IEC TS 62993

Edition 1.0 2017-07

# TECHNICAL SPECIFICATION

## Guidance for determination of clearances, creepage distances and requirements for solid insulation for equipment with a rated voltage above 1 000 V AC and 1 500 V DC, and up to 2 000 V AC and 3 000 V DC



IEC TS 62993:2017-07(en)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.080.30 ISBN 978-2-8322-4501-9

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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# GUIDANCE FOR DETERMINATION OF CLEARANCES, CREEPAGE DISTANCES AND REQUIREMENTS FOR SOLID INSULATION FOR EQUIPMENT WITH A RATED VOLTAGE ABOVE 1 000 V AC AND 1 500 V DC, AND UP TO 2 000 V AC AND 3 000 V DC

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62993, which is a technical specification, has been prepared by IEC technical committee 109: Insulation co-ordination for low-voltage equipment.

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

| Enquiry draft | Report on voting |
|---|---|
| 109/158A/DTS | 109/162/RVDTS |

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

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

In this standard, the following print types are used:

– requirements: in roman type;
– NOTES: in small roman type;
– *conformity and tests: in italic type;*
– terms used throughout this standard which have been defined in Clause 3: SMALL ROMAN CAPITALS.

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

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

The contents of the corrigendum of June 2018 have been included in this copy.

# INTRODUCTION

IEC TS 62993 is developed in a JWG between several interested committees: TC 9, SC 22G, TC 31, TC 66, TC 82, SC 121A, and ACOS under the leadership of TC 109.

This document provides additional steps for a smooth transition between the low voltage (up to 1 000 V AC and 1 500 V DC) in IEC 60664 (all parts) and high voltage insulation coordination (although IEC 60071-1 is applicable from above 1 000 V, it only gives values starting at 3 600 V). IEC 60071-1 states that it does not cover the requirements for human safety. Moreover IEC 60071-1 does not provide values for creepage distances.

This document has been requested by several TCs dealing with equipment with a rated voltage above 1 000 V AC and 1 500 V DC up to 2 000 V AC and 3 000 VDC.

It is not the intention to extend the limit of low voltage range – having a conventionally accepted limit of 1 000 V AC and 1 500 V DC – into the high voltage range.

# GUIDANCE FOR DETERMINATION OF CLEARANCES, CREEPAGE DISTANCES AND REQUIREMENTS FOR SOLID INSULATION FOR EQUIPMENT WITH A RATED VOLTAGE ABOVE 1 000 V AC AND 1 500 V DC, AND UP TO 2 000 V AC AND 3 000 V DC

## 1 Scope

IEC TS 62993, which is a Technical Specification, gives guidance to technical committees which deal with equipment having a RATED VOLTAGE of more than 1 000 V AC and up to 2 000 V AC, or a RATED VOLTAGE of more than 1 500 V DC and up to 3 000 V DC. RATED VOLTAGES up to 1 000 V AC and 1 500 V DC, as well as higher or lower internal voltages, are covered by IEC 60664-1.

This document applies to equipment for use up to 2 000 m above sea level, and provides guidance for use at higher altitudes.

This document gives guidance for CLEARANCES, CREEPAGE DISTANCES and SOLID INSULATION for equipment to achieve safety. It includes methods of electric testing.

NOTE Requirements for functional insulation are not specified as they are not regarded as safety requirements.

This document does not deal with distances

- through liquid insulation,
- through gases other than air, and
- through compressed air.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-2-2, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

IEC 60068-2-14, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60112:2003, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*
IEC 60112:2003/AMD1:2009

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

IEC 61180:2016, *High-voltage test techniques for low-voltage equipment – Definitions, test and procedure requirements, test equipment*

## 3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

**3.1**
**CLEARANCE**
shortest distance in air between two conductive parts

[SOURCE: IEC 60050-581:2008, 581-27-76]

**3.2**
**CREEPAGE DISTANCE**
shortest distance along the surface of a solid insulating material between two conductive parts

[SOURCE: IEC 60050-151:2001, 151-15-50]

**3.3**
**SOLID INSULATION**
solid insulating material, or a combination of solid insulating materials, placed between two conductive parts or between a conductive part and a body part

[SOURCE: IEC 60050-903:2015, 903-04-14]

**3.4**
**WORKING VOLTAGE**
highest RMS value of the AC or DC voltage across any particular insulation which can occur when the equipment is supplied at RATED VOLTAGE

[SOURCE: IEC 60050-581:2008, 581-21-19]

**3.5**
**RECURRING PEAK VOLTAGE**
maximum peak value of periodic excursions of the voltage waveform resulting from distortions of an AC voltage or from AC components superimposed on a DC voltage

[SOURCE: IEC 60050-442:2014, 442-09-15, modified – The note to entry has been deleted.]

**3.6**
**OVERVOLTAGE**
voltage having a peak value exceeding the corresponding peak value of maximum steady-state voltage at normal operating conditions

[SOURCE: IEC 60664-1:2007, 3.7]

**3.7**
**TEMPORARY OVERVOLTAGE**
power frequency OVERVOLTAGE of relatively long duration

[SOURCE: IEC 60050-614:2016, 614-03-13, modified – The note to entry has been deleted.]

