BS EN 62752:2016

BSI Standards Publication

In-cable control and protection device for mode 2 charging of electric road vehicles (IC-CPD) (IEC 62752:2016)

bsi.

National foreword

This British Standard is the UK implementation of EN 62752:2016. It is identical to IEC 62752:2016. It partially supersedes BS EN 61851-1:2011, specifically when an ICPD product is used for the purpose of mode 2 EV charging (see CENELEC foreword).

The UK participation in its preparation was entrusted by Technical Committee PEL/23, Electrical accessories, to Subcommittee PEL/23/1, Circuit breakers and similar equipment for household use.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 September 2016.

Amendments/corrigenda issued since publication

Date	Text affected

EUROPEAN STANDARD

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Supersedes EN 61851-1:2011 (partially)

English Version

In-cable control and protection device for mode 2 charging of electric road vehicles (IC-CPD) (IEC 62752:2016)

Appareil de contrôle et de protection intégré au câble pour la charge en mode 2 des véhicules électriques (IC-CPD) (IEC 62752:2016)

Ladeleitungsintegrierte Steuer- und Schutzeinrichtung für die Ladebetriebsart 2 von Elektro-Straßenfahrzeugen (IC-CPD) (IEC 62752:2016)

This European Standard was approved by CENELEC on 2016-04-08. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

European foreword

The text of document 23E/919/FDIS, future edition 1 of IEC 62752, prepared by SC 23E “Circuit-breakers and similar equipment for household use” of IEC/TC 23 “Electrical accessories” was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62752:2016.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2017-02-19
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2017-12-31

This European Standard partially supersedes EN 61851-1:2011 for what concerns the product IC-CPD as a cable assembly for mode 2 EV charging. The DOW will be 2017-12-31.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

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

For the relationship with EU Directives see informative Annexes ZZA and ZZB, which are integral parts of this document.

Endorsement notice

The text of the International Standard IEC 62752:2016 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60269-1:2006	NOTE	Harmonized as EN 60269-1:2007 (not modified).
IEC 60364 Series	NOTE	Harmonized as HD 384/HD 60364 Series.
IEC 60364-7-722	NOTE	Harmonized as HD 60364-7-722.
IEC 60999-1:1999	NOTE	Harmonized as EN 60999-1:2000 (not modified).
IEC 60947-1:2007	NOTE	Harmonized as EN 60947-1:2007 (not modified).
IEC 61008-1:2010	NOTE	Harmonized as EN 61008-1:2012 (modified).
IEC 62423:2009	NOTE	Harmonized as EN 62423:2009 (modified).

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

Publication	Year	Title	EN/HD	Year
IEC 60065	-	Audio, video and similar electronic apparatus - Safety requirements	EN 60065	-
IEC 60068-2-1	-	Environmental testing - Part 2-1: Tests - Test A: Cold	EN 60068-2-1	-
IEC 60068-2-5	-	Environmental testing - Part 2-5: Tests - Test Sa: Simulated solar radiation at ground level and guidance for solar radiation testing	EN 60068-2-5	-
IEC 60068-2-11	-	Basic environmental testing procedures - Part 2-11: Tests - Test Ka: Salt mist	EN 60068-2-11	-
IEC 60068-2-27	-	Environmental testing - Part 2-27: Tests - Test Ea and guidance: Shock	EN 60068-2-27	-
IEC 60068-2-30	-	Environmental testing - Part 2-30: Tests - Test Db: Damp heat, cyclic (12 h + 12 h cycle)	EN 60068-2-30	-
IEC 60068-2-31	-	Environmental testing - Part 2-31: Tests - Test Ec: Rough handling shocks, primarily for equipment-type specimens	EN 60068-2-31	-
IEC 60068-2-64	-	Environmental testing - Part 2-64: Tests - Test Fh: Vibration, broadband random and guidance	EN 60068-2-64	-
IEC 60068-3-4	-	Environmental testing - Part 3-4: Supporting documentation and guidance - Damp heat tests	EN 60068-3-4	-
IEC 60112	-	Method for the determination of the proof and the comparative tracking indices of solid insulating materials	EN 60112	-
IEC 60227	Series	Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V	-	-
IEC 60245	Series	Rubber insulated cables - Rated voltages up to and including 450/750 V	-	-
IEC 60309	Series	Plugs, socket-outlets and couplers for industrial purposes	EN 60309	Series

Publication	Year	Title	EN/HD	Year
IEC 60309-1	1999	Plugs, socket-outlets and couplers for industrial purposes - Part 1: General requirements	EN 60309-1 +A11	1999 2004
+A1 (mod)	2005		+A1	2007
+A2	2012		+A2	2012
IEC 60309-2	-	Plugs, socket-outlets and couplers for industrial purposes - Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories	EN 60309-2	-
IEC 60364-4-44 (mod)	2007	Low-voltage electrical installations - Part 4-44: Protection for safety - Protection against voltage disturbances and electromagnetic disturbances	HD 60364-4-442	2012
IEC 60384-14	Series	Fixed capacitors for use in electronic equipment - Part 14: Sectional specification - Fixed capacitors for electromagnetic interference suppression and connection to the supply mains	EN 60384-14	Series
IEC 60417-DB	-	Graphical symbols for use on equipment	-	-
IEC 60529	1989	Degrees of protection provided by enclosures (IP Code)	EN 60529 + corr. May	1991 1993
IEC 60664-1	2007	Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests	EN 60664-1	2007
IEC 60664-3	-	Insulation coordination for equipment within low-voltage systems - Part 3: Use of coating, potting or moulding for protection against pollution	EN 60664-3	-
IEC 60695-2-10	-	Fire hazard testing - Part 2-10: Glowing/hot-wire based test methods - Glow-wire apparatus and common test procedure	EN 60695-2-10	-
IEC 60695-2-11	-	Fire hazard testing - Part 2-11: Glowing/hot-wire based test methods - Glow-wire flammability test method for end-products (GWEPT)	EN 60695-2-11	-
IEC 60884-1	2002	Plugs and socket-outlets for household and similar purposes - Part 1: General requirements		-
+A1	2006		-	-
+A2	2013		-	-
IEC 61249-2	Series	Materials for printed boards and other interconnecting structures	EN 61249-2	Series
IEC 61540	-	Electrical accessories - Portable residual current devices without integral overcurrent protection for household and similar use (PRCDs)	HD 639 S1	-

Publication	Year	Title	EN/HD	Year
IEC 61543	1995	Residual current-operated protective devices (RCDs) for household and similar use - Electromagnetic compatibility	EN 61543 + corr. December +A11 +A12	1995 1997 2003 2005
+A1	2004		-	-
+A2	2005		+A2	2006
IEC 61851-1	2010	Electric vehicle conductive charging system - Part 1: General requirements	EN 61851-1	2011
IEC 62196-1	-	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 1: General requirements	EN 62196-1	-
IEC 62196-2	-	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 2: Dimensional compatibility and interchangeability requirements for a.c. pin and contact-tube accessories	EN 62196-2	-
IEC/TS 62763	2013	Pilot function through a control pilot circuit using PWM modulation and a control pilot wire	-	-
CISPR 14	Series	Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus	EN 55014	Series
ISO 178	-	Plastics - Determination of flexural properties	EN ISO 178	-
ISO 179	Series	Plastics - Determination of Charpy impact properties	EN ISO 179	Series
ISO 179-1	-	Plastics - Determination of Charpy impact properties - Part 1: Non-instrumented impact test	EN ISO 179-1	-
ISO 2409	-	Paints and varnishes - Cross-cut test	EN ISO 2409	-
ISO 4628-3	-	Paints and varnishes - Evaluation of degradation of coatings - Designation of quantity and size of defects, and of intensity of uniform changes in appearance - Part 3: Assessment of degree of rusting	EN ISO 4628-3	-
ISO 4892-2	2013	Plastics - Methods of exposure to laboratory light sources - Part 2: Xenon-arc lamps	EN ISO 4892-2	2013
ISO 16750-5	2010	Road vehicles - Environmental conditions and testing for electrical and electronic equipment - Part 5: Chemical loads	-	-
ISO 17409	2015	Electrically propelled road vehicles - Connection to an external electric power supply - Safety requirements	-	-

Annex ZB
(normative)

Special national conditions

Special national condition: National characteristic or practice that cannot be changed even over a long period, e.g. climatic conditions, electrical earthing conditions.

NOTE If it affects harmonization, it forms part of the European Standard or Harmonization Document.

For the countries in which the relevant special national conditions apply these provisions are normative, for other countries they are informative.

Country	Clause	Special national condition
Denmark	**1**	**IC-CPD:** For IC-CPDs supplied with a plug for household and similar use, repeated continuous loads of long duration, shall be limited to 6 A.
Finland	**1**	**IC-CPD:** The following additional requirement applies: for IC-CPDs supplied with a plug for household and similar use the maximum charging current is 8 A for long lasting charging.
Norway	**4.3.4**	**IC-CPD:** In Norway, pluggable types where connector is part of the ICCB shall not be used.
Switzerland	**5.3.2**	**IC-CPD:** In Switzerland, simplified control pilot circuit is not allowed.
Switzerland	**5.3.2**	**IC-CPD:** In Switzerland, the use of EN 60309-2 accessories is recommended for mode 2 connections for more than 8 A (2 kVA).
France	**8.1**	**IC-CPD:** In France, the use of solid brass pins is required.
France	**8.3.1**	**IC-CPD:** In France, For a rated current above 8 A, rewirable connections of the household plug are not allowed. Connection between the household plugs and cable shall use terminations (see definition 3.2.3).
Switzerland	**8.3.1**	**IC-CPD:** In Switzerland, the use of EN 60309-2 accessories is recommended for mode 2 connections for more than 8 A (2 kVA).
Belgium	**9.7.7.4**	**IC-CPD:** In Belgium, an IC-CPD shall be able to function properly in both LNE and LLE configurations, provided the correct voltage is available.

Annex ZC
(informative)

A-deviations

A-deviation: National deviation due to regulations, the alteration of which is for the time being outside the competence of the CEN-CENELEC national member.

This European Standard falls under Directives 2014/35/EU and 2014/30/EU.

NOTE (from CEN/CENELEC IR Part 2:2015, 2.16) Where standards fall under EC Directives or Regulations, it is the view of the Commission of the European Communities (OJ No C 59; 1982-03-09) that the effect of the decision of the Court of Justice in case 815/79 Cremonini/Vrankovich (European Court Reports 1980, p. 3583) is that compliance with A-deviations is no longer mandatory and that the free movement of products complying with such a standard should not be restricted within the EC except under the safeguard procedure provided for in the relevant Directive or Regulation.

A-deviations in an EFTA-country are valid instead of the relevant provisions of the European Standard in that country until they have been removed.

Country	Clause	A-deviation
Denmark	**General**	The requirements in this standard cannot replace or change any part of the Danish National requirements for plugs for household and similar use according to DS 60884-2-D1.

Annex ZZA
(informative)

Relationship between this European standard and the essential requirements of Directive 2014/30/EU [2014 OJ L96] aimed to be covered

This European standard has been prepared under a Commission's standardisation request as regards harmonised standards in support of Directive 2014/30/EU relating to electromagnetic compatibility,to provide one voluntary means of conforming to essential requirements of Directive 2014/30/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility [2014 OJ L96].

Once this standard is cited in the Official Journal of the European Union under that Directive, compliance with the normative clauses of this standard given in Table ZZA.1 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding essential requirements of that Directive, and associated EFTA regulations.

Table ZZA.1 – Correspondence between this European standard and Annex I of Directive 2014/30/EU [2014 OJ L96]

Essential requirements of Directive 2014/30/EU	Clause(s) / sub-clause(s) of this EN	Remarks / Notes
All requirements are covered by complying clause 9.26 of the standard	**§9.26**	

WARNING 1: Presumption of conformity stays valid only as long as a reference to this European standard is maintained in the list published in the Official Journal of the European Union. Users of this standard should consult frequently the latest list published in the Official Journal of the European Union.

WARNING 2: Other Union legislation may be applicable to the product(s) falling within the scope of this standard.

Annex ZZB
(informative)

Relationship between this European standard and the safety objectives of Directive 2014/35/EU [2014 OJ L96] aimed to be covered

This European standard has been prepared under a Commission's standardisation request relating to harmonised standards in the field of the Low Voltage Directive, M/511, to provide one voluntary means of conforming to safety objectives of Directive 2014/35/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits [2014 OJ L96].

Once this standard is cited in the Official Journal of the European Union under that Directive, compliance with the normative clauses of this standard given in Table ZZB.1 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding safety objectives of that Directive, and associated EFTA regulations.

Table ZZB.1 – Correspondence between this European standard and Annex I of Directive 2014/35/EU [2014 OJ L96]

Safety objectives of Directive 2014/35/EU	Clause(s) / sub-clause(s) of this EN	Remarks / Notes
Within the limits of the scope, all requirements are covered by complying all clauses of the standard.	All normative clauses	

WARNING 1: Presumption of conformity stays valid only as long as a reference to this European standard is maintained in the list published in the Official Journal of the European Union. Users of this standard should consult frequently the latest list published in the Official Journal of the European Union.

WARNING 2: Other Union legislation may be applicable to the product(s) falling within the scope of this standard.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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IN-CABLE CONTROL AND PROTECTION DEVICE FOR MODE 2 CHARGING OF ELECTRIC ROAD VEHICLES (IC-CPD)

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 62752 has been prepared by subcommittee 23E: Circuit-breakers and similar equipment for household use, of IEC technical committee 23: Electrical accessories.

The text of this standard is based on the following documents:

FDIS	Report on voting
23E/919/FDIS	23E/938/RVD

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

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

In this standard, the following print types are used:

– Requirements proper, in roman type;

– *Test specifications, in italic type;*

– NOTES, in smaller roman type.

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

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

NOTE The attention of National Committees is drawn to the fact that equipment manufacturers and testing organizations may need a transitional period following publication of a new, amended or revised IEC publication in which to make products in accordance with the new requirements and to equip themselves for conducting new or revised tests.

New specific requirements for IC-CPD are provided in comparison to IEC 61851-1:2010, Clause 11, which was applied to IC-CPD before the availability of this standard.

