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Railway applications — Insulation coordination Part 1: Basic requirements — Clearances and creepage distances for all electrical and electronic equipment

(includes amendments A1:2003 and A2:2005)

Applications ferroviaires — Coordination de l'isolement Partie 1: Prescriptions fondamentales — Distances d'isolement dans l'air et lignes de fuite pour tout matériel électrique et électronique (inclut les amendements A1:2003 et A2:2005)

Bahnanwendungen — Isolationskoordination Teil 1: Grundlegende Anforderungen — Luft- und Kriechstrecken für alle elektrischen und elektronischen Betriebmittel (enthält Änderungen A1:2003 und A2:2005)

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CENELEC

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Foreword

This European Standard was prepared by the Technical Committee CENELEC TC 9X, Electrical and electronic applications in railways.

The text of the draft was submitted to the formal vote and was approved by CENELEC as EN 50124-1 on 1999-10-01.

The following dates were fixed:

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Annexes designated "normative" are part of the body of the standard.

Annexes designated "informative" are given for information only.

In this standard, annexes A, B, C and D are normative and annexes E and F are informative.

Foreword to amendment A1

This amendment to the European Standard EN 50124-1:2001 was prepared by the Technical Committee CENELEC TC 9X, Electrical and electronic applications for railways.

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Annexes designated "normative" are part of the body of the standard.

Annexes designated "informative" are given for information only.

In this standard, Annexes A, B, C and D are normative and Annexes E, F and G are informative.

Foreword to amendment A2

This amendment to the European Standard EN 50124-1:2001 was prepared by the Technical Committee CENELEC TC 9X, Electrical and electronic applications for railways.

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Contents

Introduction

Special conditions occurring in railway applications and the fact that the equipment here concerned falls into the scope of both IEC 60071 (prepared by IEC/TC 28) and IEC 60664-1 (prepared by IEC/SC 28A), led to the decision to draw from these documents and from the draft IEC 60077-1 (prepared by IEC/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, *Part 1: Basic requirements — Clearances and creepage distances for all electrical and electronic equipment*;
- EN 50124-2, *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 General

1.1 Scope

The whole document deals with insulation coordination in railways. It applies to equipment for use in signalling, rolling stock and fixed installations up to 2 000 m above sea level.

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 overdimensioning 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 1.3.1.3: 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 have to 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 lines which have to comply to 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 will be resolved in the product specific signalling standard EN 50129 (in preparation).

1.2 Normative references

This European Standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate place in the text and the publications are listed thereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

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

EN 50121 (Series), *Railway applications — Electromagnetic compatibility (EMC)*

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

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

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

IEC 60060-1, *High voltage test techniques — Part 1: General definitions and test requirements* (endorsed as HD 588.1)

IEC 60112, *Method for determining the comparative and the proof indices of solid insulating materials under moist conditions* (endorsed as HD 214)

IEC 60587, *Test methods for evaluating resistance to tracking and erosion of electrical insulating materials used under severe ambient conditions* (endorsed as HD 380)

IEC 60664-1, *Insulation coordination for equipment within low voltage systems — Part 1: Principles, requirements and tests* (endorsed as HD 625.1, modified)

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

1.3 Definitions

For the purpose of this standard the following definitions apply according to the following priority order:

- the definition given here-under;
- the definition given in IEC 60664-1;
- the definition given in the documents mentioned in 1.2 other than IEC 60664-1.

1.3.1 General

1.3.1.1
clearance
shortest distance in air between two conductive parts

1.3.1.2
creepage distance
shortest distance along the surface of the insulating material between two conductive parts

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*) In preparation

1.3.1.3
section
part of an electrical circuit having its own voltage ratings for insulation coordination

Sections fall into two categories:

1.3.1.3.1
earthed section
section connected to the earth or to the car body through a circuit for which interruption is not expected

1.3.1.3.2
floating section
section isolated from earth or from the car body

NOTE 1 A section may be under electrical influence of adjacent sections.

NOTE 2 A particular point of a circuit may be considered as a section.

1.3.2 Voltages

1.3.2.1
nominal voltage (U_n)
suitable approximate voltage value used to designate or identify a given supply system

1.3.2.2
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.ms. value being supplied at its maximum permanent voltage

NOTE Permanent means that the voltage is lasting more than five minutes, as $U_{max\,1}$ in EN 50163.

1.3.2.3
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 Equipment may have more than one rated voltage value or may have a rated voltage range.

1.3.2.4
rated insulation voltage (U_{Nm})
r.m.s. withstand voltage value assigned by the manufacturer to the equipment or a part of it, characterizing the specified permanent (over five minutes) withstand capability of its insulation

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

NOTE 2 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 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 U_{Nm} is not necessarily equal to the rated voltage which is primarily related to functional performance.

1.3.2.5
working peak voltage
highest value of voltage which can occur in service across any particular insulation

1.3.2.6
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 Random overvoltages, for example due to occasional switching, are not considered to be recurring peak voltages.

1.3.2.7
rated impulse voltage (U_{Ni})
impulse voltage value assigned by the manufacturer to the equipment or a part of it, characterizing the specified withstand capability of its insulation against transient overvoltages

NOTE U_{Ni} is higher than or equal to the working peak voltage.

1.3.3
overvoltage
any voltage having a peak value exceeding the corresponding peak value (including recurrent overvoltages) of maximum steady-state voltage at normal operating conditions

1.3.3.1
temporary overvoltage
overvoltage of relatively long duration due to voltage variations

NOTE A temporary overvoltage is independent of the network load. It is characterized by a voltage/time curve.

1.3.3.2
transient overvoltage
short duration overvoltage of a few milliseconds or less due to current transfers

NOTE 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).