**3.8**
**TRANSIENT OVERVOLTAGE**
OVERVOLTAGE with a duration of a few milliseconds or less, oscillatory or non-oscillatory, usually highly damped

[SOURCE: IEC 60050-614:2016, 604-03-14]

**3.9**
**WITHSTAND VOLTAGE**
value of the test voltage to be applied under specified conditions in a withstand test, during which disruptive discharges are not tolerated

**3.10**
**IMPULSE WITHSTAND VOLTAGE**
highest peak value of impulse voltage of prescribed form and polarity which does not cause breakdown of insulation under specified conditions

[SOURCE: IEC 60050-442:2014, 442-09-18]

**3.11**
**RATED VOLTAGE**
rated 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.

Note 2 to entry For three-phase power supply, the line-to-line voltage applies.

[SOURCE: IEC 60050-442:2014, 442-09-10]

**3.12**
**RATED INSULATION VOLTAGE**
rated value of the RMS WITHSTAND VOLTAGE assigned by the manufacturer to the equipment or to a part of it, characterizing the specified (long-term) withstand capability of its insulation

Note 1 to entry The RATED INSULATION VOLTAGE is not necessarily equal to the RATED VOLTAGE of equipment which is primarily related to functional performance.

[SOURCE: IEC 60050-312:2014, 312-06-02]

**3.13**
**RATED IMPULSE VOLTAGE**
IMPULSE WITHSTAND VOLTAGE value assigned by the manufacturer to the equipment or to a part of it, characterizing the specified withstand capability of its insulation against TRANSIENT OVERVOLTAGES

**3.14**
**OVERVOLTAGE CATEGORY**
numeral defining a TRANSIENT OVERVOLTAGE condition

[SOURCE: IEC 60050-581:2008, 581-21-02]

**3.15**
**POLLUTION**
any addition of foreign matter, solid, liquid, or gaseous that can produce a permanent reduction of electric strength or surface resistivity of the insulation

[SOURCE: IEC 60050-442:1998, 442-01-28]

**3.16**
**POLLUTION DEGREE**
numeral characterizing the expected POLLUTION of the MICRO-ENVIRONMENT

[SOURCE: IEC 60050-581:2008, 581-21-07, modified – The note to entry has been deleted.]

**3.17**
**ENVIRONMENT**
surroundings in which a product or system exists, including air, water, land, natural resources, flora, fauna, humans and their interrelation

[SOURCE: IEC 60050-901:2013, 901-07-01]

**3.18**
**MICRO-ENVIRONMENT**
ambient conditions which immediately surround the CLEARANCE and CREEPAGE DISTANCE under consideration excluding self-produced POLLUTION resulting from normal operation of the accessory

Note 1 to entry The MICRO-ENVIRONMENT of the CREEPAGE DISTANCE or CLEARANCE and not the ENVIRONMENT of the accessory determines the effect on the insulation. It might be better or worse than the ENVIRONMENT of the accessory.

[SOURCE: IEC 60050-442:1998, 442-01-29]

**3.19**
**HOMOGENEOUS ELECTRIC FIELD**
electric field which has an essentially constant voltage gradient between electrodes (uniform field), such as that between two spheres where the radius of each sphere is greater than the distance between them

Note 1 to entry The HOMOGENEOUS ELECTRIC FIELD condition is referred to as case B.

[SOURCE: IEC 60050-442:2014, 442-09-02.]

**3.20**
**INHOMOGENEOUS ELECTRIC FIELD**
electric field which does not have an essentially constant voltage gradient between electrodes (non-uniform field)

Note 1 to entry The INHOMOGENEOUS ELECTRIC FIELD condition of a point-plane electrode configuration is the worst case with regard to voltage withstand capability and is referred to as case A. It is represented by a point electrode having a 30 μm radius and a plane of 1 m x 1 m.

[SOURCE: IEC 60050-442:2014, 442-09-03,.]

**3.21**
**INSULATION**
part of an electrotechnical product which separates the conducting parts at different electrical potentials

[SOURCE: IEC 60050-212:2010, 212-11-07,]

**3.22**
**BASIC INSULATION**
INSULATION of hazardous-live-parts which provides basic protection

Note 1 to entry The concept does not apply to insulation used exclusively for functional purposes.

[SOURCE: IEC 60050-826:2004, 826-12-14]

**3.23**
**SUPPLEMENTARY INSULATION**
independent INSULATION applied in addition to BASIC INSULATION for fault protection

[SOURCE: IEC 60050-826:2004, 826-12-15]

**3.24**
**DOUBLE INSULATION**
insulation comprising both BASIC INSULATION and SUPPLEMENTARY INSULATION

[SOURCE: IEC 60050-826:2004, 826-12-16]

**3.25**
**REINFORCED INSULATION**
INSULATION of hazardous-live-parts which provides a degree of protection against electric shock equivalent to DOUBLE INSULATION

Note 1 to entry REINFORCED INSULATION may comprise several layers which cannot be tested singly as BASIC INSULATION or SUPPLEMENTARY INSULATION.