It is the recommendation of the committee that the content of 5.1, 6.1 and 8.8.4, as indicated, of this publication be adopted for implementation nationally at the end of the transitional period, which is 2017-12-31.

INTRODUCTION

The essential purpose of this standard is safe and reliable access of electric vehicles to a supply system. The definition for mode 2 charging of electric vehicle is described in IEC 61851-1.

For all charging modes, protection against electric shock in case of failure of basic protection and/or fault protection is provided, at least by a type A RCD (see IEC 60364-7-722 and IEC 61851-1).

For mode 2 charging including the situation where it cannot be guaranteed that the installation is equipped with RCDs, for example charging the electric vehicle at an unknown installation, a dedicated protection is used for the connected electric vehicle. The intention of this standard is to describe the relevant requirements for an in-cable control and protection device (IC-CPD) to be used for mode 2 charging.

The IC-CPD is not a protection device for use in fixed installations.

IN-CABLE CONTROL AND PROTECTION DEVICE FOR MODE 2 CHARGING OF ELECTRIC ROAD VEHICLES (IC-CPD)

1 Scope

This International Standard applies to in-cable control and protection devices (IC-CPDs) for mode 2 charging of electric road vehicles, hereafter referred to as IC-CPD including control and safety functions.

This standard applies to portable devices performing simultaneously the functions of detection of the residual current, of comparison of the value of this current with the residual operating value and of opening of the protected circuit when the residual current exceeds this value.

The IC-CPD according to this standard

- has a control pilot function controller in accordance with IEC TS 62763;
- checks supply conditions and prevents charging in case of supply faults under specified conditions;
- may have a switched protective conductor.

These IC-CPDs are intended for use in TN-, and TT-systems.

The use of IC-CPDs in IT systems may be limited.

Residual currents with frequencies different from the rated frequency, d.c. residual currents and specific environmental situation are considered.

This standard is applicable to IC-CPDs performing the safety and control functions as required in IEC 61851-1 for mode 2 charging of electric vehicles.

This standard is applicable to IC-CPDs for single-phase circuits not exceeding 250 V or multi-phase circuits not exceeding 480 V, their maximum rated current being 32 A.

NOTE 1 In Denmark, the following additional requirement applies: for IC-CPDs supplied with a plug for household and similar use the maximum charging current is 8 A, if the charging cycle can exceed 2 h.

NOTE 2 In Finland, the following additional requirement applies: for IC-CPDs supplied with a plug for household and similar use the maximum charging current is 8 A for long lasting charging.

This standard is applicable to IC-CPDs to be used in a.c. circuits only, with preferred values of rated frequency 50 Hz, 60 Hz or 50/60 Hz. IC-CPDs according to this standard are not intended to be used to supply electric energy towards the connected grid.

This standard is applicable to IC-CPDs having a rated residual operating current not exceeding 30 mA and are intended to provide additional protection for the circuit downstream of the IC-CPD in situations where it cannot be guaranteed that the installation is equipped with an RCD with $I_{\Delta n} \leq 30$ mA.

The IC-CPD consists of:

- a plug for connection to a socket-outlet in the fixed installation;
- one or more subassemblies containing the control and protection features;
- a cable between the plug and the subassemblies (optional);

- a cable between the subassemblies and the vehicle connector (optional);
- a vehicle connector for connection to the electric vehicle.

For plugs for household and similar use the respective requirements of the national standard and specific requirements defined by the national committee of the country where the product is placed on the market apply. If no national requirements exist, IEC 60884-1 may be used. For industrial plugs IEC 60309-2 applies. For specific applications and areas non interchangeable industrial plugs may be used. In this case IEC 60309-1 applies

NOTE 3 In Denmark: the requirements in this standard cannot replace or change any part of the Danish National requirements for plugs for household and similar use according to DS 60884-2-D1.

Plugs, connectors and cables which are part of the IC-CPD are not tested according to this standard. These parts are tested separately according to their specific product standard.

NOTE 4 In the following countries, requirements for EV (mode 2) Cord Sets are covered by NMX-J 677-ANCE-2013/ CSA C22.2 No. 280-13/ UL 2594: Standard for Electric Vehicle Supply Equipment: US, CA, MX.

The switching contacts of the IC-CPD are not required to provide isolation, as isolation can be ensured by disconnecting the plug.

The IC-CPD may have a non-replaceable integral fuse in the phase(s) and/or neutral current path.

2 Normative references

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

IEC 60065, *Audio, video and similar electronic apparatus – Safety requirements*

IEC 60068-2-1, *Environmental testing – Part 2-1: Tests – Test A: Cold*

IEC 60068-2-5, *Environmental testing – Part 2-5: Tests – Test Sa: Simulated solar radiation at ground level and guidance for solar radiation testing*

IEC 60068-2-11, *Basic environmental testing procedures – Part 2-11: Tests – Test Ka: Salt mist*

IEC 60068-2-27, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC 60068-2-30, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h+ 12 h cycle)*

IEC 60068-2-31, *Environmental testing – Part 2-31: Tests – Test Ec: Rough handling shocks, primarily for equipment-type specimens*

IEC 60068-2-64, *Environmental testing – Part 2-64: Tests – Test Fh: Vibration, broadband random and guidance*

IEC 60068-3-4, *Environmental testing – Part 2-34: Supporting documentation and guidance – Damp heat tests*

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

IEC 60227 (all parts), *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V*

IEC 60245 (all parts), *Rubber insulated cables – Rated voltages up to and including 450/750V*

IEC 60309 (all parts), *Plugs, socket-outlets and couplers for industrial purposes*

IEC 60309-1:1999, *Plugs, socket-outlets and couplers for industrial purposes – Part 1: General requirements*
IEC 60309-1:1999/AMD1:2005
IEC 60309-1:1999/AMD2:2012

IEC 60309-2, *Plugs, socket-outlets and couplers for industrial purposes – Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories*

IEC 60364-4-44:2007, *Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*

IEC 60384-14 (all parts), *Fixed capacitors for use in electronic equipment – Part 14: Sectional specification – Fixed capacitors for electromagnetic interference suppression and connection to the supply mains*

IEC 60417, *Graphical symbols for use on equipment* (available at: <http://www.graphical-symbols.info/equipment>)

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*

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

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

IEC 60695-2-10, *Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure*

IEC 60695-2-11, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end-products (GWEPT)*

IEC 60884-1:2002, *Plugs and socket-outlets for household and similar purposes – Part 1: General requirements*[1]
IEC 60884-1:2002/AMD1:2006
IEC 60884-1:2002/AMD2:2013

IEC 61249-2 (all parts), *Materials for printed boards and other interconnecting structures*

IEC 61540, *Electrical accessories – Portable residual current devices without integral overcurrent protection for household and similar use (PRCDs)*

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[1] A consolidated edition (3.2) exists including IEC 60884-1 (2002) and its Amendment 1 (2006) and Amendment 2 (2013).

IEC 61543:1995, *Residual current-operated protective devices (RCDs) for household and similar use – Electromagnetic compatibility*
IEC 61543:1995/AMD1:2004
IEC 61543:1995/AMD2:2005

IEC 61851-1:2010, *Electric vehicle conductive charging system – Part 1: General requirements*

IEC 62196-1, *Plugs, socket-outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles – Part 1: General requirements*

IEC 62196-2, *Plugs, socket-outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles – Part 2: Dimensional compatibility and interchangeability requirements for a.c. pin and contact-tube accessories*

IEC TS 62763:2013, *Pilot function through a control pilot circuit using PWM (pulse width modulation) and a control pilot wire*

CISPR 14 (all parts), *Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus*

ISO 178, *Plastics – Determination of flexural properties*

ISO 179 (all parts), *Plastics – Determination of Charpy impact properties*

ISO 179-1, *Plastics – Determination of Charpy impact properties – Part 1: Non-instrumented impact test*

ISO 2409, *Paints and varnishes – Cross-cut test*

ISO 4628-3, *Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of defects, and of intensity of uniform changes in appearance – Part 3: Assessment of degree of rusting*

ISO 4892-2:2013, *Plastics – Methods of exposure to laboratory light sources – Part 2: Xenon-arc lamps*

ISO 16750-5:2010, *Road vehicles – Environmental conditions and testing for electrical and electronic equipment – Part 5: Chemical loads*

ISO 17409:2015, *Electrically propelled road vehicles – Connection to an external electric power supply – Safety requirements*

3 Terms and definitions

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

NOTE 1 Where the terms "voltage" and "current" are used, they imply r.m.s. values, unless otherwise specified.

NOTE 2 Throughout this standard, the word "earthing" is used for "protective earthing".

NOTE 3 The term "accessory" is used as a general term covering plugs, socket-outlets, vehicle connectors and vehicle couplers.

3.1 Terms and definitions relating to plugs and socket-outlets

3.1.1
plug
accessory intended for frequent use by ordinary persons, having pins designed to engage with the contacts of a socket-outlet, also incorporating means for the electrical connection and mechanical retention of one flexible cable

Note 1 to entry: For special purposes such as lighting chains (see also IEC 60598-2-20), two or three single-core cables can be connected within the plug.

[SOURCE: IEC 60884-1:2002/AMD2:2013, 3.1]

3.1.2
socket-outlet
accessory intended for frequent use by ordinary persons, having socket contacts designed to engage with the pins of a plug and having terminals or terminations for the connection of cable

[SOURCE: IEC 60884-1:2002/AMD2:2013, 3.2]

3.1.3
non-rewirable plug
non-rewirable vehicle connector
accessory so constructed that it forms a complete unit with the flexible cable or cord after connection and assembly by the manufacturer of the accessory

Note 1 to entry: See also 14.1 of IEC 60884-1:2002.

3.1.4
rewirable accessory by manufacturer
accessory so constructed that the flexible cable can be replaced

Note 1 to entry: The accessory is so constructed that it can only be rewired, repaired or replaced by the manufacturer's authorized personnel, its agent or similar qualified person.

3.1.5
vehicle coupler
electric vehicle coupler
means enabling the connection at will of a flexible cable to an electric vehicle

Note 1 to entry: It consists of two parts: a vehicle connector and a vehicle inlet

[SOURCE: IEC 62196-1:2014, 3.3]

3.1.6
vehicle connector
electric vehicle connector
part of a vehicle coupler integral with, or intended to be attached to, one flexible cable

[SOURCE: IEC 62196-1:2014, 3.3.1]

3.1.7
vehicle inlet
electric vehicle inlet
part of a vehicle coupler incorporated in, or fixed to, the electric vehicle

[SOURCE: IEC 62196-1:2014, 3.3.2]

3.1.8
pluggable
electrical connection which is intended to be plugged or unplugged by the end-user

3.1.9
portable equipment
cord and plug connected equipment, cable assembly, adaptors or other accessories that are capable to be carried by one person and may be carried within the EV

3.1.10
adaptor
portable accessory constructed as an integral unit incorporating both a plug portion and one socket-outlet portion

3.2 Terms and definitions relating to terminals

3.2.1
clamping unit
part(s) of the terminal necessary for the mechanical clamping and the electrical connection of the conductor(s), including the parts which are necessary to ensure the correct contact pressure

[SOURCE: IEC 60999-1:1999, 3.1]

3.2.2
terminal
conductive part of one pole, composed of one or more clamping unit(s) and insulation if necessary

[SOURCE: IEC 60999-1:1999, 3.2]

3.2.3
termination
conductive part of a device, provided for reusable electrical connection to external circuits

3.2.4
screw-type terminal
terminal for the connection and subsequent disconnection of a conductor or for the interconnection of two or more conductors capable of being dismantled, the connection being made, directly or indirectly, by means of screws or nuts of any kind

3.2.5
screw terminal
screw-type terminal in which the conductor is clamped under the head of the screw at which the clamping pressure may be applied directly by the head of the screw or through an intermediate part, such as a washer, clamping plate or anti-spread device

3.2.6
screwless terminal
connecting terminal for the connection and subsequent disconnection of one conductor or the dismountable interconnection of two or more conductors capable of being dismantled, the connection being made, directly or indirectly, by means of springs, wedges, eccentrics or cones, etc., without special preparation of the conductor other than removal of insulation

[SOURCE: IEC 61008-1:2010, 3.6.8]

3.3 Terms and definitions relating to residual current functions

3.3.1 Terms and definitions relating to currents flowing from live parts to earth

3.3.1.1
earth fault current
current flowing to earth due to an insulation fault

[SOURCE: IEC 61008-1:2010, 3.1.1]

3.3.1.2
earth leakage current
current flowing from the live parts of the installation to earth in the absence of an insulation fault

[SOURCE: IEC 61008-1:2010, 3.1.2]

3.3.1.3
pulsating direct current
current of pulsating waveform which assumes, in each period of the rated power frequency, the value 0 or a value not exceeding 0,006 A d.c. during one single interval of time, expressed in angular measure, of at least 150°

[SOURCE: IEC 61008-1:2010, 3.1.3]

3.3.1.4
current delay angle α
time, expressed in angular measure, by which the starting instant of current conduction is delayed by phase control

[SOURCE: IEC 61008-1:2010, 3.1.4]

3.3.1.5
supply failure
– open neutral;
– open line(s).

Note 1 to entry: See 3.3.3.18 for hazardous live protective conductor.

[SOURCE: IEC 62335:2008, 3.2.1.6, modified – "open protective earth" has been deleted.]

3.3.1.6
smooth direct current
direct current which is ripple free

[SOURCE: IEC 62423:2009, 3.1]

3.3.1.7
composite current
current which consists of more than one significant sinusoidal frequency

3.3.2 Terms and definitions relating to the energization of the residual current function

3.3.2.1
residual current
I_{Δ}
vector sum of the instantaneous values of the current flowing in the main circuit of the residual current function (expressed as r.m.s. value)

[SOURCE: IEC 61008-1:2010, 3.2.3, modified – “RCCB” has been replaced by “residual current function”]

3.3.2.2
residual operating current
value of residual current which causes the residual current function to operate under specified conditions

[SOURCE: IEC 61008-1:2010, 3.2.4, modified – replacement of “RCCB” by “residual current function”]

3.3.2.3
residual non-operating current
value of residual current at and below which the residual current function does not operate under specified conditions

[SOURCE: IEC 61008-1:2010, 3.2.5, modified – replacement of “RCCB” by “residual current function”]

3.3.3 Terms and definitions relating to the operation and to the functions of the IC-CPD

3.3.3.1
residual current function
function incorporating the means of detection of a residual current, of comparison of its value to the residual current operating value and of opening the protected circuit when the residual current exceeds this value

3.3.3.2
IC-CPD
in-cable control and protection device
assembly of linked parts or components including cables, plug and vehicle connector for supplying electric vehicles in charging mode 2, which performs control functions and safety functions

Note 1 to entry: For the use of the IC-CPD, see Figure 32.