Two particular transient overvoltages are defined:

1.3.3.2.1
switching overvoltage
transient overvoltage at any point of the system due to specific switching operation or fault

1.3.3.2.2
lightning overvoltage
transient overvoltage at any point of the system due to a specific lightning discharge.

NOTE The definitions of 1.3.3 are in accordance with those of IEC 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 IEC 60664-1).
Long-term (typically 20 ms to typically 2 s), medium-term (typically 20 µs to typically 20 ms) and short-term (less than typically 20 µs) overvoltages defined in EN 50163, dedicated to contact line networks, are equivalent to respectively temporary, transient and lightning overvoltages.

1.3.4 Insulations

1.3.4.1
functional insulation
insulation between conductive parts which is necessary only for the proper functioning

1.3.4.2
basic insulation
insulation applied to live parts to provide basic protection against electric shock

1.3.4.3
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

1.3.4.4
double insulation
insulation comprising both basic insulation and supplementary insulation

1.3.4.5
reinforced insulation
single insulation system applied to live parts, which provides a degree of protection against electric shock equivalent to double insulation

NOTE The term "a 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.

2 Basis for insulation coordination

2.1 Basic principles

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.

2.1.1 Insulation coordination with regard to voltage

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.

2.1.1.1 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.

2.1.1.2 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 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.

NOTE 2 A probabilistic analysis is recommended to assess whether inherent control exists or whether protective control is needed.

NOTE 3 The specific overvoltage attenuating means may 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 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 the Table A.3.

2.1.1.3 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 (under consideration).

2.1.1.4 Insulation coordination with regard to temporary overvoltage

This subclause is under consideration.

2.1.2 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.

2.2 Voltages and voltage ratings

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 this subclause 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.

2.2.1 Rated insulation voltage (U_{Nm})

The rated insulation voltage required as a minimum for a section is equal to the highest working voltage appearing within the section, or produced by adjacent sections.

Long-term 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.

2.2.2 Rated impulse voltage (U_{Ni})

The rated impulse voltage required as a minimum for a section is 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.

2.2.2.1 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 the Table D.1 of the normative 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 may be endangered by lightning or switching overvoltages.

Further details for specific applications are given in clause 6.

In method 1, the rated impulse voltage required as a minimum for a section is determined as follows:

- or circuits not connected to traction supply systems, the rated impulse voltage is given by Table A.1;
- For circuits connected to traction supply systems 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 this protective device.

2.2.2.2 Method 2

In method 2, the rated impulse voltage required as a minimum for a section is equal to the working peak voltage appearing within the section, or produced by adjacent sections.

2.2.2.3 Contingency

No contingency is to be applied to the rated impulse voltage, whatever the method.

2.2.3 Determination of rated recurring peak voltage

Under consideration.

2.3 Frequency

Under consideration.

2.4 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.

2.5 Pollution

The micro-environment determines the effect of pollution on the insulation. The macro-environment, however, has to 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 may 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 gasses 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 IEC 60664-1, IEC 60815 and IEC 60077-1, but some definitions are not identical. The main reason is that PD4 of IEC 60664-1 and IEC 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 IEC 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.

2.6 Insulating material

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

2.6.1 Comparative tracking index (CTI)

2.6.1.1 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.

2.6.1.2 A method of classification for insulating materials according to 2.6.1.1 does not exist. The behaviour of the insulating material under various contaminants and voltages is extremely complex. Under these conditions many of the materials may exhibit two, or even three of the characteristics stated. A direct correlation with the material groups of 2.6.1.3 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 part uses the CTI values to categorize insulation materials.

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

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

The CTI values above refer to values obtained, in accordance with IEC 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 IEC 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.

3 Requirements and dimensioning rules for clearances

3.1 General

Clearances shall be dimensioned to withstand the voltages referred to in 3.2, taking into account all the parameters affecting breakdown insulation during the whole life of the equipment.

For correct measurement of clearances, the requirements of clause 5 apply.

3.2 Minimum clearances

3.2.1 Functional insulation

Minimum clearances for functional insulation are based on the rated impulse voltage, according to Table A.3.

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 equal to U_i or the value of U_{ac} or U_{dc} of Table A.8.

3.2.2 Basic and supplementary insulation

Minimum clearances for basic and supplementary insulation are based on the rated impulse voltage, according to Table A.3.

Smaller values are not allowed.

3.2.3 Reinforced insulation

When dimensioning reinforced insulation, 3.2.2 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.

3.3 Contingency

Attention is drawn to the fact that a higher value of U_{Ni} may be determined by EMC test requirements as those given in 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;
- altitude above 2 000 m;
- bacteria, biological and chemical substances;
- etc.

NOTE In method 1, the most common of these margins are more or less integrated in the selection of the rated impulse voltage.
In method 2, the manufacturer applies a safety factor based on his own experience, the criteria of said choice being subject to approval by the purchaser.

4 Dimensioning rules for creepage distances

4.1 General

Creepage distances shall be dimensioned to withstand the voltages referred to in 4.2, 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 2.

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 5 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 3.2 or 4.2.

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

NOTE Some experiments lead to the conclusion that voltage peaks may generate flash over under moist conditions. This matter is under consideration.

4.2 Minimum creepage distances

4.2.1 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.

4.2.2 Reinforced insulation

When dimensioning reinforced insulation, 4.2.1 applies with the following modification: the rated insulation voltage shall be two times the rated insulation voltage required for the basic insulation.

5 Tests and measurements

This clause deals only with verification of the requirements of clauses 3 and 4.

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

5.1 General

If required, clearances and creepage distances shall be measured on a representative item in accordance with 5.2.

If clearances of functional insulation are actually smaller than those specified in clause 3, or impossible to be measured, a test shall be carried out on the electrical parts involved, on a clean representative item.