[SOURCE: IEC 60050-826:2004, 826-12-17]

**3.26**
**PARTIAL DISCHARGE**
electric discharge that partially bridges the INSULATION

[SOURCE: IEC 60050-442:2014, 442-09-05]

**3.27**
**ROUTINE TEST**
test to which each individual device is subjected during or after manufacture to ascertain whether it complies with certain criteria

[SOURCE:IEC 60050-151:2001, 151-16-17]

**3.28**
**TYPE TEST**
test of one or more devices made to a certain design to show that the design meets certain specifications

[SOURCE: IEC 60050-151:2011, 151-16-16]



# 4 Basic information for the determination of INSULATION requirements

## 4.1 General

To determine the requirements for INSULATION, several aspects need to be considered. These aspects are

- voltages (see 4.2),
- OVERVOLTAGE CATEGORIES (see 4.3),
- material groups (see 4.4),
- POLLUTION DEGREES (see 4.5).

## 4.2 Voltages

### 4.2.1 General

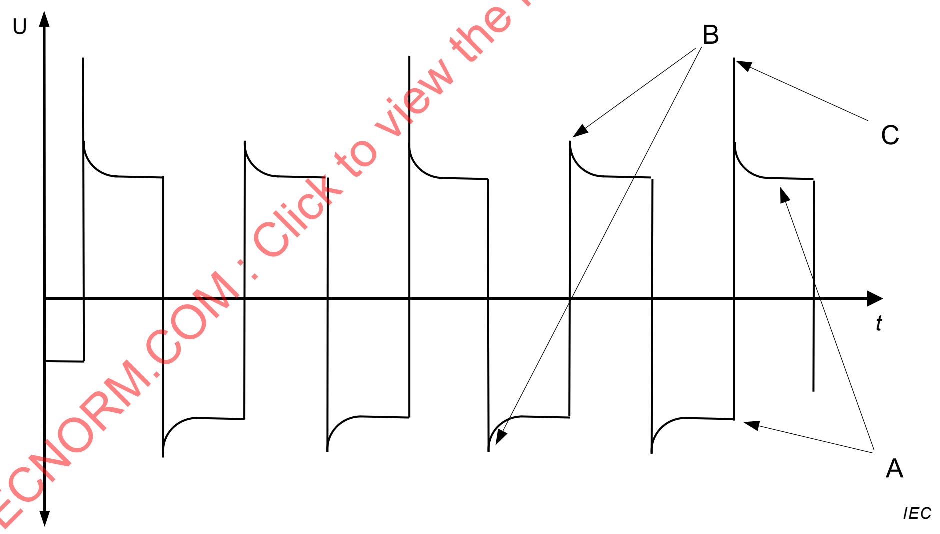
Consideration shall be given to the following voltages as applicable:

- the voltages which can appear within the system;
- the voltages generated by the equipment (which could adversely affect other equipment in the system);
- RECURRING PEAK VOLTAGES (see 4.2.2);
- RATED VOLTAGES;
- RATED INSULATION VOLTAGES;
- WORKING VOLTAGES;
- TRANSIENT OVERVOLTAGES;
- TEMPORARY OVERVOLTAGES.

For the mains voltages in the range of this document, there are no standard TEMPORARY OVERVOLTAGES defined. Technical committees shall determine which TEMPORARY OVERVOLTAGES will apply to their equipment.

### 4.2.2 Determination of RECURRING PEAK VOLTAGE

The wave shape of the voltage is measured by an oscilloscope of sufficient bandwidth, from which the peak amplitude is determined according to Figure 1.






**Key**

A WORKING VOLTAGE value

B peak of working value

C RECURRING PEAK VOLTAGE

**Figure 1 – RECURRING PEAK VOLTAGE**

## 4.3 OVERVOLTAGE categories

The concept of OVERVOLTAGE CATEGORIES is used for equipment energized directly from the mains. Technical committees shall specify the OVERVOLTAGE CATEGORY as based on the following general explanation of OVERVOLTAGE CATEGORIES.

a) Equipment with a RATED IMPULSE VOLTAGE corresponding to OVERVOLTAGE CATEGORY IV is suitable for use at, or in the proximity of, the origin of the installation, for example upstream of the main distribution board. Equipment of category IV has a very high impulse withstand capability providing the required high degree of reliability, and shall have a rated IMPULSE WITHSTAND VOLTAGE not less than the value specified in Table 1.

NOTE 1 Examples of such equipment are electricity meters, primary overcurrent protective devices and ripple control units.

b) Equipment with a RATED IMPULSE VOLTAGE corresponding to OVERVOLTAGE CATEGORY III is suitable for use in the fixed installation downstream of and including the main distribution board, providing a high degree of availability, and shall have a rated IMPULSE WITHSTAND VOLTAGE not less than the value specified in Table 1.

NOTE 2 Examples of such equipment are distribution boards, circuit-breakers, wiring systems (see IEC 60050-826:2004, 826-15-01), including cables, busbars, junction boxes, switches, socket-outlets) in the fixed installation, and equipment for industrial use and some other equipment, for example stationary motors with permanent connection to the fixed installation.

c) Equipment with a RATED IMPULSE VOLTAGE corresponding to OVERVOLTAGE CATEGORY II is suitable for connection to the fixed installation, providing a degree of availability normally required for current-using equipment, and shall have a rated IMPULSE WITHSTAND VOLTAGE not less than the value specified in Table 1.