Note 2 to entry: This note applies to the French language only.

3.3.3.3
switching device
device designed to make or break the current in one or more electric circuits

[SOURCE: IEC 61008-1:2010, 3.3.6]

3.3.3.4
break-time
time which elapses between the instant when the residual operating current is suddenly attained and the instant of arc extinction in all poles of an IC-CPD

3.3.3.5
closed position
position in which the predetermined continuity of the main circuit of the IC-CPD is secured

[SOURCE: IEC 61008-1:2010, 3.3.12, modified –"RCCB" has been replaced by "IC-CPD".]

3.3.3.6
open position
position in which the predetermined clearance between open contacts in the main circuit of the IC-CPD is secured

[SOURCE: IEC 61008-1:2010, 3.3.13, modified – replacement of "RCCB" by "IC-CPD".]

3.3.3.7
pole
part of an IC-CPD associated exclusively with one electrically separated conducting path of its main circuit provided with contacts intended to connect and disconnect the main circuit itself and excluding those portions which provide means for mounting and operating the poles together

[SOURCE: IEC 61008-1:2010, 3.3.14, modified – replacement of "RCCB" by "IC-CPD".]

3.3.3.8
main circuit
all conductive parts of an IC-CPD included in the current paths

3.3.3.9
control circuit
all the conductive parts (other than a path of the main circuit) of a switching device which are included in a circuit used for the closing operation or the opening operation, or both, of the device with links to IC-CPD, control pilot function controller and switching device

Note 1 to entry: See Figure E.1.

3.3.3.10
test device
device incorporated in the IC-CPD simulating the residual current conditions for the operation of the IC-CPD under specified conditions

3.3.3.11
IC-CPD type LNSE
device with a switched protective conductor that is used on a line (phase) to neutral supply (L, N, PE)

Note 1 to entry: See Annex D for examples.

3.3.3.12
IC-CPD type LLSE
device with a switched protective conductor that is used on a line (phase) to line (phase) supply (L1, L2, PE)

Note 1 to entry: See Annex D for examples.

3.3.3.13
IC-CPD type LLLNSE
device with a switched protective conductor that is used on a multiphase supply (L1, L2, L3, N, PE)

Note 1 to entry: A type LLLNSE IC-CPD uses one or more phases of a multiphase supply.

3.3.3.14
IC-CPD type LNE
device with a non-switched protective conductor that is used on a line (phase) to neutral supply (L, N, PE)

3.3.3.15
IC-CPD type LLE
device with a non-switched protective conductor that is used on a line (phase) to line (phase) supply (L1, L2, PE)

3.3.3.16
IC-CPD type LLLNE
device with a non-switched protective conductor that is used on a multiphase supply (L1, L2, L3, N, PE)

Note 1 to entry: A type LLLNE IC-CPD uses one or more phases of a multiphase supply.

3.3.3.17
protective conductor
PE (identification)
conductor provided for purposes of safety, for example protection against electric shock

[SOURCE: IEC 60050-195, 195-02-09:1998]

3.3.3.18
hazardous live protective conductor
miswiring or fault condition where the protective contact of the socked outlet is live

Note 1 to entry: See 3.3.1.5 for supply failure.

3.3.3.19
control pilot function controller
function controller which generates a PWM-signal and detects a charging state

Note 1 to entry: See Figure E.1

3.3.3.20
switching function
device to switch power and / or protective conductor to the EV to provide charging

Note 1 to entry: See Figure E.1.

3.3.4 Terms and definitions relating to values and ranges of energizing quantities

3.3.4.1
non-operating overcurrent
maximum value of overcurrent of a single-phase load in the main circuit which, in the absence of any fault to frame or to earth, and in the absence of an earth leakage current, can flow through a two-pole IC-CPD without causing the IC-CPD to open the circuit

3.3.4.2
residual short-circuit withstand current
maximum value of the residual current for which the operation of the IC-CPD is ensured under specified conditions and above which the device may be damaged

[SOURCE: IEC 61008-1:2010, 3.4.3, modified – replacement of "RCCB" by "IC-CPD", and "undergo irreversible alterations" by "be damaged".]

3.3.4.3
prospective current
current that would flow in the circuit, if each main current path of the IC-CPD and of the overcurrent protective device (if any) were replaced by a conductor of negligible impedance

Note 1 to entry: This definition applies also in the same manner as an actual current, for example prospective breaking current, prospective peak current, prospective residual current.

[SOURCE: IEC 61008-1:2010, 3.4.4, modified – replacement of "RCCB" by "IC-CPD", and replacement of the note to entry.]

3.3.4.4
making capacity
value of the a.c. component of a prospective current that an IC-CPD is capable of making at a stated voltage under prescribed conditions of use and behaviour

[SOURCE: IEC 61008-1:2010, 3.4.7, modified – replacement of "RCCB" by "IC-CPD"]

3.3.4.5
breaking capacity
value of the a.c. component of a prospective current that an IC-CPD is capable of breaking at a stated voltage under prescribed conditions of use and behaviour

[SOURCE: IEC 61008-1:2010, 3.4.8, modified – replacement of "RCCB" by "IC-CPD"]

3.3.4.6
residual making and breaking capacity
value of the a.c. component of a residual prospective current which an IC-CPD can make, carry for its opening time and break under specified conditions of use and behaviour

[SOURCE: IEC 61008-1:2010, 3.4.9, modified – replacement of "RCCB" by "IC-CPD"]

3.3.4.7
conditional short-circuit current
value of the a.c. component of a prospective current, which an IC-CPD protected by a suitable short-circuit protective device (hereinafter referred to as SCPD) in series, can withstand under specified conditions of use and behaviour

[SOURCE: IEC 61008-1:2010, 3.4.10, modified – replacement of "RCCB" by "IC-CPD"]

3.3.4.8
conditional residual short-circuit current
value of the a.c. component of a residual prospective current which an IC-CPD, protected by a suitable SCPD in series, can withstand under specified conditions of use and behaviour

[SOURCE: IEC 61008-1:2010, 3.4.11, modified – replacement of "RCCB" by "IC-CPD"]

3.3.4.9
U_x
limiting value U_x of the line voltage for IC-CPDs to perform its intended functions as declared by the manufacturer for IC-CPDs

3.3.4.10
I^2t
joule integral
integral of the square of the current, over a given time interval (t_0, t_1):

$$I^2t = \int_{t_0}^{t_1} I^2 dt$$

3.3.4.11
recovery voltage
voltage which appears across the supply connections of an IC-CPD after the breaking of the current

Note 1 to entry: This voltage comprises two successive intervals of time, one during which a transient voltage exists, followed by a second one during which power-frequency voltage alone exists.

[SOURCE: IEC 61008-1:2010, 3.4.14, modified – replacement of "a pole of an RCCB" by "the supply connections of an IC-CPD" and replacement of the note to entry.]

3.3.4.11.1
transient recovery voltage
recovery voltage during the time in which it has a significant transient character

Note 1 to entry: The transient voltage is an oscillatory or non-oscillatory or a combination of these depending on the characteristics of the circuit and of the IC-CPD.

[SOURCE: IEC 61008-1:2010, 3.4.14.1, modified – replacement of "RCCB" by "IC-CPD" and deletion of the last sentence of the note to entry.]

3.3.4.11.2
power-frequency recovery voltage
recovery voltage after the transient voltage phenomena have subsided

[SOURCE: IEC 61008-1:2010, 3.4.14.2]

3.3.5 Terms and definitions relating to values and ranges of influencing quantities

3.3.5.1
influencing quantity
any quantity likely to modify the specified behaviour of an IC-CPD

3.3.5.2
ambient air temperature
temperature, determined under the prescribed conditions, of the air surrounding the IC-CPD

[SOURCE: IEC 61008-1:2010, 3.5.6, modified – replacement of "RCCB (for an enclosed RCCB it is the air outside the enclosure)" by "IC-CPD".]

3.3.6 Conditions of operation

3.3.6.1
operation
transfer of the moving contact(s) from the open position to the closed position or vice versa

Note 1 to entry: If distinction is necessary, an operation in the electrical sense (e.g. make or break) is referred to as a switching operation and an operation in the mechanical sense (e.g. close or open) is referred to as a mechanical operation.

[SOURCE: IEC 61008-1:2010, 3.7.1]

3.3.6.2
closing operation
operation by which the IC-CPD is brought from the open position to the closed position

[SOURCE: IEC 61008-1:2010, 3.7.2, modified – replacement of "RCCB" by "IC-CPD".]

3.3.6.3
opening operation
operation by which the IC-CPD is brought from the closed position to the open position

[SOURCE: IEC 61008-1:2010, 3.7.3, modified – replacement of "RCCB" by "IC-CPD".]

3.3.6.4
operating cycle
succession of operations from one position to another and back to the first position

[SOURCE: IEC 61008-1:2010, 3.7.4, modified – deletion of "through all other positions, if any".]

3.3.6.5
sequence of operation
succession of specified operations with specified time intervals

[SOURCE: IEC 61008-1:2010, 3.7.5]

3.3.7 Terms and definitions relating to control functions between electric vehicle and IC-CPD

3.3.7.1
pilot function
any means, electronic or mechanical, that insures the conditions related to the safety or the transmission of data required for the mode of operation

[SOURCE: IEC 61851-1:2010, 3.17]

3.3.7.2
system state
state which indicates different states during charging process according to IEC TS 62763

EXAMPLE Connected, ready to charge, charging.

3.4 Terms and definitions relating to tests

3.4.1
type test
test of one or more devices made to a certain design to show that the design meets certain requirements

[SOURCE: IEC 61008-1:2010, 3.8.1]

3.4.2
routine test
test to which each individual device is subjected during and/or after manufacture to ascertain whether it complies with certain criteria

[SOURCE: IEC 61008-1:2010, 3.8.2]

3.4.3
self test
automatically initiated verification of the ability of the IC-CPD to detect a residual current

3.5 Terms and definitions relating to construction

3.5.1
function box
control functions and / or safety functions integrated in appropriate enclosures which are part of the IC-CPD

Note 1 to entry: The function box is located in a detachable cable assembly or connector or plug that is not part of the fixed installation.

3.5.2
class I equipment
equipment with basic insulation as provision for basic protection and protective bonding as provision for fault protection

[SOURCE: IEC 62335:2008, 3.1.22]

4 Classification

4.1 According to the supply

4.1.1 General

An IC-CPD can be classified to be compatible with more than one supply system.

4.1.2 IC-CPD supplied from one phase and neutral (LNSE or LNE)

IC-CPDs according to this classification are supplied from one phase and neutral.

4.1.3 IC-CPD supplied from two phases (LLSE or LLE)

IC-CPDs according to this classification are supplied from two phases.

4.1.4 IC-CPD supplied from three phases and neutral (LLLNSE or LLLNE)

IC-CPDs according to this classification are supplied from three phase and neutral.

NOTE This classification covers IC-CPDs using one or more phases of a multiphase supply.

4.2 According to the construction

4.2.1 General

An IC-CPD can be classified according to one of the following constructions.

4.2.2 IC-CPD including the function box separated from the plug and connector

Residual current function, switching device and control pilot function controller integrated into a function box between the plug and the vehicle connector (see Figure F.1)

4.2.3 IC-CPD with the function box integrated together with the plug

Residual current function, switching device and control pilot function controller integrated into the plug (see Figure F.2).

NOTE 1 The requirements for the plug parts are covered by the relevant standards.

NOTE 2 The maximum torque is given in 9.23.

4.2.4 Modular IC-CPD

A modular IC-CPD can be one of the following constructions:

a) residual current function and switching device integrated into the plug and control pilot function controller integrated into a separate function box between the plug and the vehicle connector (see Figure F.3);

NOTE 1 In the following countries, the IC-CPD function box is required to be an integral part of the attachment plug or shall be located in the power-supply cord not more than 300 mm from the attachment plug: US

b) residual current function and switching device integrated into the plug and control pilot function controller integrated into the vehicle connector (see Figure F.4).

NOTE 2 In the following countries, the control pilot circuit is not permitted within the body of the vehicle connector: US

4.3 According to the method of connecting the cable(s)

4.3.1 General

Cables in-between different components of the IC-CPD can be connected to these components by different methods. If in one cord set different connection methods are used the IC-CPD shall be classified to all methods used and the different parts shall be declared separately.

4.3.2 Non-rewirable IC-CPDs

The IC-CPD or the declared part is provided as a full functional cord set including all components. Cables in-between plug, in-cable housing (if any) and vehicle connector are not intended to be replaced or exchanged by the user or others after connection and assembly by the manufacturer.

4.3.3 IC-CPDs wired by the manufacturer

A connection to the IC-CPD or the declared part such that any replacement can be made only by the manufacturer, its service agent or similar qualified person using a special tool.

The IC-CPD is provided as a full functional cord set or only the unit(s) containing the residual current function and control pilot function controller are provided (see 3.1.4).

4.3.4 Pluggable IC-CPD

The IC-CPD or the declared part includes at least one pluggable electrical connection which is intended to be plugged or unplugged by the end-user or others to fit, replace or exchange components of the IC-CPD cable assembly.

NOTE 1 In the following countries pluggable types where connector is part of the ICCB shall not be used: NO.

NOTE 2 In the following countries the connect to the output side of the ICCB (function box) shall not be pluggable: US

4.4 Classification according to the protective conductor path

4.4.1 General

An IC-CPD can be classified to have a switched or a non-switched protective conductor.

4.4.2 IC-CPDs with switched protective conductor

This classification covers IC-CPDs which have a switched protective conductor.

NOTE In the following countries, a switched protective earthing conductor is not permitted: US.

4.4.3 IC-CPDs with non-switched protective conductor

This classification covers IC-CPDs which have a non-switched protective conductor.

4.5 Classification according to behaviour in case of open protective conductor

4.5.1 General

An IC-CPD can be classified according to the behaviour related to the availability of the upstream protective conductor.

