
Guide to
**Insulation co-ordination within low-voltage
systems including clearances and creepage
distances for equipment**

Guide pour la co-ordination de l'isolement dans les systèmes à basse tension y compris les distances d'isolement dans l'air et les lignes de fuite des matériels

Leitfaden zur Isolationsabstufung in Niederspannungssystemen einschließlich Luft- und Kriechstrecken für Geräte

Amendment No. 1
published and effective from 29 May 1987
to PD 6499 : 1981

**Guide to insulation co-ordination within
low-voltage systems including clearances
and creepage distances for equipment**

AMD 5416
[IEC Publication 664A : 1981]

Revised text

This Amendment is identical with IEC Publication 664A : 1981 which was the first supplement to IEC Publication 664 : 1980. It should be noted that the page numbers quoted in the text of the Amendment refer to the page numbers of IEC 664A which also appear in square brackets at the foot of each page of the Amendment. The opportunity has also been taken to make consequential amendments to the national foreword.

AMD 5416
May 1987

Covers

Beneath 'IEC 664 : 1980' which occurs once on the front cover, and twice on the back cover, insert 'IEC 664A : 1981'.

5416
1987

National foreword

Delete the existing national foreword and substitute the following.

'National foreword

This Published Document, which has been prepared under the direction of the General Electrotechnical Engineering Standards Committee, is identical with the Report of the International Electrotechnical Commission, IEC Publication 664 : 1980 and first Supplement 664A : 1981 'Insulation co-ordination within low-voltage systems including clearances and creepage distances for equipment'. Although not at present considered suitable for publication as a British Standard, it is thought that this Published Document (PD) will be of interest to members of appropriate Technical Committees and to those concerned with the development of products where the specified insulation co-ordination is inadequate or non-existent. Attention is drawn to the Explanatory Note on page 26, which indicates ways in which the PD should be used.

Existing British Standards for related products and equipment may have insulation values other than those given in this PD, in which case the values in the British Standards take precedence.

With regard to the footnote on page 4, the British Committees parallel to the IEC Committees listed there also consider 1500 V d.c. as the upper limit of the low-voltage range.

Terminology and conventions. The texts of IEC 664 and 664A have been approved as suitable for publication as a Published Document without deviation. Some terminology and certain conventions are not identical with those used in British Standard publications; attention is especially drawn to the following.

Wherever the word 'report' appears, referring to this document, it should be read as 'Published Document'.

In certain places italic (sloping) type has been used for SI unit symbols instead of roman (upright) type as required by convention.

References within the text to page numbers relate to IEC page numbers given in brackets at the bottom of each page.

Cross references*

International standard	Corresponding British Standard
IEC 60	BS 923 Guide on high-voltage testing techniques
IEC 60-1 : 1973	Part 1 : 1980 General (Identical)
IEC 60-2 : 1973	Part 2 : 1980 Test procedures (Identical)
IEC 60-3 : 1976	Part 3 : 1980 Measuring devices (Identical)
IEC 60-4 : 1977	Part 4 : 1980 Application guide for measuring devices (Identical)

IEC 71-1 : 1976	BS 5622 Guide for insulation coordination Part 1 : 1979 Terms, definitions, principles and rules (Identical)
IEC 112 : 1979	BS 5901 : 1980 Method of test for determining the comparative and the proof tracking indices of solid insulating materials under moist conditions (Identical)
IEC 335-1 : 1970	BS 3456 Specification for safety of household and similar electrical appliances Part 101 : 1978 General requirements (Technically equivalent)

The Technical Committee has reviewed the provisions of IEC 99-1 and 536 and has decided that they are acceptable for use in conjunction with this PD. The related British Standard for IEC 99-1 : 1970 is BS 2914 : 1972 'Surge divertors for alternating current systems', and for IEC 536 : 1976 is BS 2754 : 1976 'Memorandum. Construction of electrical equipment for protection against electric shock.

NOTE 1. With the publication of IEC 664A the second sentence in the introduction is no longer applicable.

NOTE 2. *Textual error.* In the introduction, paragraph 2, line 3, 'non-existent' should be read as 'non-existent'.

*Undated in the text.

AMD 5416
May 1987

Contents

Below the heading for section four, delete '*Under consideration*' and substitute the following.

' 9. General	17
10. Specification of the influencing factors	
11. Dimensioning of creepage distances	
12. Measurement of creepage distances and clearances	

After Appendix B – Transient overvoltage control means (surge arrester devices), insert

'APPENDIX C – Example of dimensioning procedure for clearances and creepage distances'.