NOTE 3 Examples of such equipment are household appliances and similar loads.

d) Equipment with a RATED IMPULSE VOLTAGE corresponding to OVERVOLTAGE CATEGORY I is only suitable for use in the fixed installation where surge protection devices are installed outside the equipment to limit TRANSIENT OVERVOLTAGES to the specified level, and shall have a rated IMPULSE WITHSTAND VOLTAGE not less than the value specified in Table 1. Therefore, equipment with a rated IMPULSE WITHSTAND VOLTAGE corresponding to OVERVOLTAGE CATEGORY I should preferably not be installed at or near the origin of installation.

NOTE 4 Examples of such equipment are those containing electronic circuits like computers and home electronics.



**Table 1 – RATED IMPULSE VOLTAGES according to OVERVOLTAGE CATEGORIES**

| Highest continuous voltage line to earth[b], AC or DC<br>V | RATED IMPULSE VOLTAGE<br>V | | | |
|---|---|---|---|---|
| | OVERVOLTAGE CATEGORY | | | |
| | I | II | III | IV |
| > 1 000 ≤ 1 250 | 4 000 | 6 000 | 8 000 | 12 000 |
| > 1 250 ≤ 1 500 | 6 000 | 8 000 | 10 000 | 15 000 |
| > 1 500 ≤ 2 000 | 8 000 | 12 000 | 15 000 | 18 000 |
| > 2 000 ≤ 3 000[a] | 12 000 | 15 000 | 18 000 | 20 000 |

[a] For DC only.

[b] For unearthed or impedance-earthed three phase three wire systems and single phase two wire systems, use the line-to-line voltage. For three phase four wire systems and for single phase three wire systems, use the line-to-neutral voltage. For a product or an equipment, use the RATED INSULATION VOLTAGE when specified and otherwise the highest RATED VOLTAGE. For an installation in a supply system, use the highest continuous voltage. If the highest continuous voltage is not more than 10% higher than the nominal voltage, the nominal voltage may be used.

## 4.4 Material groups

For the purposes of this document, materials are classified into four groups according to their CTI (Comparative Tracking Indices) values. These values shall be determined in accordance with IEC 60112 using solution A. The groups are as follows:

- material group I: 600 ≤ CTI;
- material group II: 400 ≤ CTI < 600;
- material group IIIa: 175 ≤ CTI < 400;
- material group IIIb: 100 ≤ CTI < 175.

The CTI values have no relationship to the RATED VOLTAGE.

## 4.5 POLLUTION DEGREES

### 4.5.1 General

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.

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

Conductive POLLUTION by ionized gases and metallic depositions occurs only in specific instances, for example in arc chambers of switchgear or controlgear, and is not covered by this document.

### 4.5.2 Degrees of POLLUTION in the MICRO-ENVIRONMENT

For the purpose of evaluating CREEPAGE DISTANCES and CLEARANCES, the following four degrees of POLLUTION in the MICRO-ENVIRONMENT are established:

**a) POLLUTION DEGREE 1**

No POLLUTION or only dry, non-conductive POLLUTION occurs. The POLLUTION has no influence.

**b) POLLUTION DEGREE 2**

Only non-conductive POLLUTION occurs, except that occasionally a temporary conductivity caused by condensation is to be expected.

**c) POLLUTION DEGREE 3**

Conductive POLLUTION occurs temporarily or dry non-conductive POLLUTION occurs which becomes conductive due to condensation which is to be expected.

**d) POLLUTION DEGREE 4**

Continuous conductivity occurs due to conductive dust, rain or other wet conditions.

### 4.5.3 Conditions of conductive POLLUTION

The dimensions for CREEPAGE DISTANCE cannot be specified where permanently conductive POLLUTION is present (POLLUTION DEGREE 4). For temporarily conductive POLLUTION (POLLUTION DEGREE 3), the surface of the INSULATION may be designed to avoid a continuous path of conductive POLLUTION, for example by means of ribs and grooves (see 5.2.4).

### 4.5.4 Clearances

The minimum CLEARANCES specified in this standard do not apply where ionized gases occur. Special requirements for such situations may be specified at the discretion of the relevant technical committee.

# 5 Dimensioning rules

## 5.1 Clearances

CLEARANCES shall be dimensioned to withstand the voltages which can appear within the system, as applicable:

– TRANSIENT OVERVOLTAGES;
– WORKING VOLTAGES;
– RECURRING PEAK VOLTAGES;
– TEMPORARY OVERVOLTAGES.

The TRANSIENT OVERVOLTAGES are determined by the required IMPULSE WITHSTAND VOLTAGE. For equipment directly connected to the mains, the required IMPULSE WITHSTAND VOLTAGE is the RATED IMPULSE VOLTAGE established on the basis of Table 1. The corresponding values for the CLEARANCES of Table 2 shall be used.

CLEARANCES to withstand the peak value of the WORKING VOLTAGE, the RECURRING PEAK VOLTAGE and TEMPORARY OVERVOLTAGES shall be dimensioned according to Table 3.