4.5.2 IC-CPD with verification of the availability of the upstream protective conductor

IC-CPD detecting the presence and continuity of the protective conductor upstream of the socket-outlet. In IT-systems it may happen that these devices cannot be used as the protective conductor verification will not be successful.

An IC-CPD classified according to 4.5.2 may have a function to deactivate the verification check of the availability of the upstream protective conductor. It shall be indicated by a permanent visual or audible warning signal that the detection function is deactivated.

4.5.3 IC-CPD without verification of the availability of the upstream protective conductor

IC-CPD not detecting the presence and continuity of the protective conductor upstream of the socket-outlet. These devices are also suitable for use in IT-systems.

NOTE In the following countries either an IC-CPD according to 4.5.2 is allowed or the IC-CPD shall be capable of detecting a 5 mA leakage: US.

5 Characteristics of IC-CPDs

5.1 Summary of characteristics

IC-CPDs are provided with switching contacts for line(s) and neutral, if applicable. IC-CPDs according to 4.4.2 are provided with a switching contact for the protective conductor.

IC-CPDs have a defined residual current operation function. This function provides protection against electric shock for the connected electric vehicle in case of failure of basic protection and / or fault protection in accordance with IEC 61851-1.

The residual current function of the IC-CPD shall be ensured

- for residual sinusoidal alternating currents and residual pulsating direct currents;
- for a residual pulsating direct current superimposed on a smooth d.c. residual current up to 6 mA;
- for composite residual currents intended for circuit supplied between phase and neutral;
- with or without phase angle control, independent of polarity, whether suddenly applied or slowly rising.

In addition IC-CPDs shall have a defined behaviour in case of supply failures or miswiring according to 9.7.7.

In addition the IC-CPD:

- checks by means of the pilot signal that the protective conductor is connected to the electric vehicle,

- trips if the d.c. residual currents exceeds 6 mA.

  NOTE 1 Regarding this characteristic see also the Foreword.

- verify that the electric vehicle is connected,

  NOTE 2 The connection to the electric vehicle is checked by the pilot signal.

- switches on or off in response to the system states according to IEC TS 62763.

5.2 Rated quantities and other characteristics

5.2.1 Rated voltages

5.2.1.1 Rated operational voltage (U_e)

The value of voltage or the voltage range, assigned by the manufacturer, to which the performance of the IC-CPD is referred.

NOTE The same IC-CPD can be assigned to more than one rated voltage.

5.2.1.2 Rated insulation voltage (U_i)

The value of voltage, assigned by the manufacturer, to which dielectric test voltages and creepage distances of the IC-CPD are referred.

Unless otherwise stated, the rated insulation voltage is the value of the maximum rated voltage of the IC-CPD. In no case shall the maximum rated voltage exceed the rated insulation voltage.

5.2.2 Rated current (I_n)

The value of current, assigned to the IC-CPD by the manufacturer, which the IC-CPD can carry under permanent load conditions.

5.2.3 Rated residual operating current ($I_{\Delta n}$)

The value of residual operating current (see 3.3.2.2), assigned to the IC-CPD by the manufacturer, at which the IC-CPD shall operate under specified conditions.

5.2.4 Rated residual non-operating current ($I_{\Delta no}$)

The value of residual non-operating current (see 3.3.2.3), assigned to the IC-CPD by the manufacturer, at which the IC-CPD does not operate under specified conditions.

5.2.5 Rated frequency

The power frequency for which the IC-CPD is designed and to which the values of the other characteristics correspond.

The same IC-CPD may be assigned to more than one rated frequency.

5.2.6 Rated making and breaking capacity (I_m)

The r.m.s. value of the a.c. component of prospective current (see 3.3.4.3), assigned by the manufacturer, which an IC-CPD can make, carry and break under specified conditions.

The conditions are those specified in 9.9.2.2.

5.2.7 Rated residual making and breaking capacity ($I_{\Delta m}$)

The r.m.s. value of the a.c. component of residual prospective current (see 3.3.2.1 and 3.3.4.3), assigned by the manufacturer, which an IC-CPD can make, carry and break under specified conditions.

The conditions are those specified in 9.9.2.3.

5.2.8 Operating characteristics in case of residual currents comprising a d.c. component

The operating characteristics of an IC-CPD are such that tripping is ensured for residual sinusoidal alternating currents, residual pulsating direct currents and smooth residual direct currents exceeding 6mA, whether suddenly applied or slowly rising.

5.2.9 Insulation coordination including creepage distances and clearances

Creepage and clearance distances are given in 8.4.3.

5.2.10 Coordination with short-circuit protection devices (SCPDs)

5.2.10.1 General

Coordination between IC-CPDs and SCPDs shall be verified under the general conditions of 9.9.2.1, by means of the tests described in 9.9.2.4 which verify that there is adequate protection against currents up to the rated conditional short-circuit current I_{nc} and up to the rated conditional residual short-circuit current $I_{\Delta c}$.

5.2.10.2 Rated conditional short-circuit current (I_{nc})

The r.m.s. value of prospective current, assigned by the manufacturer, which an IC-CPD protected by an SCPD can withstand under specified conditions without undergoing alterations impairing its functions. The conditions are those specified in 9.9.2.4a).

5.2.10.3 Rated conditional residual short-circuit current ($I_{\Delta c}$)

The value of residual prospective current, assigned by the manufacturer, which an IC-CPD, protected by an SCPD, can withstand under specified conditions without undergoing damage. The conditions are those specified in 9.9.2.4 c).

5.3 Standard and preferred values

5.3.1 Preferred values of rated operational voltage (U_e)

Preferred values of rated voltage are 120 V, 230 V, 400 V and 480 V.

Wherever in this standard there is a reference to 230 V or 400 V, they may be read as 220 V or 240 V, 380 V or 415 V, respectively.

Wherever in this standard there is a reference to 120 V or 120/240 V or 240 V, they may be read as 100 V or 100/200 V or 200 V, respectively.

Wherever in this standard there is a reference to 240 V three phases, it may be read as 100 V or 120/208 V.

5.3.2 Preferred values of rated current (I_n)

The preferred values of the rated current are indicated in Table 1.

Table 1 – Preferred values of rated current and corresponding preferred values of rated voltages

Type	Rated voltage V	Rated current A
Three-phase systems	480[a]	6, 8, 10, 13, 15, 16, 20, 24, 30, 32
	400	6, 8, 10, 13, 15, 16, 20, 25, 32
	240	15, 20, 30
Single- and two-phase systems	230	6, 8, 10, 13, 15, 16, 20, 25, 30, 32
	120	6, 8, 10, 12, 15, 16, 20, 30, 32.
[a] Only for mid-point or star-point earthed systems with voltage to earth 240 V or 277 V, as applicable.		

If the IC-CPD supports simplified control pilot circuit the rated current shall be 10 A or higher.

NOTE 1 In some countries simplified control pilot circuit is not allowed: US, CH.

The rated current shall not be higher than 32A.

NOTE 2 In the following countries, the use of IEC 60309-2 accessories is recommended for mode 2 connections for more than 8 A (2 kVA): CH.

5.3.3 Standard values of rated residual operating current ($I_{\Delta n}$)

Standard values of rated residual operating current are:

0,006 A – 0,01 A – 0,015 A – 0,02 A – 0,03 A.

NOTE In the following countries, the residual operating current is frequency dependent and limited according to national standards: US, CA, MX.

5.3.4 Standard value of rated residual non-operating current ($I_{\Delta no}$)

The standard value of alternating residual non-operating current is 0,5 $I_{\Delta n}$.

If for IC-CPD according to 4.4.2 the protective conductor is passed with more turns than the live conductors through the current transformer on a $I_{\Delta n}$ = 30 mA device this value may be reduced to 0,25 $I_{\Delta n}$.

5.3.5 Standard minimum value of the non-operating overcurrent through the IC-CPD

The standard minimum value of the non-operating overcurrent through the IC-CPD is 4 I_n.

5.3.6 Preferred values of rated frequency

Preferred values of rated frequency are 50 Hz, 60 Hz or 50/60 Hz.

NOTE In the following countries, a device which measures leakage current over a range of frequencies and trips at predefined levels of leakage current, based upon the frequency, is required by national standards: US, CA, MX.

5.3.7 Minimum value of the rated making and breaking capacity (I_m)

The minimum value of the rated making and breaking capacity I_m is 100 A.

5.3.8 Minimum value of the rated residual making and breaking capacity ($I_{\Delta m}$)

The minimum value of the rated residual making and breaking capacity is 100 A.

5.3.9 Standard value of the rated conditional short-circuit current (I_{nc})

The standard value of the rated conditional short-circuit current is 1 500 A.

5.3.10 Standard value of the rated conditional residual short-circuit current ($I_{\Delta c}$)

The standard value of the rated conditional residual short-circuit current is 1 500 A.

5.3.11 Limit values of break time

The limit values of break time are given in Table 2 for a.c. residual currents, in Table 3 for smooth d.c. residual currents and in Table 4 for residual pulsating direct currents which may result from rectifying circuits supplied from two or three phases.

Table 2 – Limit values of break time for a.c. residual currents at rated frequency

Limit values of break time at a residual current (I_{Δ}) equal to s			
$I_{\Delta n}$	2 $I_{\Delta n}$	5 $I_{\Delta n}$	5 A, 10 A, 20 A, 50 A, 100 A [a]
0,3	0,15	0,04	0,04
The maximum value of the test current should not exceed I_m. NOTE For operation with residual currents having a d.c. component, see 9.7.4. [a] The tests at 5 A, 10 A, 20 A, 50 A and 100 A are only made during the verification of the correct operation as mentioned in 9.7.3.5.			

Table 3 – Limit values of break time for smooth d.c. residual currents

Limit values of break time at a d.c residual current equal to s		
6 mA	**60 mA**	**300 mA**
10,0	0,3	0,04

Table 4 – Limit values of break time for residual pulsating direct currents which may result from rectifying circuits supplied from two or three phases

Limit values of break time at a residual pulsating direct current (I_{Δ}) equal to s			
2 $I_{\Delta n}$	4 $I_{\Delta n}$	10 $I_{\Delta n}$	5 A, 10 A, 20 A, 50 A
0,3	0,15	0,04	0,04

6 Marking and other product information

6.1 Data to be marked on the IC-CPD

The IC-CPD shall be marked in a durable manner with the following data:

a) the manufacturer's or distributor’s name or trademark;

b) type designation, catalogue number or serial number;

c) rated voltage;

d) rated frequency, if the IC-CPD is designed for frequencies other than 50 Hz and 60 Hz (see 5.3.6);

e) rated current;

f) rated residual operating current;

g) degree of protection. The IP degree is applicable only to the function box and marking g) shall be on the function box;

h) the marking with the name of the product: IC-CPD;

j) IC-CPD shall be marked with the symbol 

;

k) for IC-CPD according to 4.5.2, a statement that the IC-CPD may not operate if used on IT or other unearthed systems such as an isolated winding generator or isolating transformer.

Marking with the following symbol:  IEC 60417-6293 (2015-05);

A statement is not needed for an IC-CPD according to 4.5.2 with a function to deactivate the verification check of the availability of the upstream protective conductor.

NOTE 1 This information can be on a durable label attached to the cord.

l) value of the residual non-operating current $I_{\Delta no}$, if different from 0,5 $I_{\Delta n}$;

m) indication according to the design of the protective conductor path as follows:

– classified according to 4.4.2 with marking  IEC 60417-6289 (2015-03)

– classified according to 4.4.3 with marking:  IEC 60417-6290 (2015-03)

The symbol may be integrated in a wiring diagram;

n) additional information about technical data at higher altitudes, if applicable;

o) the maximum charging current of the IC-CPD, if lower than the rated current;

p) information about the behaviour at smooth d.c. residual currents above 6 mA, if applicable.

For the marking of rated current and rated voltage marking, numbers alone may be used. These figures shall be placed on one line, separated or not by an oblique line, or the number for rated current shall be placed above the number for rated voltage, separated by a horizontal line.

The marking for the nature of supply shall be placed next to the marking for rated current and rated voltage.

Examples of marking for current, voltage and nature of supply:

$$16\ \text{A}\ 230\ \text{V}\sim,\ \text{or}\ \frac{16}{230}\sim,\ \text{or}\ 16\ \text{A}\ 230\ \text{V a.c.},\ \text{or}\ 16/230\ \text{a.c.},\ \text{etc.}$$

When symbols are used, they shall be as follows:

– amperes A

– volts V

– alternating current ~ IEC 60417-5032 (2002-10)

– neutral N

– protective earth; protective ground  IEC 60417-5019 (2006-08)

For details of the symbols for a.c. and protective conductor, see IEC 60417.

The markings a), b), c), d), e), f), h), j), k), l), m) and o) shall be on the enclosure of the function box itself or on a nameplate or nameplates attached to the IC-CPD and shall be located so that they are visible and legible when the IC-CPD is assembled as for normal use.

Information k) shall also be given in the instruction sheet.

NOTE 2 This information can be given within the car manual.

Information n) shall be given in the instruction sheet.

For IC-CPD without the integrated function to trip at maximum 6 mA smooth d.c. residual currents, in addition to information p) on the product, detailed information shall be given in the instruction sheet, including the information, that this IC-CPD shall not be used for vehicles which may cause smooth d.c. residual currents under first fault conditions.

This requirement including p) is limited to the transition period (see Foreword) and is not applicable afterwards.

Operating and indication means shall be marked in accordance with the operating instruction.

Terminals exclusively intended for the connection of the neutral circuit shall be indicated by the letter "N".

For non-rewirable IC-CPD, the indication of "N" is not necessary.

NOTE 3 In the following countries, the terminal for the neutral conductor shall also be colored silver or white: US.

If it is necessary to distinguish between the supply and the load terminals, they shall be clearly marked (e.g. by "line" and "load" placed near the corresponding terminals or by arrows indicating the direction of power flow).

Terminals intended for the protective conductor shall be indicated by the symbol for protective earth; protective ground  IEC 60417-5019 (2006-08).

NOTE 4 In the following countries, the terminal for the protective conductor shall also be colored green: US.

In addition, screwless terminals of devices according to 4.3.3 shall be marked with an appropriate marking indicating the length of insulation to be removed before the insertion of the conductor into the screwless terminal.