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

The preferred electric test is an impulse voltage test in accordance with 5.3.

Alternatively, clearances may be verified by a power frequency voltage test in accordance with 5.4, or a d.c. voltage test in accordance with 5.5.

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

NOTE 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 may be damaged by the test. Product standards should take this into account when requiring high a.c. or d.c. test voltages.

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.

5.2 Measurement of creepage distances and clearances

5.2.1 Method and values

Clearances are defined in clause 3 and creepage distances in clause 4.

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

5.2.2 Acceptance criteria

Smaller values than those specified in clauses 3 and 4 shall not be allowed.

5.3 Verification of clearances by impulse test

5.3.1 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 equal to the value U_i given in Table A.8, the distance to be considered being as determined in clause 2.

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...).

5.3.2 Test acceptance criteria

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

5.4 Verification of clearances by power-frequency test

5.4.1 Method and values

The test shall be carried out in accordance to IEC 60060-1.

The test voltage shall be equal to the value Uac given in Table A.8, the distance to be considered being as determined in clause 2.

The test frequency is 50 Hz ± 10 %.

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

5.4.2 Test acceptance criteria

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

5.5 Verification of clearances by d.c. voltage test

5.5.1 Method and values

The test voltage shall be equal to the value Udc given in Table A.8, the distance to be considered being as determined in clause 2.

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 %).

5.5.2 Test acceptance criteria

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

6 Specific requirements for applications in the railway field

It is acknowledged that some requirements may be more specific or even may escape the set of common requirements stated in clauses 2, 3, 4 and 5, provided that they apply to limited areas and are supported by technical or economical reasons.

6.1 Specific requirements for signalling

6.1.1 Overvoltage categories

In addition to the overvoltage provisions given in 2.2.2.1, 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 indoor.

- 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.

6.1.2 Rated impulse voltages

In the absence of any specific information of rated impulse voltages, clearances shall be determined according to 6.1.2.1 and 6.1.2.2.

NOTE The value of 6.1.2.1 is higher than that of 6.1.2.2 for reliability reasons: it is more difficult to detect a failed remote equipment.

6.1.2.1 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.

6.1.2.2 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.

6.1.3 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.

6.1.4 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.

6.1.5 Pollution degrees

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

Insulation of equipment that 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 that fulfils the requirements for IP65 (according to EN 60529) or better may be dimensioned for PD1.

6.2 Specific requirements for rolling stock

6.2.1 Determination of U_{Ni} by method 1

In addition to the overvoltage provisions given in 2.2.2.1, 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 component 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 should be 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}.

6.2.2 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.

6.2.3 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.

6.3 Specific requirements for fixed installations

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

In addition to the overvoltage provisions given in 2.2.2.1, the following may serve as a guideline when defining overvoltage categories in fixed installations:

6.3.1.1 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} and the distances shall be increased up to 25 % in case a switching device is intended to cut off the supply from all or a discrete section of the installation, by separating the installation or section from every source of electrical energy for reasons of safety (EN 60947-1, subclause 2.1.19).

6.3.1.2 Overhead lines

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

Therefore the rated impulse voltage is chosen among the preferred values given in Table A.2, but irrespective of the correspondence with the insulation voltages and of the overvoltage levels stated in said table.

Table A.3 is based on the worst dielectric conditions of electrodes. In overhead lines different conditions are present and by consequence different clearances are allowed from U_{Ni} = 95 kV upwards.

EN 50119 gives actual clearances to be kept in overhead lines.

6.3.2 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, smelting works near the ocean with frequent fog are close by.

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

Annex A (normative)

Tables

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

Not to be used in Method 2

Nominal voltage U_n of the supply system (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 to 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 For 3-phase equipment, the rated insulation voltage refers to the voltage line-to-neutral.

NOTE 3 National regulations may impose a minimum U_{Ni}.

NOTE 4 This table is cited in 2.2.2.1.

Table A.2 — Rated impulse voltages (U_{Ni}) for circuits powered by the contact line

Not to be used in Method 2.

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

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

NOTE 2 This table is cited in 2.2.2.1 and 6.3.1.

[a] For rolling stock only.

[b] For fixed installations only.

[c] Higher values for special requirements only.

Table A.3 — Minimum clearances in air (in mm) based on the rated impulse voltage U_{Ni}

U_{Ni} (kV)	PD1	PD2	PD3	PD3A	PD4	PD4A	PD4B
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				5,5		
3,5	2,5				6,2		
4	3				7,0		
4,5	3,5				8,0		
5	4				8,5		
6	5,5				10	18	20
8	8				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	32				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

NOTE 1 For contact lines, see 6.3.1.2

NOTE 2 For definition of U_{Ni}, see 1.3.2.7.
For definition of PD1...PD4B, see 2.5, Table A.4, annex E.

NOTE 3 This table does not apply to roof installations in rolling stock (see 6.2)

NOTE 4 Interpolation between adjacent values of the table is permitted, but the values of the first column are preferred values (see 2.1.1.2)

NOTE 5 This table is cited in 2.1.1.2, 3.2.1, 3.2.2, 4.1, 5.1, 6.3.1.2, Table A.7 and B.2.1

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 (1)	- occasionally conductive coming from heavy pollution	- rain, snow, ice, fog
PD4B (2)	- occasionally conductive coming from very heavy pollution	- rain, snow, ice, fog

(1) Fixed installations and track side equipment e.g. for signalling

(2) Fixed installations only

NOTE This table is cited in 2.5 and Table A.3

Table A.5 — Minimum creepage distances (in mm) 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	PD2 Material Groups I-II-IIIa
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
1000	3,20	5,00

NOTE 1 For definition of U_{Nm} see 1.3.2.4

NOTE 2 Interpolation between adjacent values of the table is permitted

NOTE 3 This table is cited in 2.4, 4.1 and 4.2.1

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

U_{Nm} (V)	PD1	PD2			PD3			PD3A and PD4		
	Material Groups I-II-IIIa-IIIb	**Material Group**			**Material Group**			**Material Group**		
		I	**II**	**III**	**I**	**II**	**III**	**I**	**II**	**III**
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	0,2	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

NOTE 1 Interpolation between adjacent values is permitted.