The values in Table 2 and Table 3 are valid for altitudes up to 2 000 m above sea level. For different higher altitudes, the altitude correction factors of Table 4 shall be applied.

The dimensions according to Table 3 shall be compared with Table 2. The larger CLEARANCE of these shall be selected as the required CLEARANCE.



**Table 2 – Clearances to withstand TRANSIENT OVERVOLTAGES**

| RATED IMPULSE VOLTAGE kV | Minimum CLEARANCES up to 2 000 m above sea level (BASIC INSULATION or SUPPLEMENTARY INSULATION) | |
|---|---|---|
| | Case A INHOMOGENEOUS ELECTRIC FIELD mm | Case B HOMOGENEOUS ELECTRIC FIELD mm |
| 4 | 3,0 | 1,2 |
| 6 | 5,5 | 2,0 |
| 8 | 8,0 | 3,0 |
| 10 | 11 | 3,5 |
| 12 | 14 | 4,5 |
| 15 | 18 | 5,5 |
| 18 | 22 | 7,0 |
| 20 | 25 | 8 |

**Table 3 – Dimensioning of clearances to WORKING VOLTAGES, TEMPORARY OVERVOLTAGES or RECURRING PEAK VOLTAGES**

| peak value of the voltage kV | Minimum CLEARANCES up to 2 000 m above sea level (BASIC INSULATION or SUPPLEMENTARY INSULATION) | |
|---|---|---|
| | Case A INHOMOGENEOUS ELECTRIC FIELD mm | Case B HOMOGENEOUS ELECTRIC FIELD mm |
| 1,0 | 0,26 | 0,15 |
| 1,2 | 0,42 | 0,2 |
| 1,5 | 0,76 | 0,3 |
| 2,0 | 1,27 | 0,45 |
| 2,5 | 1,8 | 0,6 |
| 3,0 | 2,4 | 0,8 |
| 4,0 | 3,8 | 1,2 |
| 5,0 | 5,7 | 1,5 |
| 6,0 | 7,9 | 2,0 |
| 8,0 | 11,0 | 3,0 |
| 10 | 15,2 | 3,5 |
| 12 | 19 | 4,5 |
| 15 | 25 | 5,5 |
| 20 | 34 | 8 |
| 25 | 44 | 10 |
| 30 | 55 | 12,5 |
| 40 | 77 | 17 |
| 50 | 100 | 22 |
| 60 | | 27 |
| 80 | | 35 |
| 100 | | 45 |
| Linear interpolations for CLEARANCES are allowed. | | |

For REINFORCED INSULATION, the CLEARANCE shall be twice the value for BASIC INSULATION.

**Table 4 – Altitude correction factors**

| Altitude<br>m | Normal barometric pressure<br>kPa | Correction factor for CLEARANCES |
|---|---|---|
| 2 000 | 80,0 | 1,00 |
| 3 000 | 70,0 | 1,14 |
| 4 000 | 62,0 | 1,29 |
| 5 000 | 54,0 | 1,48 |
| 6 000 | 47,0 | 1,70 |
| 7 000 | 41,0 | 1,95 |
| 8 000 | 35,5 | 2,25 |
| 9 000 | 30,5 | 2,62 |
| 10 000 | 26,5 | 3,02 |
| 15 000 | 12,0 | 6,67 |
| 20 000 | 5,5 | 14,5 |
| Linear interpolation for the correction factor for CLEARANCES is allowed. | | |



## 5.2 CREEPAGE DISTANCES

### 5.2.1 General

CREEPAGE DISTANCES shall be selected from Table 5. The following influencing factors are taken into account:

– long term voltages (see 5.2.2);
– MICRO-ENVIRONMENT (see 5.2.3);
– shape of insulating surface (see 5.2.4);
– insulating materials (see 4.4);
– POLLUTION DEGREES (see 4.5).

### 5.2.2 Voltage

The basis for the determination of a CREEPAGE DISTANCE is the long-term RMS value of the voltage existing across it. This voltage is the WORKING VOLTAGE, the RATED VOLTAGE of the equipment, or the RATED INSULATION VOLTAGE.

TRANSIENT OVERVOLTAGES are neglected since they will normally not influence the tracking phenomenon. However, TEMPORARY OVERVOLTAGES and RECURRING PEAK VOLTAGES have to be taken into account if their duration and frequency of occurrence can influence tracking.

### 5.2.3 POLLUTION

The influence of the POLLUTION DEGREES in the MICRO-ENVIRONMENT, specified in 4.5.2, on the dimensioning of CREEPAGE DISTANCES is taken into account in Table 5.

Different conditions for the MICRO-ENVIRONMENT can exist at several locations inside the same equipment.

### 5.2.4 Shape of insulating surface

Shaping of insulating surfaces is effective for dimensioning of CREEPAGE DISTANCES under POLLUTION DEGREE 3 only. Preferably, the surface of SOLID INSULATION should include transverse ribs and grooves that break the continuity of the leakage path caused by

POLLUTION. Likewise, ribs and grooves may be used to divert any water away from INSULATION which is electrically stressed. Joints or grooves joining conductive parts should be avoided since they can collect POLLUTION or retain water.