Marking shall be indelible, legible and shall not be placed on screws, washers or other removable parts.

Compliance is checked by inspection and by the test of 9.3.

6.2 Information to be provided to the end-user

The information to be provided to the end-user is:

a) information for the user about the automatic process of verification for the self test;

b) information that the device shall not be used if it fails to operate correctly in accordance with the instructions and to seek advice from the manufacturer, responsible vendor or an electrician;

c) information warning against storage or use beyond the service conditions given in Table 5 and against misuse such as dropping, immersion, etc.;

d) information instructing the user that the IC-CPD shall be plugged in without the use of an adaptor except if the adaptor is part of the IC-CPD and meets the requirements of a pluggable IC-CPD.;

e) information instructing the user that the IC-CPD shall be plugged in directly into the fixed socket-outlet without the use of an extension cord;

f) information about the detected failures and the related indications given by the product in this case;

g) information that the components of a pluggable IC-CPD shall not be connected or disconnected while the IC-CPD is in use (infrastructure plug connected in a socket-outlet or the vehicle connector is engaged in a vehicle inlet);

h) a list of instructions about how to connect the IC-CPD to the socket-outlet and to the car, and how to store it properly.

Compliance is checked by inspection.

7 Standard conditions for operation in service and for installation

7.1 Standard conditions

IC-CPDs complying with this standard shall be capable of operating under the standard conditions shown in Table 5.

Table 5 – Standard conditions for operation in service

Influencing quantity	Standard range of application	Reference value	Test tolerances [e]
Ambient temperature [a, f, h]	–25 °C to +45 °C [b]	23 °C	±5 °C
Altitude	Up to 2 000 m [g]		
Relative humidity (maximum value at 40 °C)	75 % [c]		
External magnetic field	Not exceeding five times the earth's magnetic field in any direction	Earth's magnetic field	[d]
Frequency	Reference value ±5 %	Rated value	±2 %
Sinusoidal wave distortion	Not exceeding 5 %	Zero	5 %

[a] The maximum value of the mean daily temperature is +35 °C.

[b] Values outside this range are admissible where more severe climatic conditions prevail, subject to agreement between manufacturer and user.

[c] Higher relative humidities are admitted at lower temperature (for example 90 % at 20 °C).

[d] IC-CPDs should not be used in the proximity of a strong magnetic field. In this case, supplementary requirements may be necessary.

[e] The tolerances given apply unless otherwise specified in the relevant test.

[f] Extreme limits of -40 °C and 85 °C, for IC-CPDs are admissible during storage and transportation.

[g] For higher altitudes it is necessary to take into account the reduction of the dielectric strength and the cooling effect of the air. Therefore the increased clearances and creepage distances according to Table 7 shall be considered and the manufacturer shall provide additional information about technical data for use at higher altitudes.

[h] If the IC-CPD is equipped with a plug according to a standard with a lower standard maximum temperature or a higher standard minimum value then this temperature is applicable for the whole IC-CPD. For plugs according to IEC 60884-1 the maximum temperature is 35 °C, the minimum temperature is -5 °C and for plugs according to IEC 60309-1 the upper temperature is 40 °C the minimum temperature is -25 °C unless higher performances are stated by the manufacturer.

7.2 Conditions for installations

IC-CPDs shall be used in accordance with their instructions.

8 Requirements for construction and operation

8.1 Mechanical design

IC-CPDs shall be so designed and constructed that in normal use their performance is reliable and the risk of danger to the user or surroundings, even in the case of miswiring conditions as defined in this standard, is minimised.

For devices according to 4.3.2 (non re-wirable) and 4.3.4, it shall be verified that it is not possible to change wiring of the device without leaving permanent and visible damage.

For devices according to 4.3.3 (wired by the manufacturer), it shall be verified that the user cannot re-wire the device without leaving permanent and visible damage.

Pluggable IC-CPDs according to 4.3.4 shall be provided with a retaining means which holds accessories in position when properly engaged and prevents their unintentional withdrawal.

Pluggable IC-CPDs according to 4.3.4 shall not be operational without engaged retaining means.

The IC-CPD shall not be functional until all mandatory functions are properly connected.

The IC-CPD, without considering plugs and vehicle connector, shall have a minimum degree of protection of IPXXD according to IEC 60529 after assembly as for normal use.

Components of pluggable IC-CPDs according to 4.3.4 shall have a minimum degree of protection of IPXXB according to IEC 60529 before being connected to each other.

A maximum length of cord of 1,7 m is allowed between the plug and the function box.

NOTE 1 In the following countries, the interrupting device of the personnel protection system (IC-CPD) shall be located within 0,3 m from the plug or be an integral part of the plug according to national rules: US, MX.

If the function box(es) is (are) located at more than 0,3 m of the plug it/they shall have drive-over capability as defined in 9.34.

If a pluggable electrical connection of a pluggable IC-CPD according to 4.3.4 is located at more than 0,3 m of the plug, it shall have drive-over capability in a mated position as defined in 9.34.

For IC-CPDs the protective conductor shall be coloured green and yellow.

NOTE 2 In the following countries, the color for the protective conductor may be solid green: US.

There shall be no provision to alter the residual operating characteristics of IC-CPDs.

The plugs of the IC-CPDs shall be mechanically and electrically compatible with the socket outlet system in which they are intended to be used, and the requirements of the national standard shall be used. If no national requirements exist, the requirements of IEC 60884-1 shall apply for plugs for household and similar use and the IEC 60309 series shall apply for industrial plugs.

It is recommended to use plugs with solid brass pins, if plugs are pin type.

NOTE 3 In the following countries the use of solid brass pins is required: FR.

For specific applications and areas, non interchangeable industrial plugs may be used in conjunction with the IEC 60309 series.

Where reference is made to vehicle connectors the IEC 62196 series applies.

Compliance is checked by inspection and by the tests of the relevant clauses.

NOTE 4 In the following countries IC-CPD according to 4.1.2 or 4.1.3 must fulfil both 4.1.2 and 4.1.3 specification and requirements: NO.

8.2 Pluggable electrical connections of pluggable IC-CPDs according to 4.3.4

8.2.1 General

Connections of an IC-CPD shall be designed in a way that only accessories fulfilling 8.2 can be connected. Components of a pluggable IC-CPD shall not be intermateable in any other way than intended by the manufacturer.

If components of an IC-CPD with different rated currents are intermateable, an automatic means which the end-user cannot influence shall be provided to limit the maximum current given by the control pilot signal of the IC-CPD to the lowest rated current of any of the components.

The manufacturer shall specify the minimum level of engagement of each contact of the electrical connection from which it can be used at nominal current.

The connection shall meet the requirements in Clause 22 of IEC 60309-1:1999, IEC 60309-1:1999/AMD1:2005 and IEC 60309-1:1999/AMD2:2012 at the minimum level of engagement of each contact specified by the manufacturer for its use at nominal current.

For pluggable electrical connections which are intended to be plugged or unplugged by the user or others the fitting, replacement or exchange of components of the IC-CPD assembly shall be in accordance with the tests in IEC 60309-1.

– Only accessories classified according to 6.1.3 of IEC 60309-1:1999 as accessories with earthing contact shall be used.
– Only accessories classified according to 6.1.4 of IEC 60309-1:1999 as non-rewirable plugs and connectors shall be used.
– Only socket-outlets and connectors classified according to 6.1.8 of IEC 60309-1:1999 and IEC 60309-1:1999/AMD2:2012 as accessories providing for a minimum of IPXXB shall be used.
– The retaining means may be rendered ineffective before the test, if agreed upon by the manufacturer.

Compliance is checked by inspection and by the tests of the relevant clauses.

8.2.2 Degree of protection of pluggable electrical connection against solid foreign objects and water for pluggable IC-CPD

All accessories shall provide for IP55 in the mated position.

All accessories shall provide for IP24 in the unmated position. IP24 may be obtained by the combination of the accessory and a lid or cap.

8.2.3 Breaking capacity of pluggable electrical connection for pluggable IC-CPD

The breaking capacity shall be tested according to Clause 20 of IEC 60309-1:1999 and IEC 60309-1:1999/AMD2:2012 by using a current of 2 A or a current specified by the manufacturer, whichever is lower.

The on-load tests shall be conducted according to Clause 21 of IEC 60309-1:1999, IEC 60309-1:1999/AMD1:2005 and IEC 60309-1:1999/AMD2:2012 by using a current of 2 A or a current specified by the manufacturer, whichever is lower.

The number of off-load tests according to Clause 21 of IEC 60309-1:1999, IEC 60309-1:1999/AMD1:2005 and IEC 60309-1:1999/AMD2:2012 shall be determined by the rated current and the corresponding number of cycles given in Table 7 of IEC 60309-1:1999 and IEC 60309-1:1999/AMD2:2012.

If it is not intended to limit the load, the maximum breaking capacity shall be provided. In that case 8.2.4 does not apply.

8.2.4 Additional requirements

Additional requirements as follows:

a) For pluggable electrical connections located between the contacts of the plug and the contact mechanism controlled by the pilot function of the IC-CPD a means shall be provided for
   - limiting the load on each contact not properly engaged with its counterpart to 2 A or its maximum breaking capacity, whichever is lower;
   - limiting the load on each contact when being plugged to 2 A or its maximum breaking capacity, whichever is lower, before the contact is not yet engaged at least to the minimum level specified by the manufacturer for its use at nominal current;
   - limiting the load on each contact when being unplugged to 2 A or its maximum breaking capacity, whichever is lower, before the contact is no longer engaged at least to the minimum level specified by the manufacturer for its use at nominal current.

   Compliance is checked by inspection.

b) For pluggable electrical connections located between the contact mechanism controlled by the pilot function of the IC-CPD and the contacts of the vehicle connector a means shall be provided for
   - limiting the voltage on each contact of an accessory not sufficiently engaged with its counterpart to provide for IPXXD to 30 V a.c. or 60 V d.c;
   - limiting the load on each contact not properly engaged with its counterpart to 2 A or its maximum breaking capacity, whichever is lower;
   - limiting the load on each contact when being plugged to 2 A or its maximum breaking capacity, whichever is lower, before the contact is not yet engaged at least to the minimum level specified by the manufacturer for its use at nominal current;
   - limiting the load on each contact when being unplugged to 2 A or its maximum breaking capacity, whichever is lower, before the contact is no longer engaged at least to the minimum level specified by the manufacturer for its use at nominal current.

   Compliance is checked by inspection.

8.3 Construction

8.3.1 General

It shall not be possible to disassemble an IC-CPD classified according to 4.3.2.

If the IC-CPD is provided with a suspension means the relevant tests as given in IEC 60884-1:2002, IEC 60884-1:2002/AMD1:2006 and IEC 60884-1:2002/AMD2:2013, 24.1, 24.11, 24.12 and 24.13 shall be made.

Parts of the assembly classified according to 4.3.3 shall be securely assembled and it shall not be possible to disassemble them without the aid of a tool.

Except for the pluggable connections of IC-CPDs classified according to 4.3.4, it shall not be possible to disassemble the IC-CPD without the aid of a special purpose tool.

The control pilot function controller shall not be able to close the switching device in case of

– single fault inside the control pilot function controller, or
– single fault of the control circuit of the switching device, or
– after residual current fault without a reset of the IC-CPD

Under single fault conditions of the control pilot function (PWM), no critical overload situation shall appear.

Compliance is checked by fault analysis provided by the manufacturer (e.g. FMEA).

NOTE 1 In France for a rated current above 8 A, rewirable connections of the household plug are not allowed. Connection between the household plugs and cable shall use terminations (see definition 3.2.3).

NOTE 2 In Switzerland the use of IEC 60309-2 accessories is recommended for mode 2 connections for more than 8 A (2 kVA).

8.3.2 Terminations of IC-CPDs

Terminations of IC-CPDs shall be so located or protected that they cannot create a dangerous situation.

Compliance is checked by the test of 9.4.

8.3.3 Enclosure of IC-CPDs according to 4.3.3

The enclosure of IC-CPDs according to 4.3.3 shall completely enclose the terminals and the ends of flexible cables and cords.

The construction shall be such that the conductors can be properly connected and such that, when the accessory is wired and assembled as for normal use, there is no risk that

– the conductors are pressed against each other,
– a core, the conductor of which is connected to a live terminal, comes into contact with accessible metal parts,
– a core, the conductor of which is connected to the earthing terminal, comes into contact with live parts.

Compliance is checked by inspection and by manual test.

8.3.4 Terminal screws or nuts of IC-CPDs according to 4.3.3

The IC-CPD shall be so designed that terminal screws or nuts cannot become loose and fall out of position in such a way that they establish an electrical connection between live parts and the earthing terminal or metal parts connected to the earthing terminal.

Compliance is checked by inspection and by manual test.

8.3.5 Strain on the conductors of IC-CPDs according to 4.3.3

IC-CPDs according to 4.3.3 shall be designed with ample space for slack of the earthing conductor in such a way that, if the strain relief should fail, the connection of the earthing conductor is subjected to strain after the connections of the current-carrying conductors and such that, in case of excessive stresses, the earthing conductor will break after the current-carrying conductors.

Compliance is checked by the test of 9.22.

8.3.6 Additional requirements for IC-CPDs according to 4.3.3

For IC-CPDs according to 4.3.3 the following additional requirements apply:

– it shall be clear how the relief from strain and the prevention of twisting is intended to be effected;
– the cord anchorage, or at least part of it, shall be integral with or permanently fixed to one of the component parts;
– makeshift methods, such as tying the cable or cord in a knot or tying the ends with string, shall not be used;
– cord anchorages shall be suitable for the different types of flexible cable or cord which may be connected, and their effectiveness shall not depend upon the assembly of the parts of the body;
– cord anchorages shall be of insulating material or be provided with an insulating lining fixed to the metal parts,
– metal parts of the cord anchorage, if any, including clamping screws, shall be insulated from the earthing circuit.

Compliance is checked by inspecting the construction and documents provided by the manufacturer.

8.3.7 Insulating parts which keep the live parts in position

They shall be reliably fixed.

Compliance is checked by inspection and by manual test.

8.3.8 Screws for IC-CPD according to 4.3.3

The use of tight-fitting washers of cardboard or the like is deemed to be an adequate method for securing screws which are to be captive.