NOTE 2 This table is cited in 2.4, 4.1 and 4.2.1

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

	Above 1 000 V					Above 500 V	
Material Groups	**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						

NOTE 1 For rolling stock, see 6.2.2 and 6.2.3.

NOTE 2 The minimum creepage distance shall be at least equal to the minimum clearance given by Table A.3.

NOTE 3 This table is cited in 2.4 and 4.2.1.

Table A.8 — Test voltages for verifying clearances, 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	0,5	0,7
0,5	1,55	0,84	1,19
1,5	2,56	1,39	1,97
2	3,1	1,69	2,39
2,5	3,6	1,96	2,77
3	4,06	2,21	3,13
3,5	4,51	2,45	3,47
4,5	5,33	2,9	4,1
5,5	6,09	3,32	4,69
8	7,82	4,26	6,02
11	9,95	5,4	7,63
14	12,2	6,61	9,35
18	15,1	8,17	11,6
22	17,8	9,68	13,7
25	19,9	10,8	15,3
32	24,5	13,3	18,8
40	29,5	16,	22,7
60	41,6	22,6	31,9
90	58,5	31,7	44,9
120	74,6	40,5	57,2
160	95	51,5	72,9
260	143	77,6	110
310	166	90	127
370	193	104	148
480	240	130	184
600	289	157	222

NOTE 1 U_i is the amplitude of the 1,2/50 impulse test voltage;
U_{ac} is the r.m.s value of the power frequency test voltage;
U_{dc} is the value of the d.c. test voltage.

NOTE 2 Interpolation between adjacent values of the table is permitted.

NOTE 3 This table is cited in 3.2.1, 5.1, 5.3.1, 5.4.1, 5.5.1

Annex B (normative)

Provisions for type and routine dielectric tests for equipment

NOTE This annex is cited in 1.1 and clause 5

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 5. 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

Unless otherwise stated or agreed, the tests specified here 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.2.2 and B.2.3 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 according to IEC 60060-1 and relevant product documents.

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.2.1 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 2, and shall fall into the series of preferred values that are listed in the first column of Table A.3.

B.2.2 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.2.3 D.C. 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 electromechanical equipment connected to the contact line — Short-duration power-frequency (a.c.) test levels U_a (kV r.m.s.) based on the rated insulation voltage U_{Nm} (kV r.m.s.) and on the rated impulse voltage U_{Ni} (kV_{crest})

Rated impulse voltage U_{Ni} kV_{crest}	Test voltage for rolling stock U_a kV	Test voltage for fixed installations U_a kV
0,33	0,2	0,2
0,5	0,3	0,3
0,8	0,42	0,42
1,5	0,7	0,7
2,5	1,2	1,2
3	1,4	1,4
3,5	1,6	1,6
4	2	1,9
4,5		2
5	2,5	2,3
6	3,3	2,8
8	3,9	3,6
10	5,2	4,6
12	6,6	5,5
15	8	6,9
18	9	8,3
20	9,4	9,2
25	11,6	11,5
30	15	14
35	17	17
40	20	18,5
50	25	23
60		27,5
75	34,5	34,5
95	44	44
125	50	50
145	70	70
170	80	80
200	95	95
250	95	95
325		140
NOTE If equipment for standardised three-phase a. c. systems according to IEC 60071-1 is used, devices have to be selected in accordance with U_{Ni} and U_a.		

NOTE After the test described in 9.3.3.4 the component shall be able to withstand the dielectric tests required as a routine test in 9.3.3.3 of EN 60077-1, but with the test voltage values reduced to 75%.

Annex C (normative)

Methods of measuring creepage distances and clearances

NOTE This annex is cited in 5.2.1

The methods of measuring creepage distances and clearances are indicated in the following examples 1 to 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

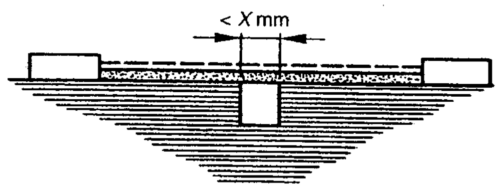
Pollution degree	Width X of grooves: Minimum values (mm)
PD1	0,25
PD2	1,0
PD3	1,5
PD3A	2,5
PD4	4
PD4A	7
PD4B	10

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.

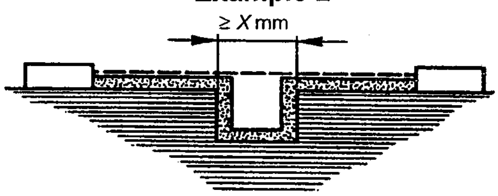
Example 1



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.

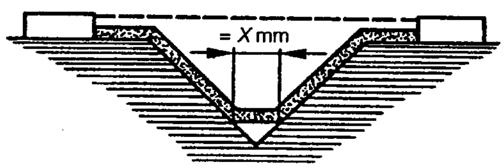
Example 2



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

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

Example 3



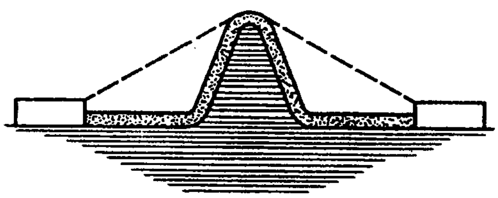
Condition: Path under consideration includes a V-shaped groove with a width greater than X mm.