Required CREEPAGE DISTANCES equal to or larger than 8 mm under POLLUTION DEGREE 3 may be reduced by the use of a rib. The values of these reduced CREEPAGE DISTANCES are those values listed in Table 5 in brackets (see footnote b of Table 5). The rib shall have a minimum width ($W$) of 20 % and a minimum height ($H$) of 25 % of the required CREEPAGE DISTANCE including the rib as measured in Figure 2.

Where more than one rib is used, the required CREEPAGE DISTANCE shall be divided into sections equal to the number of wanted ribs. For each section, the requirements of the above paragraph shall apply. The minimum distance between the multiple ribs shall be equal to the minimum width of the rib applicable for each section, measured from the base of the rib.

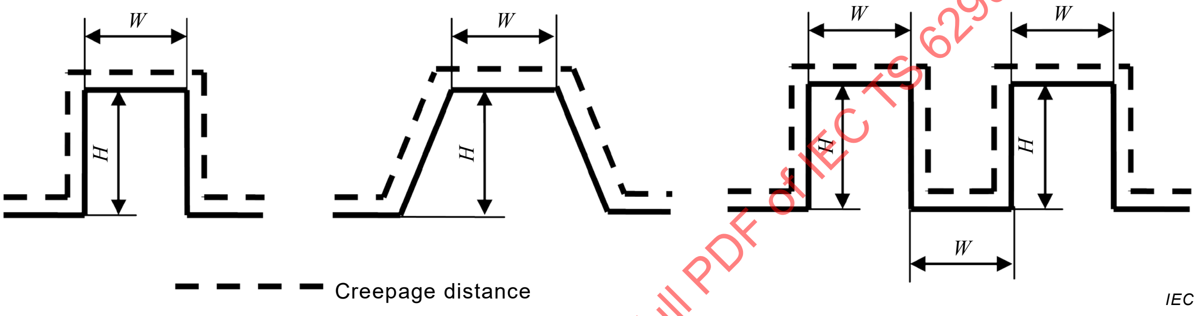



**Figure 2 – Determination of the width ($W$) and height ($H$) of a rib**

NOTE For railway applications, IEC 62497-1 does not allow reduction of CREEPAGE DISTANCES by the use of ribs (see 6.2 of IEC 62497-1:2010).

### 5.2.5 Relationship to CLEARANCE

A CREEPAGE DISTANCE cannot be less than the associated CLEARANCE so that the shortest CREEPAGE DISTANCE possible is equal to the required CLEARANCE. However, there is no physical relationship, other than this dimensional limitation, between the minimum CLEARANCE in airand the minimum acceptable CREEPAGE DISTANCE.

CREEPAGE DISTANCES less than the CLEARANCES required in case A of Table 2 or Table 3 may only be used when the CREEPAGE DISTANCE can withstand the test voltage required for the associated CLEARANCE of Table 2 or Table 3 (see 6.1.2). The test to demonstrate that the CREEPAGE DISTANCE will withstand the test voltage for the associated CLEARANCE shall take into account the altitude correction factor (see Table 4).

### 5.2.6 CREEPAGE DISTANCES where more than one material is used or more than one POLLUTION DEGREE occurs

A CREEPAGE DISTANCE may be split in several portions of different materials and/or have different POLLUTION DEGREES if one of the CREEPAGE DISTANCES is dimensioned to withstand the total voltage or if the total distance is dimensioned according to the material having the lowest CTI and the highest POLLUTION DEGREE.

### 5.2.7 CREEPAGE DISTANCES split by floating conductive part

A CREEPAGE DISTANCE may be split into several parts, made with the same INSULATION material, including or separated by floating conductors as long as the sum of the distances across each individual part is equal or greater than the CREEPAGE DISTANCE required if the floating part did not exist.

The minimum distance $X$ for each individual part of the CREEPAGE DISTANCE is given in 6.2 of IEC 60664-1:2007.

### 5.2.8 Dimensioning of CREEPAGE DISTANCES of BASIC INSULATION, SUPPLEMENTARY INSULATION and REINFORCED INSULATION

CREEPAGE DISTANCES of BASIC INSULATION and SUPPLEMENTARY INSULATION shall be selected from Table 5 for the WORKING VOLTAGE, the RATED VOLTAGE or the RATED INSULATION VOLTAGE.

For SUPPLEMENTARY INSULATION, the POLLUTION DEGREE, insulating material, mechanical stresses and ENVIRONMENTAL conditions of use may be different from those for BASIC INSULATION.

It is allowed to interpolate values for intermediate voltages. Linear interpolation shall be used.

CREEPAGE DISTANCES of DOUBLE INSULATION are the sum of the values of the BASIC INSULATION and SUPPLEMENTARY INSULATION which make up the DOUBLE INSULATION system.

CREEPAGE DISTANCES for REINFORCED INSULATION shall be twice the CREEPAGE DISTANCE for BASIC INSULATION from Table 5.

When dimensioning CREEPAGE DISTANCES to accessible surfaces of insulating material, such surfaces are assumed to be covered by metal foil. Further details can be specified by technical committees.