Compliance is checked by inspection.

8.3.9 Means for suspension from a wall or other mounting surfaces

An IC-CPD with means for suspension mounted or not mounted shall fulfill requirements for protection against electric shock according to 8.5.

Verification is under consideration.

8.3.10 Plug as an integral part of plug-in equipment

If a plug is an integral part of plug-in equipment, that equipment shall not cause overheating of the pins.

For plugs having rated currents and voltages up to and including 16 A and 250 V compliance is checked by the tests of 9.6.

The IC-CPD shall not impose undue strain on fixed socket-outlets.

For an IC-CPD with a plug for household and similar use compliance is checked by the test of 9.23.

8.3.11 Flexible cables and cords and their connection

8.3.11.1 Cord anchorage

Any part of IC-CPD according to 4.3.3 and 4.3.4, if relevant, shall be provided with a cord anchorage such that the conductors are relieved from strain, including twisting, when they are connected to the terminals or terminations, and their covering is protected from abrasion.

The sheath, if any, of the cord shall be clamped within the cord anchorage.

Compliance is checked by inspection and by the test of 9.24.

8.3.11.2 Minimum cross section

IC-CPDs shall be provided with a flexible copper cable complying with IEC 60227 or IEC 60245.

NOTE IEC 62893 for EV charging cables is under development.

The minimum cross-sectional areas of the load conductors and the protective earth conductor are given in Table 6 in relation to the current limit given by the control pilot signal.

Table 6 – Minimum cross-sectional area of flexible cable or cord

Current limit given by control pilot signal	Minimum cross-section mm^2	AWG 1Ø
≤ 13 A	1,5	16
13 A < *I* ≤ 15 A	2,5	14
15 A < *I* ≤ 20 A	2,5	14
20 A < *I* ≤ 30 A	6	10
30 A < *I* ≤ 32 A	6	10

The control pilot wire shall have a minimum cross-section of 0,5 mm²/AWG20.

Compliance is checked by inspection, by measurement and by checking that the flexible cables or cords are in accordance with the IEC 60227 series or the IEC 60245 series, as applicable.

8.3.11.3 Bending

Parts of IC-CPDs shall be so designed that the flexible cable or cord is protected against excessive bending where it enters the accessory.

Guards provided for this purpose shall be of insulating material and shall be fixed in a reliable manner.

NOTE Helical metal springs, whether bare or covered with insulating material are not suitable to be used as cord guards.

Compliance is checked by inspection and by the test of 9.25.

8.4 Electrical performance

8.4.1 Protective conductor path

The switched contact within the protective conductor path, if any, shall provide adequate contact pressure and shall not deteriorate in normal use.

The protective conductor may pass through the sensing toroid as long as the unit complies with the appropriate operating test.

It shall be verified by inspection that the protective conductor path does not have any semiconductor device connected in series.

Compliance is checked by the temperature rise test of 9.6.2, the residual short-circuit test of 9.9.2.3 and the conditional short-circuit test of 9.9.2.4 c).

8.4.2 Contact mechanism

Each line conductor and the neutral conductor, if any, of the IC-CPD shall be provided with switching contacts. For IC-CPDs according to 4.4.2 the protective conductor shall be provided with a switching contact. The line contacts and the neutral contact, if any, shall be mechanically or electrically coupled such that they make and break substantially together.

The protective conductor contact, if any, may be mechanically or electrically coupled to the line and neutral contacts.

The switching contact of the protective conductor path, if any, shall close before and open after the switching contacts of the live conductors or close and open substantially together with the live conductors.

It may be possible to switch off the IC-CPD when energized as in normal use. A test device may be used for that purpose.

The IC-CPD shall have means for manual reset after a residual current operation. This may be done by a dedicated means or by disconnecting from the socket-outlet.

NOTE The following countries allow automatic reset after successful self test with limitations as imposed by 14.3 and 17.7 of UL 2231-2: US.

A test device may be provided.

An automatic verification shall ensure detection of unintended closed contacts.

The IC-CPD shall have an indicator showing the state of the contacts and give a clear indication or response in case of unintentionally closed contacts.

The action of the mechanism shall not be influenced by the position of enclosures or covers and shall be independent of any removable part.

A cover sealed in position by the manufacturer is considered to be a non-removable part.

Compliance with the above requirements is checked by inspection and by the relevant tests of 9.7.

8.4.3 Clearances and creepage distances (see Annex C)

Clearances and creepage distances shall not be less than the values shown in Table 7, when the IC-CPD is mounted as in normal use. The values in Table 7 are based on the IC-CPD being designed for operating in an environment with pollution degree 2 and overvoltage category II.

NOTE If higher altitudes, pollution degrees or overvoltage category are considered, the appropriate clearances and creepage distances are defined in IEC 60664-1.

Compliance for item 1 in Table 7 is checked by measurement or by the test of 9.5.5.3.1 and 9.5.5.3.2. The test is carried out with samples not submitted to the humidity treatment described in 9.5.1.

The clearances of items 2 and 4 may be reduced provided that the measured clearances are not shorter than the minimum allowed in IEC 60664-1 for homogenous field conditions. In this case, after the humidity treatment described in 9.5.1, compliance for items 2 and 4 and the arrangements of 9.5.2, items b), c), d) and e) is checked in the following order:

– tests according to 9.5.2,
– test according to 9.5.5.2, applied with the test voltages given in Table 10 and with the test arrangements of 9.5.2 items b), c), d), e).

If the measurement does not show any reduced clearance, test 9.5.5.2 is not applied.

Double insulation or reinforced insulation shall be provided upstream of the interrupting contacts of the IC-CPD between hazardous-live parts and

– accessible surfaces of operating means,
– screws or other means for fixing covers which may be removed when connecting the connector,
– accessible metal parts.

Compliance is checked by the test of 9.5.5.2. The test voltage shall be multiplied by 1,6.

All measurements required in 8.4.3 shall be carried out in Test sequence A on one sample and the tests 9.5.5.2 shall be carried out before 9.5.1 on three samples of Test sequence B.

The insulating materials are classified into material groups on the basis of their comparative tracking index (CTI) according to 4.8.1 of IEC 60664-1:2007.

For domestic plugs and when a national standard exists the relevant national standard applies. If no relevant national standard is available IEC 60884-1 applies.

For industrial plugs, the IEC 60309 series applies.

For vehicle connectors IEC 62196-1 or IEC 62196-2 applies.

The verification of clearances and creepage distances on printed circuit boards is made by the tests of 9.27.

Table 7 – Minimum clearances and creepage distances (rated voltage 230 V, 230/400 V)

	Minimum clearances [g] mm				**Minimum creepage distances** [c, g] mm											
					Group IIIa [d] **(175 V ≤ CTI < 400 V)**[b]				**Group II (400 V ≤ CTI < 600 V)**[b]				**Group I (600 V ≤ CTI)**[b]			
	Rated voltage V[e]				**Working voltage** V											
	U_{imp} 1,5 kV	U_{imp} 2,5 kV														
Description	120	250	230/400	480	120	250	400	480	120	250	400	480	120	250	400	480
1. between live parts which are separated when the main contacts are in the open position [a]	0,5	1,5			1,5	2,5	4,0	5	1,05	1,8	2,8	3,6	0,75	1,5	2,0	2,5
2. between live parts of different polarity	0,5	1,5			1,5	2,5	4,0	5	1,05	1,8	2,8	3,6	0,75	1,5	2,0	2,5
3. void																
					Rated voltage V											
					120	250	230/400	480	120	250	230/400	480	120	250	230/400	480
4. downstream interrupting contacts of the IC-CPD between live parts and - accessible surfaces of operating means - screws or other means for fixing covers which may be removed when connecting the connector - accessible metal parts [f] - PE	0,5	1,5			1,5	2,5	4	5	1,05	1,8	2,8	3,6	0,75	1,5	2,0	2,5
5. upstream interrupting contacts of the IC-CPD between live parts and - accessible surfaces of operating means	1,5	3			2,5	5	8	10	2,1	3,6	5,6	7,2	1,5	3	4	5

	Minimum clearances [g] mm		Minimum creepage distances [c, g] mm											
			Group IIIa [d] (175 V ≤ CTI < 400 V)[b]			Group II (400 V ≤ CTI < 600 V)[b]			Group I (600 V ≤ CTI)[b]					
	Rated voltage V[e]		Working voltage V											
	U_{im} 1,5[p] kV	U_{imp} 2,5 kV												
- screws or other means for fixing covers which may be removed when connecting the connector - accessible metal parts [f]														

NOTE 1 The parts of the neutral path, if any, are considered to be live parts.

NOTE 2 Clearances and creepage distances of the secondary circuit and between the primary windings of the IC-CPD transformer are not considered.

[a] For auxiliary and control contacts the values are given in the relevant standard.

[b] See IEC 60112.

[c] Interpolation is allowed in determining creepage distances corresponding to voltage values intermediate to those listed as working voltage. When interpolating, linear interpolation shall be used and values shall be rounded to the same number of digits as the values picked up from the tables. For determination of creepage distances, see Annex C.

[d] For material group IIIb (100 V ≤ CTI < 175 V) the values for material group IIIa multiplied by 1,6 apply.

[e] The rated voltage is the maximum operational voltage to earth.

[f] Including a metal foil in contact with the surfaces of insulating material which are accessible after installation for normal use. The foil is pushed into corners, grooves, etc., by means of a test wire according to 9.4 (see Figure 9).

[g] For altitudes of 3 000 m the values shall be multiplied by 1,14, for 4 000 m they shall be multiplied by 1,29.

8.5 Protection against electric shock

8.5.1 General

IC-CPDs shall be so designed that, when they are used according to the manufacturers' instructions, live parts are not accessible.

External parts, other than screws or other means for fixing covers and labels, which are accessible when the IC-CPD is used under normal conditions, shall either be of insulating material, or be lined throughout with insulating material, unless the live parts are within an internal enclosure of insulating material.

Such lining shall be fixed so that it is not likely to be lost. It shall have adequate thickness and mechanical strength and shall provide adequate protection even at places where sharp edges occur.

Inlet openings for cables shall either be of insulating material or be provided with bushing or similar devices of insulating material. Such devices shall be reliably fixed and shall have adequate mechanical strength.

Accessible parts of operating means shall be made of insulating material.

Metal parts of the mechanism shall not be accessible. In addition, they shall be insulated from all accessible metal parts, including metal frames, plates, screws or other means used as supporting or fixing means.

Lacquer and enamel are not considered to provide adequate insulation for the purpose of 8.5.1.

Compliance is checked by inspection and by the tests of 9.4.

8.5.2 Requirements relating to plugs, whether incorporated or not in integral items

For plugs for household and similar use, this is covered by the requirements of national standards. In the absence of national standards IEC 60884-1 applies.

For industrial plugs the IEC 60309 series applies.

8.5.3 Degree of protection of the function box

The degree of protection of the parts of the function box after assembly as for normal use shall not be less than IP55. This also means that all connections between the function box and other components of a pluggable IC-CPD are mated.

This requirement does not apply to the plug inserted in a standard socket outlet, in particular in case of IC-CPD according to 4.2.3.

The relevant tests of IEC 60529 apply.

The test conditions for the function box regarding the first and second IP number according to IEC 60529 apply as follows:

– the samples shall be tested in different positions chosen at random, if applicable;
– the samples are not connected to supply voltage;
– the dust test is performed in an enclosure of category 2.

In addition to the IP requirement the function box shall be submitted to the following test:

– test procedure according to 14.2.7 of IEC 60529:1989 with the upper part of the casing placed 5 cm under water.

After the test under the conditions of tests specified in 9.7.3.4, the IC-CPD shall trip with a test current of 1,25 $I_{\Delta n}$ and shall not trip with a current of $I_{\Delta no}$. One test only is made on one pole taken at random, without measurement of break-time.

8.5.4 Requirements relating to vehicle connectors

For vehicle connectors the IEC 62196 series applies.

8.6 Dielectric properties

IC-CPDs shall have adequate dielectric properties.

Compliance is checked by the tests of 9.5.

8.7 Temperature rise

The temperature-rises of the parts of an IC-CPD specified in Table 8, measured under the conditions specified in 9.6, shall not exceed the limiting values stated in this table.

The IC-CPD shall not suffer damage impairing its functions and its safe use.

Table 8 – Temperature-rise values

Parts [a, b, c]	**Temperature rise** [d] K
Contacts or terminals for external connections	50
Parts likely to be touched made of metallic non-metallic	 30 50
NOTE In the UK the temperature rise limit is 52 K in fused plug and socket-outlet systems.	
[a] No value is specified for the contacts, since the design of most IC-CPDs is such that a direct measurement of the temperature of those parts cannot be made without the risk of causing alterations or displacement of parts likely to affect the reproducibility of the tests. The test of 9.17.2 is considered to be sufficient for checking indirectly the behaviour of the contacts with respect to undue temperature rises in service. [b] No value is specified for parts other than those listed, but no damage shall be caused to adjacent parts of insulating materials, and the operation of the IC-CPD shall not be impaired. [c] For plugs, connectors and cables the relevant values of the individual product standards apply. [d] Values derived from touch times of 4 s, taken from IEC Guide 117.	

8.8 Operating characteristics

8.8.1 General

IC-CPDs shall present adequate operating characteristics.

Compliance is checked by the tests of 9.7.

8.8.2 Safe connection operating characteristics

It shall be verified that the protective conductor, on the load side, is connected to the vehicle.

Compliance with this requirement is checked by the test of 9.7.9.

The IC-CPD shall comply with the additional requirements of 5.1 for supply failures defined in 3.3.1.5, and hazardous live protective conductor conditions defined in 3.3.3.18 (see 8.22). The hazardous live protective conductor conditions only apply to IC-CPD classified according to 4.4.2.

8.8.3 Operating characteristics with a.c. residual currents and residual currents having a d.c. component

The break times for the IC-CPD shall be according to Table 2 in presence of a.c. residual currents at rated frequency and residual currents having a d.c. component.

The correct operation in case of residual pulsating direct currents superimposed by smooth direct currents, shall also be verified.

The IC-CPD shall also detect and break composite residual currents.

Compliance is checked by the tests of 9.7.3, 9.7.4 and 9.7.6.

