters without gaps for a.c. systems (IEC 60099-4)*

EN 60168, *Tests on indoor and outdoor post insulators of ceramic material or glass for systems with nominal voltages greater than 1 kV (IEC 60168)*

EN 60364 (all parts), *Low-voltage electrical installations (IEC 60364)*

EN 60383-1, *Insulators for overhead lines with a nominal voltage above 1 kV - Part 1: Ceramic or glass insulator units for a.c. systems - Definitions, test methods and acceptance criteria (IEC 60383 1)*

EN 60383-2, *Insulators for overhead lines with a nominal voltage above 1 kV - Part 2: Insulator strings and insulator sets for a.c. systems - Definitions, test methods and acceptance criteria (IEC 60383 2)*

EN 60507, *Artificial pollution tests on high voltage insulators to be used on a.c. systems (IEC 60507)*

EN 60529, *Degrees of protection provided by enclosures (IP Code) (IEC 60529)*

EN 60660, *Insulators - Tests on indoor post insulators of organic material for systems with nominal voltages greater than 1 kV up to but not including 300 kV (IEC 60660)*

EN 60664-3, *Insulation coordination for equipment within low-voltage systems - Part 3: Use of coating, potting or moulding for protection against pollution (IEC 60664 3)*

EN 60664-5, *Insulation coordination for equipment within low-voltage systems – Part 5: Comprehensive method for determining clearances and creepage distances equal or less than 2 mm (IEC 60664-5)*

EN 60947-1, *Low-voltage switchgear and controlgear - Part 1: General rules (IEC 60947 1)*

EN 61109, *Insulators for overhead lines - Composite suspension and tension insulators for a.c. systems with a nominal voltage greater than 1 000 V - Definitions, test methods and acceptance criteria (IEC 61109)*

IEC 61245, *Artificial pollution tests on high voltage insulators to be used on d.c. systems*

EN 61558 (all parts), *Safety of power transformers, power supplies, reactors and similar products (IEC 61558, all parts)*

EN 61936-1, *Power installations exceeding 1 kV a.c. - Part 1: Common rules (IEC 61936 1)*

EN 62271-1, *High-voltage switchgear and controlgear - Part 1: Common specifications (IEC 62271 1)*

IEC/TR 60099-3, *Surge arresters - Part 3: Artificial pollution testing of surge arresters*

IEC 60664-2-1, *Insulation coordination for equipment within low-voltage systems – Part 2-1: Application guide – Dimensioning procedure worksheets, dimensioning examples*

IEC/TR 60815:1986[1], *Guide for the selection of insulators in respect of polluted conditions*

IEC/TS 60815 (all parts), *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions*

EN 50119, *Railway applications - Fixed installations - Electric traction overhead contact lines*

[1] This IEC TR provides the correct reference for the pollution degrees used.

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