**Table 5 – CREEPAGE DISTANCES to avoid failure due to tracking**

| Voltage RMS[a] | Minimum CREEPAGE DISTANCES | | | | | | |
|---|---|---|---|---|---|---|---|
| | POLLUTION DEGREE | | | | | | |
| | 1 | 2 | | | 3 | | |
| | All material groups | Material group I | Material group II | Material group III | Material group I | Material group II | Material group IIIa |
| kV | mm | mm | mm | mm | mm[b] | mm[b] | mm[b] |
| 1,00 | 3,2 | 5,0 | 7,1 | 10,0 | 12,5 (10,2) | 14,0 (11,2) | 16,0 (12,8) |
| 1,25 | 4,2 | 6,3 | 9,0 | 12,5 | 16,0 (12,8) | 18,0 (14,4) | 20,0 (16,0) |
| 1,60 | 5,6 | 8,0 | 11,0 | 16,0 | 20,0 (16,0) | 22,0 (17,6) | 25,0 (20 0) |
| 2,00 | 7,5 | 10,0 | 14,0 | 20,0 | 25,0 (20,0) | 28,0 (22,4) | 32,0 (25,6) |
| 2,50 | 10,0 | 12,5 | 18,0 | 25,0 | 32,0 (25,6) | 36,0 (28,8) | 40,0 (32 0) |
| 3,20 | 12,5 | 16,0 | 22,0 | 32,0 | 40,0 (32,0) | 45,0 (36,0) | 50,0 (40,0) |
| 4,00 | 16,0 | 20,0 | 28,0 | 40,0 | 50,0 (40,0) | 56,0 (44,8) | 63,0 (50,4) |
| 5,00 | 20,0 | 25,0 | 36,0 | 50,0 | 63,0 (50,4) | 71,0 (56,8) | 80,0 (64,0) |
| 6,30 | 25,0 | 32,0 | 45,0 | 63,0 | 80,0 (64,0) | 90,0 (72,0) | 100 (80,0) |
| 8,00 | 32,0 | 40,0 | 56,0 | 80,0 | 100 (80,0) | 110 (88,0) | 125 (100) |
| 10,0 | 40,0 | 50,0 | 71,0 | 100 | 125 (100) | 140 (112) | 160 (128) |
| 12,5[c] | 50,0[c] | 63,0[c] | 90,0[c] | 125[c] | | | |
| 16,0[c] | 63,0[c] | 80,0[c] | 110[c] | 160[c] | | | |
| 20,0[c] | 80,0[c] | 100[c] | 140[c] | 200[c] | | | |
| 25,0[c] | 100[c] | 125[c] | 180[c] | 250[c] | | | |
| 32,0[c] | 125[c] | 160[c] | 220[c] | 320[c] | | | |
| 40,0[c] | 160[c] | 200[c] | 280[c] | 400[c] | | | |
| 50,0[c] | 200[c] | 250[c] | 360[c] | 500[c] | | | |
| 63,0[c] | 250[c] | 320[c] | 450[c] | 600[c] | | | |

[a] This voltage is

- the WORKING VOLTAGE,
- the RATED VOLTAGE, or
- the RATED INSULATION VOLTAGE.

[b] The values given in brackets may be applied to reduce the CREEPAGE DISTANCE in case of using a rib (see 5.2.4).

[c] Provisional data based on extrapolation. Technical committees who have other information based on experience may use their dimensions.



### 5.2.9 CREEPAGE DISTANCES for DC applications

Electromigration is a well-known effect across CREEPAGE DISTANCES of DC applications and may require additional measures to prevent degradation and subsequent break down of the insulating surface.

Electromigration is an effect over time and dependent on moisture, for example caused by condensation, and is also influenced by the conductive material.

Determination of CREEPAGE DISTANCES in DC applications shall consider measures to be additionally applied to the minimum CREEPAGE DISTANCES as specified in Table 5. These measures may comprise one or more of the following:

– application of coatings to the conductors, for example on printed circuit boards (see IEC 60664-3);
– installation of equipment inside of housings which prevent condensation (see IEC 60529);
– heating by anti-condensation heaters or self-heating, for example of power conductors.

Increasing the CREEPAGE DISTANCE can also reduce the effect of electromigration. However, there is no sufficient experience to provide a clear guideline.

### 5.3 SOLID INSULATION

#### 5.3.1 General

There is a general relationship between the thickness of SOLID INSULATION and the possible failure mechanisms. By a reduction of the thickness of SOLID INSULATION, the field stress is increased and leads to a higher risk of failure. As it is not possible to calculate the required thickness of SOLID INSULATION, the performance can only be verified by testing.

By the determination of the material and thickness of SOLID INSULATION, the following stresses shall be considered if applicable:

– frequency;
– heating;
– mechanical stresses;
– PARTIAL DISCHARGES;
– humidity;
– radiation, both ultraviolet and ionizing;
– chemical influences;
– migration of plasticizers;
– bacteria, moulds or fungi.

With the testing, the above possible influences and stresses shall be considered.