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.

– – – – – Clearance

Creepage distance

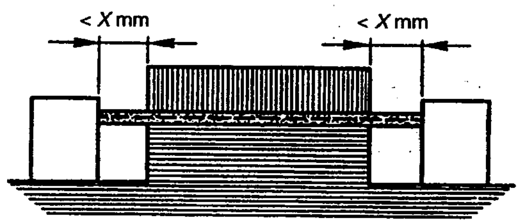
Example 4



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.

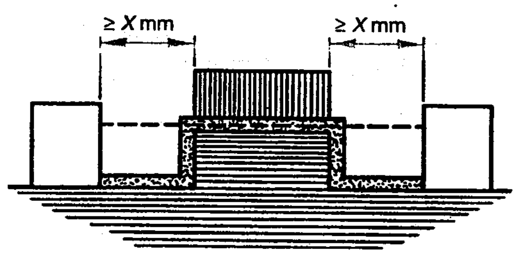
Example 5



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.

Example 6



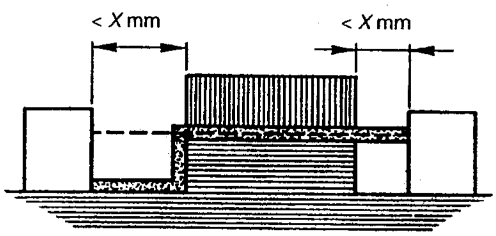
Condition: Path under consideration includes an uncemented joint with grooves equal to or more than X mm on each side.

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

- - - - - Clearance

Creepage distance

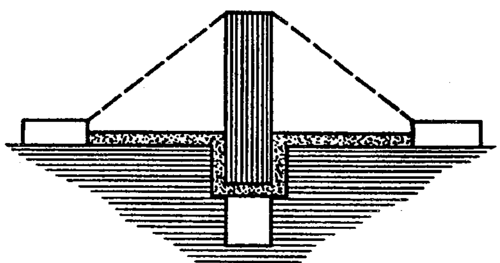
Example 7



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.

Example 8



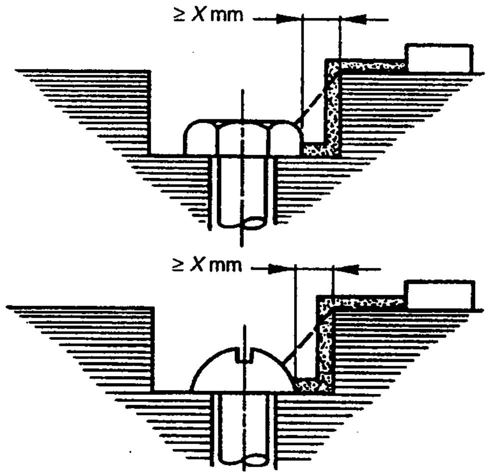
Condition: Creepage distance through uncemented joint is less than creepage distance over barrier.

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

------ Clearance

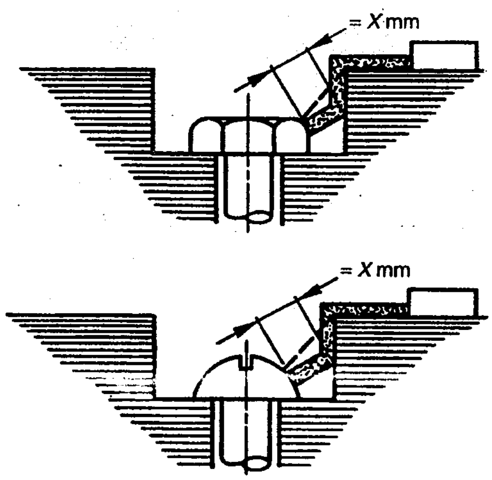
Creepage distance

Example 9



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

Example 10



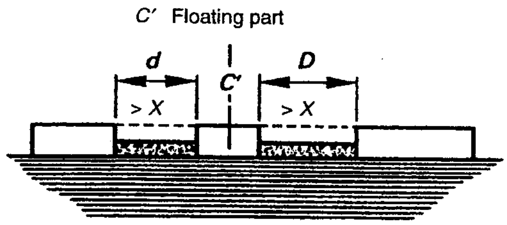
Gap between head of screw and wall of recess too narrow to be taken into account.

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

------ Clearance

Creepage distance

Example 11



Clearance is the distance = $d + D$
Creepage distance is also = $d + D$

Annex D (normative)

Correlation between U_n and U_{Nm}

NOTE Table D.1 is cited in 2.2.2.1

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}
Power supply systems according to EN 50163		Battery supply systems	
d.c. kV	a.c. kV	V	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 2.2.2.1.

[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 2.5 and Table A.3

	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 indoor.	- 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 indoor.	- 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 outdoor.	- transformer station - driver cabin; - passenger compartment; - machinery compartment; - station hall.
PD3A	- indoor location; - outdoor sheltered protected from weather conditions	- forced ventilation with air from outdoor - no filters	- machinery compartment; - cable manhole; - aerial mast - inside substations - insulators in light pollution level areas (1)
PD4	- outdoor location; - underfloor of vehicle; - roof of vehicle		- pantograph, shoe gear - covered platform - insulators in medium pollution level areas (1)
PD4A	- unprotected outdoor locations		- insulators in high pollution level areas (1)
PD4B	- unprotected outdoor locations		- insulators in very high pollution level areas (1)
(1) according to IEC 60815			

Annex F (informative)

Bibliography

The following documents may serve as guidance or are connected to this European Standard; future CENELEC documents deriving from IEC publications will prevail.