ID 5416
May 1987

Section four

Delete '*Under consideration*' and insert the additional text (clauses 9 to 12, tables IIIa, IIIb and IV, figure 2, and examples 1 to 11) attached.

D 5416
May 1987

New Appendix C

After Appendix B, insert the new Appendix C attached.

9. General

The recommendations for creepage distances are based on a considerable amount of empirical data and on a basic review of the physical mechanisms behind various influencing factors, rather than on exact measurements of known physical phenomena.

- 1) A possible deterioration over the useful life of a creepage distance or the total failure of insulation properties depends on many factors just as the magnitude of the surface leakage current over a creepage distance does not present any simple physical dependency on distance and voltage. A number of aspects have still to be studied.
- 2) For equipment operating within certain voltage ranges and under certain operating conditions a vast amount of practical experience exists, forming a useful guide for design purposes. Such empirical values form a part of this report, bearing in mind that certain existing standards require distances significantly greater than would be necessary from a technical point of view and that good experience with equipment designed in accordance with such standards is no proof that larger distances are really necessary. The values for printed boards are based on a statistical evaluation of a series of tests. Different circumstances may require greater or permit smaller creepage distances than those given in Table IV. This decision shall be made by the individual Technical Committees.
- 3) In view of the necessity that as much protection against deterioration of the properties of insulating material as possible is to be achieved, the values given in Table IV present creepage distances where the influencing factors, pollution degree and the properties of insulating material are taken into account. These distances represent conditions of continuous stress. It should be pointed out however that the exclusion or diversion of contamination by design measures and the proper selection of a suitable type of insulating material have a greater influence on the performance than the values of the creepage distances contained in Table IV.

- 4) Clearance and creepage distances serve different purposes in the insulation co-ordination, and therefore it may happen that the minimum creepage distance established on the basis of the following will be smaller than the minimum clearance determined in accordance with Section Three. In that case, the clearance becomes the deciding design basis.

9.1 *Influencing factors*

Creepage distances are determined by the micro-environment in which the distance under consideration is situated.

Note. — This means that in the same piece of equipment widely different creepage distances may be permitted.

9.2 *Fundamental factors influencing creepage distances*

9.2.1 Rated insulation voltage or working voltage (see Sub-clause 10.2).

9.2.2 Pollution (see Sub-clause 10.3).

9.2.2.1 Moisture.

9.2.2.2 Orientation and location of a creepage distance (see Sub-clause 10.5).

9.2.2.3 Shape of insulating surface (see Sub-clause 10.6).

9.2.2.4 Electrostatic precipitation (see Sub-clause 10.7).

9.2.3 Insulating materials (see Sub-clause 10.4).

9.2.4 Relationship to clearance (see Sub-clause 10.1).

9.2.5 Time under voltage stress (see Sub-clause 10.8).

9.2.6 Other factors which may influence creepage distance.

9.2.6.1 Surface leakage current (see Sub-clause 10.9).

It may be necessary to reduce the surface leakage current in order:

- a) to prevent damage to insulating material;
- b) to prevent perception current (electric shock);
- c) to maintain proper functioning of the equipment (crosstalk).

9.2.6.2 Consequences of an insulation fault in a circuit, including continuity of service (see Sub-clause 10.10).

9.2.6.3 Constructional aspects (see Sub-clause 10.11).

9.2.6.4 Properties of electrode material (see Sub-clause 10.12).

10. **Specification of the influencing factors**

10.1 *Relationship to clearance*

A creepage distance cannot be less than the associated clearance, so that the shortest creepage distance possible is equal to the clearance. However, there is no physical relation between the

minimum clearance in air and the minimum acceptable creepage distance, except for this dimensional limitation.

With respect to flashover, creepage distances less than the clearances required by Case A of Table II may only be used under conditions of pollution degree 1 in which situation the associated clearance test by impulse withstand voltage or equivalent r.m.s. voltage test for the creepage distances is sufficient.

10.2 *Voltage*

The basis for the determination of a creepage distance is the r.m.s. or d.c. value of the voltage existing between electrodes and across the creepage distance for an extended period of time. Transient overvoltages are neglected on the basis of the fact that they will normally not influence the tracking phenomenon. However, temporary and functional overvoltages may have to be considered, depending upon duration and frequency of occurrence. Voltages which result in partial discharges also require additional consideration in the selection of insulating material.

10.3 *Pollution* (see Sub-clause 6.3.1)

The degrees of pollution which were specified for clearances shall apply also to creepage distances.