#### 5.3.2 Withstand of voltage stresses

SOLID INSULATION shall, as applicable, withstand the following voltage stresses:

– WORKING VOLTAGES,
– RATED VOLTAGES,
– RATED INSULATION VOLTAGES,
– TRANSIENT OVERVOLTAGES,
– TEMPORARY OVERVOLTAGES,
– RECURRING PEAK VOLTAGES,
– high frequency voltages.

## 6 Tests and measurements

### 6.1 Tests

#### 6.1.1 General

The following test procedures apply to TYPE TESTING, so that a possible deterioration of the test specimen may be tolerated. It is assumed that further use of the test specimen is not intended.

If further use of the test specimen is intended or required, particular consideration is necessary by the technical committee. In such cases, any high-voltage test should be combined with a PARTIAL DISCHARGE measurement (see 6.1.3.5).

Test procedures are specified for

– the verification of CLEARANCES (see 6.1.2), and
– the verification of SOLID INSULATION (see 6.1.3).

The stresses for CLEARANCES and SOLID INSULATION caused by TRANSIENT OVERVOLTAGES are assessed by the impulse voltage test (see 6.1.2.2), which may be substituted by an AC voltage test (see 6.1.2.3) or a DC voltage test (see 6.1.2.4). The withstand capability of CLEARANCES equal to or larger than case A of Table 2 or Table 3 may be verified by measurement or by a voltage test. If they are smaller than the values according to the values of case A of Table 2 or Table 3, they shall be verified by a voltage test.

The ability of SOLID INSULATION to withstand the voltage stresses shall be verified by a voltage test in any case. The stresses caused by TRANSIENT OVERVOLTAGES are assessed by the impulse voltage test, which may be substituted by an AC voltage test or a DC voltage test. The stresses caused by an AC steady-state voltage stress can only be assessed by an AC voltage test. The DC voltage test with a test voltage equal to the peak value of the AC voltage is not fully equivalent to the AC voltage test due to the different withstand characteristics of SOLID INSULATION for these types of voltages. However, in case of a pure DC voltage stress, the DC voltage test is appropriate.

While it is possible to substitute an impulse voltage test for CLEARANCES by an AC voltage test or by a DC voltage test, it is in principle not possible to substitute an AC voltage test for SOLID INSULATION by an impulse voltage test. The main reasons for this are the different propagation of the impulse voltages compared to power frequency voltages, especially in complex circuits, and the dependency of the withstand characteristics of SOLID INSULATION on the shape and the duration of the voltage stress.

### 6.1.2 Test for verification of CLEARANCES

#### 6.1.2.1 General

When the equipment is subjected to electrical tests for verifying CLEARANCES, the test shall be in accordance with WITHSTAND VOLTAGE requirements specified in 5.1. The appropriate test for the verification of CLEARANCES needed to withstand the TRANSIENT OVERVOLTAGES is the impulse voltage test, but as stated in 6.1.1, the test is only required for CLEARANCES smaller than case A values of Table 2.

If the withstand against WORKING VOLTAGES, RECURRING PEAK VOLTAGES or TEMPORARY OVERVOLTAGES according to 5.1 is decisive for the dimensioning of CLEARANCES and if those CLEARANCES are smaller than the case A values of Table 3, an AC test voltage according to 6.1.2.3 is required.

When verifying CLEARANCES within equipment by an impulse voltage test, it is necessary to ensure that the specified impulse voltage appears at the CLEARANCE under test.

The electric testing of CLEARANCES will also stress the associated SOLID INSULATION.

#### 6.1.2.2 Impulse voltage dielectric test

The impulse voltage dielectric tests are performed with the equipment according to Clause 7 of IEC 61180:2016 with the test voltages according to the second column of Table 6.

Values for the test site altitude corrections are given in Table 7.

**Table 6 – Test voltages based on CLEARANCES and a test site altitude of 2 000 m above sea level**

| Required CLEARANCE<br>mm | Test voltage<br>AC RMS 50/60 Hz<br>V | Test voltage<br>Impulse 1,2/50 µs<br>Peak value<br>V |
|---|---|---|
| 0,2 | 620 | 1 150 |
| 0,3 | 710 | 1 310 |
| 0,5 | 840 | 1 550 |
| 1,0 | 1 060 | 1 950 |
| 1,5 | 1 390 | 2 560 |
| 2,0 | 1 680 | 3 090 |
| 2,5 | 1 960 | 3 600 |
| 3,0 | 2 210 | 4 070 |
| 4,0 | 2 680 | 4 930 |
| 4,5 | 2 900 | 5 330 |
| 5,0 | 3 110 | 5 720 |
| 6,0 | 3 510 | 6 460 |
| 8,0 | 4 260 | 7 840 |
| 10,0 | 4 950 | 9 100 |
| 12,0 | 5 780 | 10 600 |
| 15,0 | 7 000 | 12 900 |
| 20 | 8 980 | 16 400 |
| 25 | 10 800 | 19 900 |
| 30 | 12 700 | 23 300 |
| 40 | 16 200 | 29 800 |
| 50 | 19 600 | 36 000 |
| 60 | 22 800 | 42 000 |
| 80 | 29 200 | 53 700 |
| 100 | 35 400 | 65 000 |
| Linear interpolation of test voltages for other CLEARANCES is allowed. | | |