EN 50123 (series), *Railway applications — Fixed installations — D.C. switchgear*

EN 50125 (series), *Railway applications — Environmental conditions for equipment*

EN 50129 [1], *Railway applications — Safety related electronic systems for signalling*

EN 50152 (series), *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 coordination — Part 2: Application guide* (IEC 60071-2)

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 voltage greater than 1 kV* (IEC 60168)

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*

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 60383-1)

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 61558 (series), *Safety of power transformers, power supply units and similar devices*

HD 384 (series), *Electrical installations of buildings* (IEC 60364, modified)

HD 625.3, *Insulation coordination for equipment within low voltage systems — Part 3: Use of coating to achieve insulation coordination of printed board assemblies* (IEC 60664-3)

HD 637 S1, *Power installations exceeding 1 kV a.c.*

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

IEC 60099-3, *Surge arresters — Part 3: Artificial pollution testing of surge arresters* (Technical Report)

IEC 60815, *Guide for the selection of insulators in respect of polluted conditions* (Technical Report)

IEC 61109, *Composite insulators for a.c. overhead lines with a nominal voltage greater than 1 000 V — Definitions, test methods and acceptance criteria*

[1] In preparation

Annex G (informative)

Application guide

G.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 creepages 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 1.1 it can be assumed that the insulation values in the product standards were derived in accordance with this European Standard.

G.2 Determination of minimum clearances and creepage distances

G.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 regarded 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 regarded section and adjacent sections, creepage 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.

G.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.