8.8.4 Operating characteristics with smooth d.c. residual current

The IC-CPD shall verify that smooth d.c. residual currents do not exceed the value of 6 mA and ensure a break time according to Table 3 in case that this limit is exceeded.

NOTE Regarding this requirement, see also the Foreword.

Compliance is checked by the tests of 9.7.6.

8.8.5 Behaviour of the IC-CPD after a residual current operation

After operation due to a residual current a re-closure without a user interaction shall not be possible.

The user interaction shall initiate a self test before charging.

Compliance is checked by the tests of 9.13.

8.8.6 Residual pulsating direct currents which may result from rectifying circuits supplied from two phases

IC-CPDs operating on two-phase supply (according to 4.1.3) shall operate in response to a steady increase of residual pulsating direct current resulting from rectifying circuits within the limits of 3,5 mA and 7 mA.

Compliance is checked by the tests of 9.7.11 a).

IC-CPDs operating on two-phase supply shall operate in response to a sudden appearance of residual pulsating direct current resulting from rectifying circuits according to the limits specified in Table 4.

Compliance is checked by the tests of 9.7.11 b).

8.8.7 Residual pulsating direct currents which may result from rectifying circuits supplied from three phases

IC-CPDs according to 4.1.4 shall operate in response to a steady increase of residual pulsating direct current resulting from rectifying circuits within the limits of 3,1 mA and 6,2 mA.

Compliance is checked by the tests of 9.7.12 a).

IC-CPDs according to 4.1.4 shall operate in response to a sudden appearance of residual pulsating direct current resulting from rectifying circuits according to the limits specified in Table 4.

Compliance is checked by the tests of 9.7.12 b).

8.9 Mechanical and electrical endurance

IC-CPDs shall be capable of performing an adequate number of mechanical and electrical operations.

The IC-CPD shall withstand an inrush current representing a typical charger of an electric vehicle.

NOTE The requirement for the inrush current of an electric vehicle is based on ISO 17409.

Compliance is checked by the tests of 9.8.1 and 9.8.2.

8.10 Performance at short-circuit currents

IC-CPDs shall be capable of performing a specified number of short-circuit operations.

Compliance is checked by the tests of 9.9.

8.11 Resistance to mechanical shock and impact

IC-CPDs shall have adequate mechanical strength so as to withstand the stresses imposed during connection and use.

Compliance is checked by the test of 9.10.

8.12 Resistance to heat

IC-CPDs shall be sufficiently resistant to heat.

Compliance is checked by the test of 9.11.

8.13 Resistance to abnormal heat and to fire

External parts of IC-CPDs made of insulating material shall not be liable to ignite and to spread fire if current-carrying parts in their vicinity, under fault or overload conditions, attain a high temperature.

Compliance is checked by the test of 9.12.

8.14 Performance of the test function

IC-CPDs shall be provided with an automatically initiated self test to verify the ability of the IC-CPD to detect a residual current event. The self test shall cover the whole function chain consisting of the detection and evaluation of the residual current. The contact mechanism is excluded.

The automatic self test shall be performed each time

– the IC-CPD is connected to the supply;
– the vehicle coupler is connected to the vehicle (only applicable if connected to the supply) or the vehicle has requested to initiate a charging session.

One self test is sufficient within a 10 min interval.

The 10 min are understood as follows: If a self test has already been performed within the past 10 min another test is not required on power-up or when connected to the vehicle. It is not required to do a self test every 10 min.

The contact closing shall only be initiated if the result of the self test was positive.

Detected failures, including unintended closed contact(s), shall result in not charging the EV by using the PWM signal. A detected unintentional closed contact shall also result in closing the protective conductor contact, if the protective conductor is switched.

If the self test failed it shall be indicated.

The operation of the IC-CPD shall be such that the protective conductor of the installation shall not become live and the circuit on the load side shall not be energized during the self test.

The verification is made by inspection and by tests with a special prepared sample as described in 9.13.

8.15 Behaviour in case of loss of the supply voltage

The tests shall verify the operation of the IC-CPD within its voltage range according to the classification.

The IC-CPD shall operate correctly at any value of the line voltage between 0,85 times and 1,1 times its rated voltage.

Compliance is checked by the tests of 9.7 and 9.14.

The IC-CPD shall open automatically in case of a voltage drop and reinitiate the charging cycle when the line voltage is restored.

However, after an operation due to a residual fault followed by a drop of line voltage the charging cycle shall not be reinitiated automatically when the supply voltage is restored.

According to IEC TS 62763, the IC-CPD shall open automatically in case of a voltage drop and reinitiate charging cycle in accordance with IEC TS 62763, when the line voltage is restored.

Compliance is checked by the tests of 9.14.

8.16 Resistance of IC-CPDs against unwanted tripping due to surge currents to earth resulting from impulse voltages

IC-CPDs shall adequately withstand impulse voltages.

Compliance is checked by the test of 9.16.

8.17 Control pilot function controller

The control pilot circuit shall be according to IEC TS 62763.

PWM values shall not allow a current exceeding the rating of the IC-CPD.

Compliance is checked by testing according to IEC TS 62763.

8.18 Reliability

IC-CPDs shall operate reliably even after long service, taking into account the ageing of their components.

Compliance is checked by the tests of 9.17, 9.18 and 9.29.

8.19 Resistance to tracking

Parts of insulating materials in contact with live parts shall be resistant to tracking.

Compliance is checked by the test of 9.19.

8.20 Electromagnetic compatibility (EMC)

EMC tests shall be performed according to 9.26.

8.21 Behaviour of the IC-CPD at low ambient air temperature

IC-CPDs shall operate reliably at their limits of ambient air temperatures.

Compliance is checked by the tests of 9.7.3.7 and 9.7.3.8.

8.22 Operation with supply failure and hazardous live protective conductor conditions

The IC-CPD shall comply with the additional requirements of 5.1 for supply failures defined in 3.3.1.5, and hazardous live protective conductor conditions defined in 3.3.3.18. The hazardous live protective conductor conditions only apply to IC-CPD classified according to 4.4.2.

Compliance with this requirement is checked by the test of 9.7.7.

8.23 Verification of a standing current in the protective conductor in normal service

The current flowing under normal conditions on the supply side from the IC-CPD to the protective conductor shall not exceed 1 mA r.m.s. at 1,1 U_e in the open and 1,5 mA r.m.s. in the closed positions.

NOTE The value in the closed position takes into account the capacitance of the cable length.

Compliance is checked by the test of 9.7.10.

8.24 Behaviour at specific environmental conditions

IC-CPDs shall operate reliably under specific environmental conditions such as

– resistance to chemical loads;
– solar radiation;
– ultra-violet (UV) radiation;
– coastal environments;
– in case of vehicle drive-over (if applicable);
– after low temperature storage.

Compliance is checked by the tests of 9.29 to 9.35.

8.25 Resistance to vibration and shock

The IC-CPD shall have an adequate withstand to vibrations and shock.

Compliance is checked by the tests of 9.36

9 Tests

9.1 General

9.1.1 Opening and closing of contacts

If specific operating cycles are not described for tests requiring the opening or closing of contacts, the control pilot function controller with an appropriate PWM signal shall be used to operate the IC-CPD by simulation of the different vehicle states as described by IEC TS 62763. For that purpose a special assembled dummy may be used.

The opening and closing sequence shall be triggered by the control pilot.

The Control pilot function controller including the PWM signal is defined in IEC TS 62763.

9.1.2 Type tests

The characteristics of IC-CPDs are checked by means of type tests.

The type tests required by this standard are listed in Table 9.

NOTE Plugs that have already been type-tested to their relevant standard need not be tested again.

Table 9 – List of type tests

Tests	Subclause
– Indelibility of marking	9.3
– Protection against electric shock	9.4
– Dielectric properties	9.5
– Temperature rise test	9.6
– Operating characteristic	9.7
– Mechanical and electrical endurance	9.8
– Behaviour of IC-CPDs under overcurrent conditions	9.9
– Resistance to mechanical shock and impact	9.10
– Resistance to heat	9.11
– Resistance of insulating material to abnormal heat and to fire	9.12
– Verification of the residual current function by self test	9.13
– Behaviour of IC-CPDs in case of loss of the supply voltage	9.14
– Limiting values of the non-operating current under overcurrent conditions	9.15
– Resistance against unwanted tripping due to surge currents to earth resulting from impulse voltages	9.16
– Reliability	9.17
– Resistance to ageing	9.18
– Resistance to tracking	9.19
– Tests on pins provided with insulating sleeves	9.20
– Mechanical strength of non-solid pins of plugs	9.21
– Effects of strain on the conductors	9.22
– Torque exerted by IC-CPDs on fixed socket-outlets	9.23
– Tests of cord anchorage	9.24
– Flexing test of non-rewirable IC-CPDs	9.25
– Electromagnetic compatibility (EMC)	9.26
– Tests replacing verifications of creepage distances and clearances	9.27
– Verifications for single electronic components used in IC-CPDs	9.28
– Chemical loads	9.29
– Heat test under solar radiation	9.30
– UV radiation	9.31
– Damp and salt mist test for marine and coastal environments	9.32
– Hot damp test for tropical environments	9.33
– Vehicle drive-over	9.34
– Low storage temperature test	9.35
– Vibration and shock test	9.36

9.1.3 Test sequences

For the purpose of verification of conformity with this standard, type tests are carried out in test sequences.

The test sequences and the number of samples to be submitted are stated in Annex A.

Unless otherwise specified, each type test (or sequence of type tests) is made on IC-CPDs in a clean and new condition, the influencing quantities having their normal reference values (see Table 5).

The non-replaceable integral fuse, if any, of an IC-CPD shall not open during tests unless otherwise stated.

9.1.4 Routine tests

Routine tests are intended to detect faults in materials and workmanship and to ascertain safety and proper functioning of the IC-CPD. They shall be made on each individual device of the IC-CPD.

Routine tests to be carried out by the manufacturer are given in Annex B.

9.2 Test conditions

The tests are made on new samples representative of the production.

Unless otherwise specified, the IC-CPD is connected as in normal use supplied by rated voltage, using plugs, and/or socket-outlets of the same system, at an ambient temperature between 20 °C and 25 °C and according to the manufacturer's instructions.

For type LLLNSE or LLLNE IC-CPDs designed to use less than three phases of a three-phase supply, the tests shall be made only with the wired phases.

The plug and socket outlet are connected according to the test conditions of Clause 19 of IEC 60884-1:2002/AMD2:2013 or the national standard for plugs for household and similar use or Clause 22 of IEC 60309-1:1999, IEC 60309-1:1999/AMD1:2005 and IEC 60309-1:1999/AMD2:2012 for industrial plugs or to the relevant clause of the national standard.

Sample selection shall be made at discretion between manufacturer and test laboratory.

The vehicle connector and vehicle inlet are connected according to the test conditions of Clause 24 of IEC 62196-1:2014 for an EV connector.

The ambient air temperature shall be measured during the last quarter of the test period by means of at least two thermometers or thermocouples symmetrically distributed around the IC-CPD at about half its height and at a distance of about 1 m from the IC-CPD.

The thermometers or thermocouples shall be protected against draughts and radiant heat.

Care should be taken to avoid errors due to sudden temperature changes.

Where tolerances are not specified, type tests are carried out at values not less than those specified in this standard. Unless otherwise specified, tests are carried out at the rated frequency ±5 %.

9.3 Test of indelibility of marking

The test is made by rubbing the marking by hand for 15 s with a piece of cotton cloth soaked with water and again for 15 s with a piece of cotton cloth soaked with an aliphatic solvent hexane (with a content of aromatics of maximum 0,1 % volume, a kauributanol value of 29, an initial boiling point approximately 65 °C, a dry point of approximately 69 °C and a specific gravity of 0,68 g/cm^3).

Markings made by impressing, moulding or engraving are not subjected to this test.

After this test, the marking shall be easily legible. The marking shall also remain easily legible after all the tests of this standard.

It shall not be easily possible to remove labels and they shall show no curling.

9.4 Verification of protection against electric shock

The sample is connected as for normal use. IC-CPDs are tested as supplied by the manufacturer.

For the IC-CPD, the standard test wire shown in Figure 9 is applied in every possible position on every part except plug and vehicle connector.

An electrical indicator with a voltage not less than 40 V and not more than 50 V is used to show contact with the relevant part.

For IC-CPDs where the use of elastomeric or thermoplastic material is likely to influence the requirement, the test is repeated but at an ambient temperature of (35 ± 2) °C, the IC-CPD being at this temperature.

During this additional test, IC-CPDs are subjected for 1 min to the test force of the test wire. This wire, with an electrical indicator as described above, is applied to all places where yielding of the insulating material could impair the safety of the IC-CPD.

During this test, the IC-CPDs shall not deform to such an extent that those dimensions shown in the relevant standard sheets which ensure safety are unduly altered and no live part shall be accessible by the standard test wire (see Figure 9).

If the plug portion is an integral part of the function box

– the assembly is pressed between two flat surfaces with a force of 300 N for 1 min, as shown in Figure 13,

or

– it is tested according to national requirements of the country where the product is placed on the market.

Fifteen minutes after removal of the test apparatus the sample shall not show such deformation as would result in a situation where live parts are accessible.

9.5 Test of dielectric properties

9.5.1 Resistance to humidity

9.5.1.1 Preparation of the IC-CPD for test

Parts of the IC-CPDs which can be removed without the aid of a tool are removed and subjected to the humidity treatment together with the main part. Spring lids, if any, are kept open during this treatment.

Inlet openings, if any, are left open.

9.5.1.2 Test conditions

The humidity treatment is carried out in a humidity cabinet containing air with a relative humidity maintained between 91 % and 95 %.

The temperature of the air in which the sample is placed is maintained within ±1 K at any convenient value T between 20 °C and 30 °C.

Before being placed in the humidity cabinet the sample is brought to a temperature between T °C and (T + 4) °C.

9.5.1.3 Test procedure

The sample is kept in the cabinet for 48 h.

NOTE A relative humidity between 91 % and 95 % is obtained by placing in the humidity cabinet a saturated solution of sodium sulphate (Na_2SO_4) or potassium nitrate (KNO_3) in water having a sufficiently large surface in contact with the air.

In order to achieve the specified conditions within the cabinet, it is recommended to ensure constant circulation of the air within and to use a cabinet which is thermally insulated.