10.3.1 *Condensation*

The condensation of water shall always be considered a possibility, except in the case of pollution degree 1. Condensation will occur in the case of pollution degrees 2, 3 and 4 as a result of the following conditions:

1. Where the temperature of the insulation surface falls below the dew-point of the surrounding air.

Notes 1. — The statement in Item 1 implies that the risk of condensation is negligible within a certain type of equipment (for example, a radio receiver) used in an enclosed space, such as a weekend house.

Cooling of the house will, when the dew-point is attained, result in condensation on the walls of the house, but not to condensation in the equipment located inside the house.

When heating the house (from the outside or from the inside), parts having a high thermal capacity (walls, structure, etc.) will always lag with regard to equipment having a relatively low thermal capacity. Hence there is a negligible risk resulting from condensation within the equipment and pollution degree 1 conditions normally exist. A similar consideration is valid for small components located within a larger enclosure.

On the other hand, an enclosure exposed to a low temperature ambient, but constructed in a manner that allows the exchange of air with a higher ambient temperature, may be subject to continuous condensation.

Examples are boxes built into external walls, but with openings to an inside room or conduits passing through a low-temperature area. Unless properly drained, condensate may collect in such enclosures.

Enclosures subject to variation of temperature (for example, between day and night) are particularly prone to cumulative condensation because the variations promote the air exchange (breathing).

2. — In the case of creepage distances in the vicinity of components dissipating a small quantity of heat, the micro-environment may differ considerably from the surrounding environment of the equipment as far as condensation and tracking are concerned. Close to the source of heat, drying-out is achieved quickly,

which results in low conductivity of the surface so that tracking will not occur. However, for certain designs, the water vapour may recondense on cold spots located elsewhere and may thus increase the risk of tracking at such places.

2. Where the insulation surface is contaminated with:

- a) hygroscopic dust, or
- b) salt and the relative humidity is above a particular value.

Note. — For example, in the presence of salt, condensation may take place where the surrounding air has a relative humidity as low as 40%.

Unless suitable precautions are taken, condensation may occur in any enclosure but condensation may be reduced or eliminated by one or more of the following means:

- the use of a dried and hermetically sealed enclosure; it should be noted that “hermetically sealed” implies an absolutely airtight enclosure so that an exchange of humid air, caused by a normal change in air pressure, is impossible;
- the use of an enclosure with ventilation;
- the heating of the equipment either by continuous energization or by the use of supplementary heaters;
- the maintaining of the surrounding air at constant temperature and a suitably low relative humidity;
- encapsulation (for example, potting).

10.3.2 *Conductive dust*

In certain locations, conductive deposits may be present. Such deposits can be avoided by means of suitable enclosures around the creepage distance in question, but attention must be paid to the fact that within that enclosure conductive deposits may be produced, for example those originating from carbon brushes, in which case this enclosure will not ensure protection and may even aggravate the problem.

Conductive dust can lead to very high values of surface leakage currents, and can lead to failure by a flashover, but it seldom leads to progressive tracking.

10.4 *Insulating materials*

10.4.1 *Characteristics of insulating materials*

Insulating materials can be roughly characterized according to the damage they may suffer from concentrated release of energy as a result of the action of electric arcs (mini-arcs) when a surface leakage current is interrupted, i.e. due to drying of the contaminated surface. The following behaviour of insulating materials in the presence of mini-arcs may occur:

- a) no decomposition of the insulating material;
- b) decomposition of material into volatile components (erosion);
- c) decomposition of material resulting in carbon residues (tracking).

Notes 1. — The test in accordance with IEC Publication 112 makes it possible to visually determine whether the insulating material under test will:

- remain unaffected by the test conditions, or
- have a tendency to erode, or
- have a tendency to form tracks.

But in practice, erosion and tracking can be more or less intermixed, depending on the kind of insulating material, contamination and current (a.c. or d.c.)

2. — Tracking or erosion cannot occur unless the surface leakage current exceeds a limiting value related to the minimum energy, necessary to create the chemical decomposition required for tracking in a localized drying-out situation or equivalent changes in the surface conductivity. These situations arise when the electrodes of a contaminated creepage distance are energized or when the creepage distance between energized electrodes becomes contaminated. The magnitude of the surface leakage current depends upon the conductivity of the contamination of the surface and on the configuration of the relevant parts. The progression of tracking or of erosion increases with the number of localized drying-out incidents.

A method of classification for insulating materials according to groups *a)*, *b)* and *c)*, does not exist. The behaviour of the insulating material under various contaminants and voltages is extremely complex. Under these various conditions many materials will fall into two or even all three of groups *a)*, *b)* and *c)*.

A direct correlation of groups *a)*, *b)* and *c)* with the material groups of Sub-clause 10.4.2 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 report uses the CTI values to establish a selection of insulation materials for dimensioning in Table IV.