G.2.3 How to determine minimum clearances and creepage distances

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

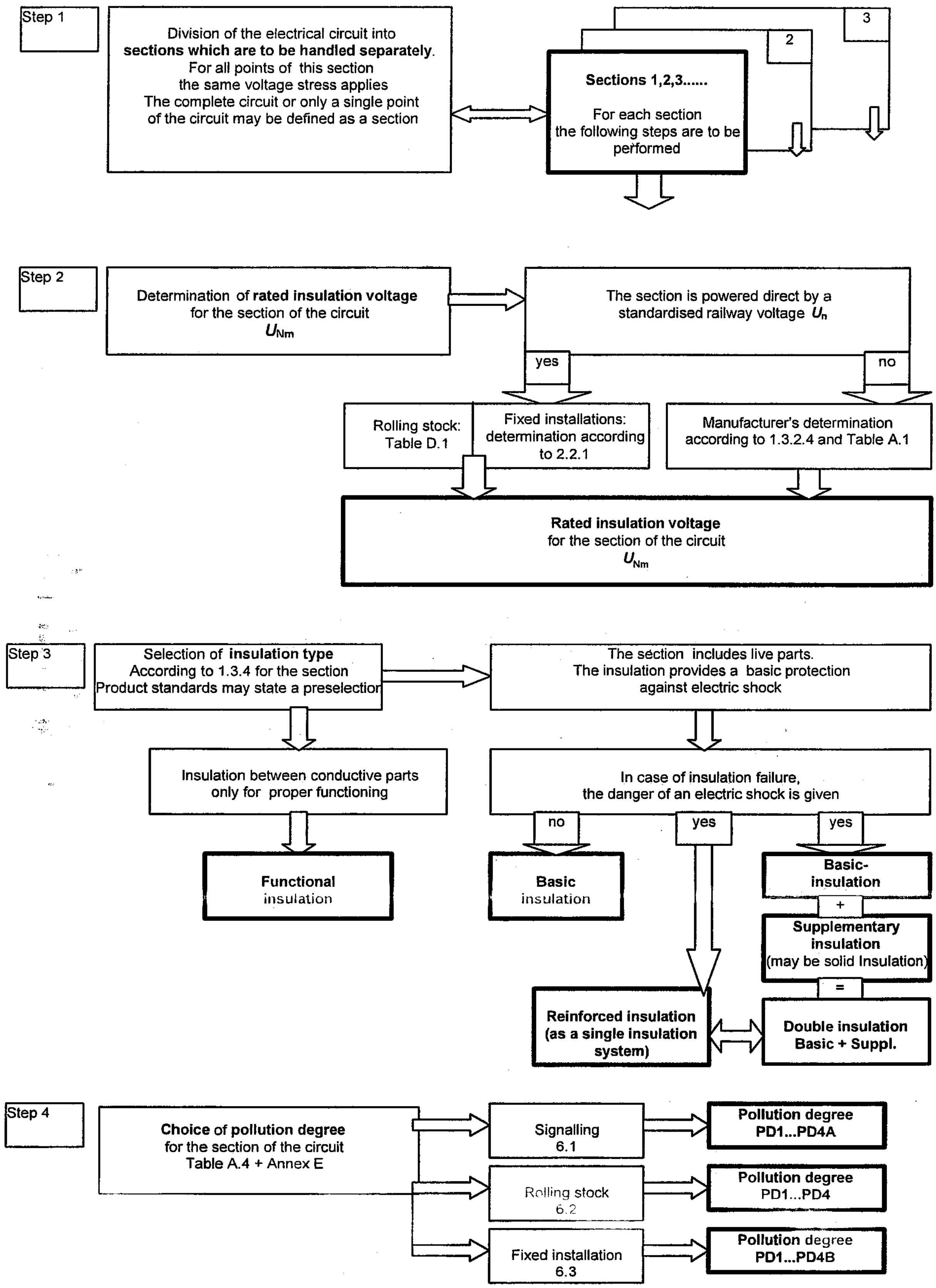


Figure G.1 – Determination of minimum clearances and creepage distances

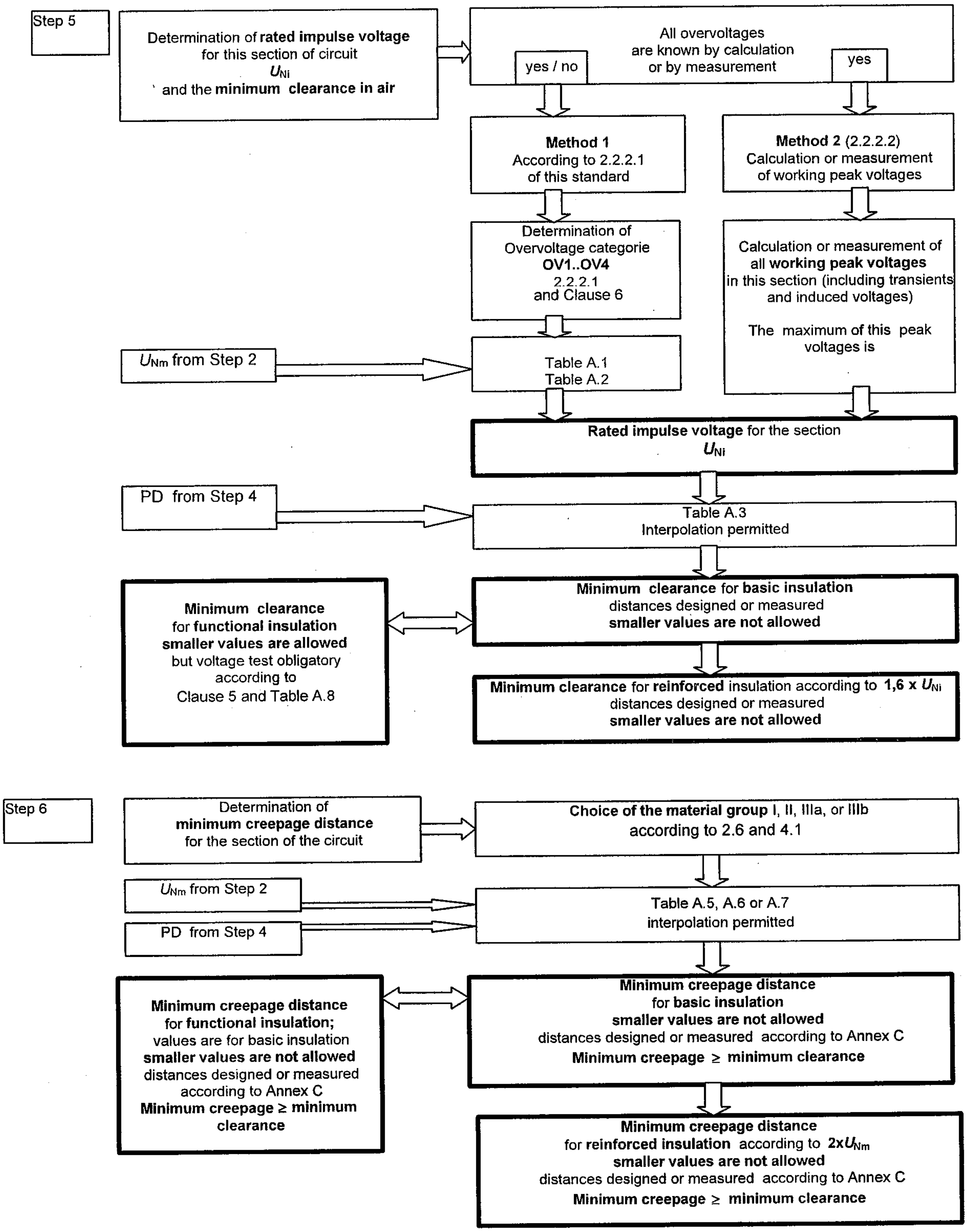


Figure G.1 – Determination of minimum clearances and creepage distances (concluded)

G.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 60815, 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, characterised by no rain for long periods, exposed to strong winds carrying sand and salt, and subjected to regular condensation.

G.2.5 Creepages

For creepages, 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.

G.2.6 Insulations

G.2.6.1 Types of insulation

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

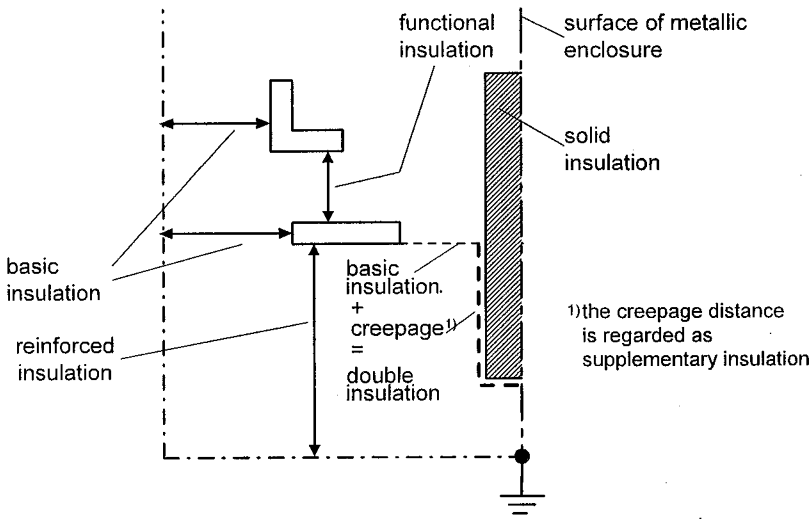


Figure G.2 – Example for types of insulation

G.2.6.2 Supplementary insulation

A supplementary insulation (see definition 1.3.4.3) 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.

NOTE 1 Supplementary insulation may be performed as a layer of solid insulation.

NOTE 2 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 1.3.4.3, e.g. in the case of the outer sheath of a cable.

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

G.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.

G.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 series EN 61558.

G.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.

G.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 creepages on the roof due to the level of pollution likely to be expected in that area.

G.2.9 Special cases of switching arrangements in fixed installations (see Table A.2, footnote 3)

Table A.2 gives values for U_{Ni} for the rated insulation voltage 52 kV a.c.

Switchgear intended to fulfil those 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 standardised value is then 52 kV in accordance with EN 60071-1.

In all other cases the relevant value of N_{Nm} is either 27,5 kV or 36 kV for a U_n of 25 kV.

G.2.10 Insulation conditions in fixed installations (see 6.3.1.1)

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 series EN 50123, for a.c. switching devices in the series EN 50152.

G.3 Examples

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

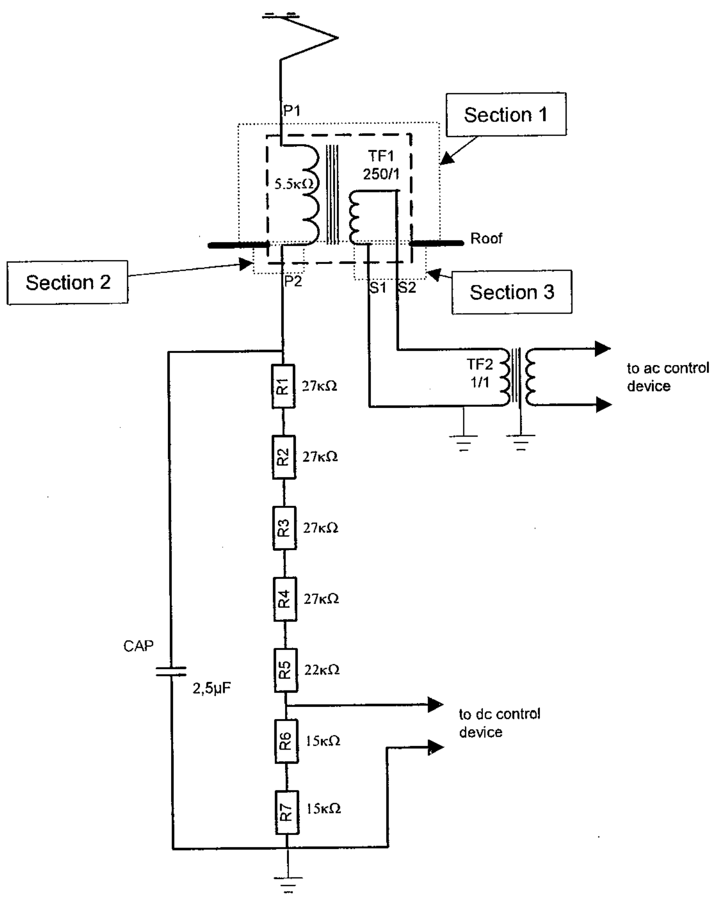


Figure G.3 – Monitoring circuit showing examples of sections

Figure G.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 G.3.

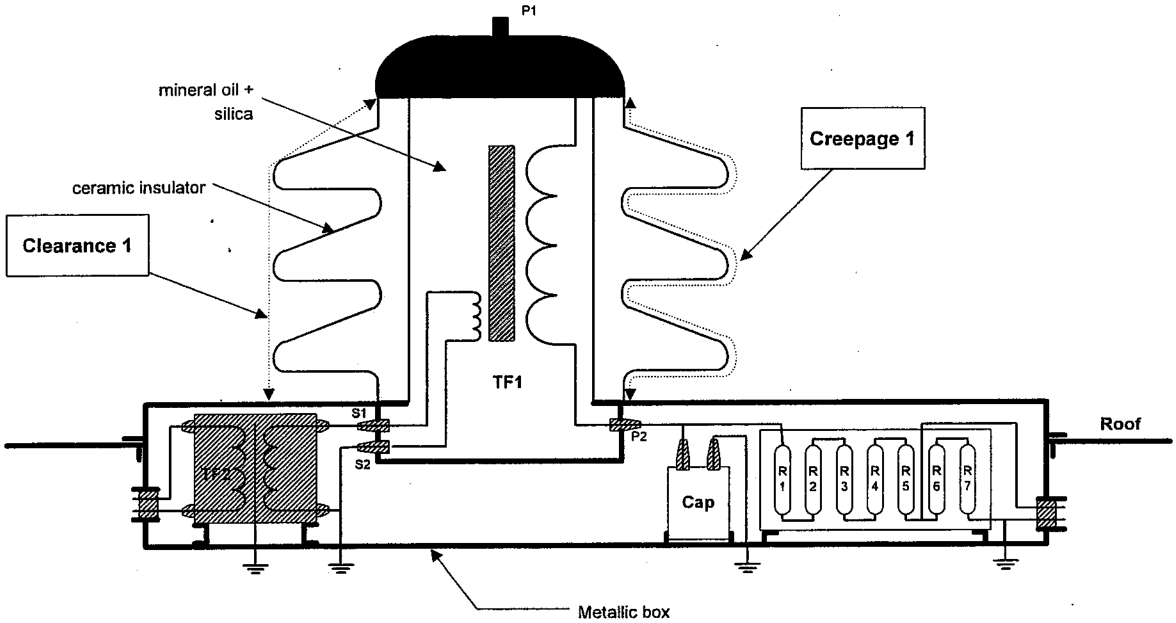


Figure G.4 – Drawing of monitoring device

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.

Step 1 (see diagram)	**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} = 10 kV** Table A.3 **Minimum clearance = 11 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**

Figure G.5 – Example for the determination of clearances and creepage distances

G.4 Tests

G.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 5.3, 5.4 or 5.5 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.

G.4.2 Testing

Two kinds of voltage tests are given in this standard:

a) Tests for verification of clearances (see Clause 5 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 5 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.