10.4.2 Comparative Tracking Index (CTI)

The test for Comparative Tracking Index in accordance with IEC Publication 112: Method for Determining the Comparative and the Proof Tracking Indices of Solid Insulating Materials under Moist Conditions, is designed to compare the performance of various insulating materials under test conditions, namely drops of an aqueous contaminant falling on a horizontal surface leading to electrolytic conduction. Basically, it gives a qualitative comparison, but in the case of insulating materials having a tendency to form tracks it may also give a quantitative comparison, the Comparative Tracking Index.

For the purpose of this publication materials are separated into four groups by their CTI values, as follows:

Material Group I	$600 \leq \text{CTI}$
Material Group II	$400 \leq \text{CTI} < 600$
Material Group IIIa	$175 \leq \text{CTI} < 400$
Material Group IIIb	$100 \leq \text{CTI} < 175$

The CTI values above refer to values obtained, in accordance with IEC Publication 112, on samples specifically made for the purpose and tested with solution A.

Note. — For inorganic insulating materials, for example glass or ceramics, which do not track, creepage distances need not be greater than their associated clearance for the purpose of insulation co-ordination.

10.5 *Orientation and location of a creepage distance*

The orientation and location of a creepage distance is significant in the following ways:

- 1) The tendency to collect dust which is deposited by gravity, centrifugal force or by draughts of air as a result of natural or induced circulation.
- 2) The flow pattern or drops of water over the surface in between electrodes or from one electrode to another.
- 3) The location of a creepage distance with respect to a heat source causing accelerated uniform drying of the insulating surface.

The pollution is influenced by the position in which the equipment or component is installed in a room, frame, or enclosure. All intended positions should be considered when evaluating the pollution for the creepage distance. Particular attention should be given to equipment or components that may change their position while in use, for example, portable equipment or moving parts of mechanically operated switches.

Notes 1. — The manufacturer should indicate the intended orientation of the equipment or component, if a particular orientation is required or excluded.

2. — It should be recognized that equipment may be stored in one orientation but be used in another and this may influence the collection of dust.

10.6 *Shape of insulating surface*

Preferably, creepage distances may include transverse ridges and grooves that break the continuity of the leakage path caused by conductive surface layers. Likewise, ridges and grooves may be used to divert the flow of drops of water to areas not under electrical stress. Joints, grooves or cracks running parallel between the conductive parts (the electrodes) should be avoided as they may collect pollution or retain water by capillary action.

Examples of the evaluation of the length of a creepage path are given in the examples 1 to 11, of Clause 12.

10.7 *Electrostatic precipitation*

In the presence of electrostatic fields, contaminating non-conductive dust particles can be deposited on insulating surfaces where otherwise dust may not accumulate to the same degree.

The adhesion and accumulation of precipitated dust particles result from the presence of high unidirectional electric fields and are independent of material orientation.

10.8 *Time under voltage stress*

The time under voltage stress influences the number of drying-out incidents capable of causing mini-arcs of an 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 any equipment on the input side of any switch and between the line and load (input and output) terminals of any switch supplied from the mains;
- in any equipment subject to condensation for longer periods, and being frequently switched on and off.

The creepage distances shown in Table IV have been determined for insulation intended to be under voltage stress for a long time (or continuously). Technical Committees concerned with insulation for equipment which is under voltage stress for only a short time may consider using shorter creepage distances than those recommended in Table IV.

Note. — For pollution degree 2, a material of lower CTI may be used as suggested in Note 1 to Table IV.

Alternatively, except for pollution degree 4, the creepage distance corresponding to one voltage step lower may be used for insulation stressed for a total of 15 000 h or less. Similarly, for insulation stressed 1 500 h or less, the creepage distance corresponding to two voltage steps lower may be used. These degrees of relaxation from the conditions of continuous stress are provisional and under consideration. Therefore, interested Technical Committees are invited to give their experience.

The same consideration may be given to insulation which is only intermittently stressed within equipment which is itself under voltage stress for a long time. Consideration of even smaller distances may be given in the cases of insulation of floating (not energized or not capable of being earthed) parts.

10.9 *Considerations to reduce leakage current*

The consequence of a creepage distance with conductive contamination, whether it is inherently conductive or conductive because of humidity, is that it permits a leakage current over the insulating surface. The magnitude of this leakage current is a function of the voltage and impedance of the source, the conductivity of the pollution and both the length and width of creepage distance.

10.9.1 *Protection against electric shock*

Any leakage current to an accessible part presents a risk of electric shock if leakage current can exceed the perception level when the accessible part is touched by a human body in contact with earth. The leakage current to be considered is the sum of the capacitive, conductive and surface leakage current but only the latter is dealt with here.

When evaluating the risk of electric shock by a surface leakage current from an accessible part which is not earthed directly or indirectly, it should be remembered that such a current can only flow when the accessible part is earthed, for example by touching. Therefore, a wet surface will not dry out due to leakage current, but by the same fact no tracking can occur.

Consideration should be given to joints, cracks, and crevices that may retain water by capillary action and also form part of the leakage path.

Note. — With regard to safety (perception current), the possibility of such joints, cracks and crevices becoming conductive should be considered.

Similar considerations relate to the collection of conductive dust, for example from the commutator of motors or from other switching devices.

10.9.2 *Protection against malfunctioning*

Considerations very similar to those relating to electric shock are valid in connection with leakage current, crosstalk or similar malfunction. Because of its irregular and unpredictable nature, surface leakage currents should be considered when evaluating the influence of one circuit on the operation of another circuit, such as in communications equipment and in sensitive control circuits. However, it is not possible to indicate specific values of leakage current since the highest tolerable value depends upon circumstances. In general, proper attention to the character and location of the circuits is of far greater significance than the dimensioning of the creepage distances involved. Sensitive circuitry may require the exclusion of contamination and moisture (see also last paragraph of Sub-clause 10.3.1).

10.10 *Consequences of an insulation fault in a circuit*

Tracking of the insulation is likely to result in permanent failure. The possible consequence of this, whether it is the starting of a fire, the interruption of an essential supply or any other undesirable circumstance, must be considered by the Technical Committees which may take steps to give a greater degree of protection. These steps may include for example increased creepage distance, better materials, encapsulation, etc.

On the other hand, circumstances may justify a reduction of the creepage distances.

The following should be considered:

- a) A leakage current leading to tracking in a circuit may cause a short circuit and consequential operation of the overcurrent protective device if the circuit impedance is low enough. The damage depends upon the resulting current and the operating characteristics of the overcurrent protective device.
- b) A fire may be caused by a leakage current leading to tracking in a circuit where impedance is too high to cause the overcurrent protective device to operate.
- c) In high-power circuits, the power of the fault arc can be appreciable, so, although the operation of the overcurrent protective device is very fast or even current limiting, the energy released can be appreciable and capable of causing mechanical damage (pressure) and fire.
- d) In some cases the impedance of the circuit is so high or the micro-environment is so favourable that tracking is unlikely to occur. Provided that a short circuit in such a case will not constitute a fire hazard, electric shock or malfunction, the creepage distance need not exceed the clearance.

10.11 *Constructional aspects*

Special attention should be given to terminals, where the effective creepage distance can be shortened by the conductors attached to the terminals, for example by touching ridges separating two terminals or by hygroscopic action of the conductor insulation. Minimum creepage distances associated with terminals may be solely governed by constructional considerations as specified by the relevant Technical Committees.

Note. — See also Sub-clause 7.2.

10.12 *Properties of electrode material*

For small values of creepage distances, it may be necessary to consider the fact that some electrode materials have a tendency to migrate under the influence of a leakage current or to form dendrites (“whiskers”) which may reduce both clearance and creepage distances. Other materials, or particular alloys may exhibit dimensional growth due to recrystallization, usually very slowly in the order of years. Some electrode materials tend to dissolve in electrolytic pollutants, thereby increasing the conductivity and thus increasing the probability of tracking or flashover.

10.13 *Other conditions*

Other conditions may require the consideration of supplementary factors which are not directly dimensionable and are the responsibility of the individual Technical Committees.

Considerations of ribs and grooves are given in Sub-clause 10.6.

11. **Dimensioning of creepage distances**

The values of creepage distances given in Table IV are based upon existing empirical data and are suitable for a majority of applications but exclude certain applications for which other values of creepage distances are appropriate.

Technical Committees may have experiences which are valid under specified conditions relevant to their products. In these cases other creepage distances either smaller or larger than those given in Table IV may be selected taking the influencing factors of Sub-clauses 10.5 to 10.12 into account.

Where the working voltage is used for dimensioning, it may be appropriate to interpolate values for intermediate voltages.

11.1 *Selected voltage values*

The Technical Committees can select a rated insulation voltage or system voltage from the voltage values given in Table IV.

The R 10 series voltage values given in Table IV are derived from Figure 2, page 31, and the table includes values of typical system voltages. If necessary, Technical Committees can select other voltages.

Tables IIIa and IIIb are for the purpose of relating the voltage values of Table IV to the most commonly used supply systems voltages.