9.5.1.4 Condition of the IC-CPD after the test

After this treatment, the sample shall show no damage within the meaning of this standard and shall withstand the tests of 9.5.2 and 9.5.3.

9.5.2 Insulation resistance of the main circuit

The IC-CPD having been treated as specified in 9.5.1 is then removed from the cabinet.

After an interval between 30 min and 60 min following this treatment, the insulation resistance is measured 5 s after application of a d.c. voltage of approximately 500 V, successively as follows:

a) with the IC-CPD in the open position, in turn between each pair of the terminals or pins which are electrically connected together when the IC-CPD is in the closed position;

b) with the IC-CPD in the closed position, from each pole in turn to the other two connected together, electronic components connected between current paths being disconnected for the test, including the protective conductor circuit and other circuits.

   Where it is not possible to keep the IC-CPD in the closed position, each pole is bridged by an outside connection;

c) with the IC-CPD in the closed position, from all poles connected together to the frame, including a metal foil in contact with the outer surface of the internal enclosure of insulating material, if any;

d) between internal metal parts of the mechanism and the frame.

   Access to the internal metal part of the mechanism may be specifically provided for this measurement by the manufacturer;

e) for IC-CPDs with a metal enclosure having an internal lining of insulating material, between the frame and a metal foil in contact with the inner surface of the lining of insulating material, if any, including bushing and similar devices.

The term "frame" includes:

– all accessible metal parts and a metal foil in contact with the surfaces of insulating material which are accessible in normal use;

– screws for fixing covers which have to be removed when connecting the IC-CPD.

For the purpose of this test, the protective conductor is connected to the frame.

For the measurements according to b), c), d) and e), the metal foil is applied in such a way that the sealing compound, if any, is effectively tested.

The insulation resistance shall not be less than

– 2 MΩ for the measurements according to a) and b);

– 5 MΩ for the other measurements.

9.5.3 Dielectric strength of the main circuit

Immediately after the IC-CPD has passed the tests of 9.5.2, the test voltage specified below is applied for 1 min between the parts indicated in 9.5.2, the electronic components, if any, being disconnected for the test, including the protective conductor circuit and other circuits.

The test voltage shall have a practically sinusoidal waveform and a frequency between 45 Hz and 65 Hz.

The source of the test voltage shall be capable of supplying a short-circuit current of at least 0,2 A.

No overcurrent tripping device of the transformer shall operate when the current in the output circuit is lower than 100 mA.

The values of the test voltage shall be as follows:

– 2 000 V for a) to d) of 9.5.2;

– 2500 V for e) of 9.5.2.

Initially, no more than half the prescribed voltage is applied, then it is raised to the full value within 5 s.

No flashover or breakdown shall occur during the test.

Glow discharges without drop in voltage are neglected.

9.5.4 Secondary circuit of detection transformers

The secondary circuit of the detection transformer is not submitted to any insulation test, provided that the circuit has no connection with accessible metal parts or with a protective conductor or with live parts.

9.5.5 Verification of impulse withstand voltages (across clearances and across solid insulation) and of leakage current across open contacts

9.5.5.1 General testing procedure for the impulse withstand voltage tests

The impulses are given by a generator producing positive and negative impulses having a front time of 1,2 μs, and a time to half-value of 50 μs, the tolerances being as follows:

– ±5 % for the peak value;

– ±30 % for the front time;

– ±20 % for the time to half-value.

For each test, five positive impulses and five negative impulses are applied, the interval between consecutive impulses being at least 1 s for impulses of the same polarity and being at least 10 s for impulses of the opposite polarity.

When performing the impulse voltage test on a complete IC-CPD, the attenuation or amplification of the test voltage shall be taken into account. It needs to be assured that the required value of the test voltage is applied across the terminals of the equipment under test.

The surge impedance of the test apparatus shall have a nominal value not higher than 500 Ω.

The shape of the impulses is adjusted with the IC-CPD under test connected to the impulse generator. For this purpose, appropriate voltage dividers and voltage sensors shall be used. It is recommended to disconnect surge protective components before testing.

NOTE For IC-CPDs with incorporated surge arresters that cannot be disconnected, the shape of the impulses is adjusted without connection of the IC-CPD to the impulse generator.

Small oscillations in the impulses are allowed, provided that their amplitude near the peak of the impulse is less than 5 % of the peak value.

For oscillations on the first half of the front, amplitudes up to 10 % of the peak value are allowed.

There shall be no disruptive discharge (sparkover, flashover or puncture) during the tests.

It is recommended that an oscilloscope be used to observe the impulse voltage in order to detect disruptive discharge.

9.5.5.2 Verification of clearances with the impulse withstand voltage

If the measurement of the clearances of items 2 and 4 in Table 7 and the arrangements given in 9.5.2 b), c) d) and e) shows a reduction of the required length this test applies. This test is carried out immediately after the measurement of the insulation resistance in 9.5.3.

NOTE The measurement of the clearances can be replaced by this test.

The test is carried out on an IC-CPD placed on a metal support and being in the closed position.

The test impulse voltage values shall be as given in Table 10. These values are corrected for the altitude at which the tests are carried out, according to Table 10.

A first series of tests is made applying the impulse voltage between:

– the phase pole(s) and the neutral pole connected together, and
– the metal support connected to the terminal(s) intended for the protective conductor(s), if any.

A second series of tests is made applying the impulse voltage between:

– the phase pole(s), connected together, and
– the neutral pole of the IC-CPD, as applicable.

A third series of tests is made applying the impulse voltage between the arrangements given in 9.5.2 b), c), d) and e) and not tested during the two first sequences described here above.

A fourth series of tests for verification of double insulation or reinforced insulation is made applying the impulse voltage between hazardous-live parts and

– accessible parts (accessible conductive parts and accessible surfaces of insulating material), and
– circuits of the pilot signal.

The test voltage shall be multiplied by 1,6.

There shall be no disruptive discharge. If, however, only one such disruptive discharge occurs, ten additional impulses having the same polarity as that which caused the disruptive discharge are applied, the connections being the same as those with which the failure occurred.

No further disruptive discharge shall occur.

Table 10 − Test voltage for verification of impulse withstand voltage

Rated impulse withstand voltage U_{imp} kV	Test voltages at corresponding altitude $U_{1,2/50}$ a.c. peak kV				
	Sea level	200 m	500 m	1 000 m	2 000 m
2,5	2,9	2,8	2,8	2,7	2,5

9.5.5.3 Verification of the resistance of the insulation of open contacts and basic insulation against an impulse voltage in normal conditions

9.5.5.3.1 General

These tests are not preceded by the humidity treatment described in 9.5.1.

The tests in 9.5.5.3, as stated in the requirements in 8.4.3, shall be carried out before 9.5.1 on three samples of test sequence B.

The test impulse voltage values shall be chosen from Table 10, in accordance with the rated voltage of the installation for which the IC-CPD is intended to be used as given in Table 7.

These values are corrected for barometric pressure at the altitude at which the tests are carried out, according to Table 10.

9.5.5.3.2 IC-CPD in opened position

The series of tests is carried out on an IC-CPD fixed on a metal support as in normal use.

The impulses are applied between:

– the line terminals connected together, and
– the load terminals connected together with the contacts in the open position.

There shall be no disruptive discharges during the test.

9.5.5.3.3 IC-CPD in closed position

The series of tests is carried out on an IC-CPD placed on a metal support, wired as in normal use and being in the closed position.

All components bridging the basic insulation have to be disconnected.

A first series of tests is made, the impulses being applied between:

– the phase pole(s) and the neutral pole connected together, and
– the metal support connected to the terminal(s) intended for the protective conductor(s), if any.

A second series of tests is made, the impulses being applied between:

– the phase pole(s), connected together, and
– the neutral pole of the IC-CPD.

There shall be no disruptive discharge. If, however, only one such disruptive discharge occurs, ten additional impulses having the same polarity as that which caused the disruptive discharge are applied, the connections being the same as those with which the failure occurred.

No further disruptive discharge shall occur.

Afterwards a new sample is tested according to 9.5.5.3.4.

9.5.5.3.4 Verification of the behaviour of components bridging the basic insulation

Verification shall be performed to ensure that components, bridging the basic insulation and having been disconnected during the impulse voltage test for testing the basic insulation, shall not impair the behaviour or the safety of the basic insulation of the equipment during normal use.

A new IC-CPD sample is tested in order to check that components bridging the basic insulation would not reduce safety with respect to short term temporary overvoltages.

The test voltage has a frequency of 50/60 Hz. In accordance to IEC 60364-4-44:2007, Table 44.A2 and IEC 60664-1, the r.m.s. value of the test voltage for the basic insulation is 1 200 V + U_e. U_e is the nominal voltage value between line and neutral.

NOTE 1 As an example, for an IC-CPD having a rated voltage of U_e = 250 V, the value of the a.c. test voltage for basic insulation is 1 200 V + 250 V, thus the r.m.s. test voltage is 1 450 V.

The voltage is applied for 5 s between:

– the phase pole(s) and the neutral pole connected together, and
– the metal support connected to the terminal(s) intended for the protective conductor(s), if any.

The equipment is then visually inspected; no component bridging the basic insulation shall show a visible alteration.

NOTE 2 It is accepted to replace a fuse before connecting the equipment to the mains. If a fuse protecting a surge arrester has blown, it is accepted to replace the surge arrester too.

Then, the equipment is connected to the mains in accordance with the manufacturer's instruction. Under the condition of 9.7.3.4 the IC-CPD shall trip with a test current of 1,25 $I_{\Delta n}$. One test only is made on one pole, taken at random, without measurement of break time.

9.6 Temperature-rise test

9.6.1 Test conditions

The general test conditions of 9.2 apply.

IC-CPDs are tested as supplied by the manufacturer.

The necessary plugs used for the test shall have brass pins having the minimum specified dimensions.

9.6.2 Test procedure

A current equal to I_n is passed simultaneously through the two poles of type LNSE or type LLSE IC-CPDs and through the three poles of type LLLNSE or type LLLNE IC-CPDs for a period of time sufficient for the temperature rise to reach the steady-state value. In practice, this condition is reached when the variation of the temperature rise does not exceed 1 K/h.

The test is repeated with the current flowing in the protective conductor path alone and with voltage applied between line and neutral. The IC-CPD is supplied by 1,05 U_e and is connected in accordance with Figure 5, as applicable. During the tests the temperature rise shall not exceed the values in Table 8.

A specially prepared sample with the trip circuit disabled may be required if the protective conductor passes through the toroid.

9.6.3 Measurement of the temperature rise of different parts

The temperature of the different parts referred to in Table 8 shall be measured by means of fine wire thermocouples or by equivalent means at the nearest accessible position to the hottest spot.

Good heat conductivity between the thermocouple and the surface of the part under test shall be ensured.

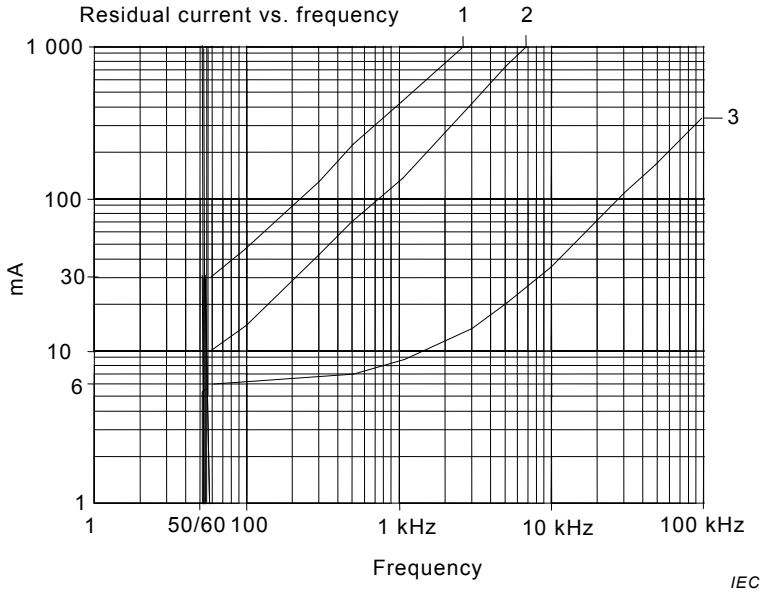
9.6.4 Temperature rise of a part

The temperature rise of a part is the difference between the temperature of this part measured in accordance with 9.6.3, and the ambient air temperature measured in accordance with 9. 2.

9.7 Verification of the operating characteristic

9.7.1 General

NOTE In the USA, the UL 2231 MIU concept is applicable to ensure detection of d.c. and high frequency components, giving consideration to the following diagram (see Figure 1).



The figure illustrates the desired characteristics for maintaining the same level of protection over the frequency range that can be anticipated for battery powered vehicle charging systems, considering devices with an $I_{\Delta n}$ of 6 mA, 10 mA, and 30 mA.

Figure 1 – Desired characteristics for maintaining the same level of protection over the frequency range

9.7.2 Test circuit

The IC-CPD is connected as for normal use, unless otherwise specified. The reset of the IC-CPD may be made with any suitable method.

The instruments for the measurement of the residual current shall show (or permit to determine) the true r.m.s. value.

The instruments for the measurement of time shall have a relative error not greater than 10 % of the measured values.

Unless otherwise specified, the tests are performed at the reference temperature of 20 °C ± 5 °C and with no load.

The IC-CPD shall perform the tests of 9.7.3, 9.7.4, 9.7.5, 9.7.6, 9.7.7, 9.7.8, 9.7.9, 9.7.10, 9.7.11 and 9.7.12. Each test is made on one pole only, taken at random, with five measurements, unless otherwise specified.

For IC-CPDs having more than one rated frequency, the tests shall be carried out at the lowest and highest frequency.

9.7.3 Residual sinusoidal alternating currents tests

9.7.3.1 General

Each test is made at the following values of the line voltage applied to the relevant terminals: 1,1 times and 0,85 times the rated voltage.

The test circuit shall be of negligible inductance and shall be in accordance with Figure 2a), Figure 2b) or Figure 2c), as applicable.

9.7.3.2 Verification of the correct operation in case of a steady increase of the residual current

With test switch S1 in the closed position, S2 in the open position and S3 in position 1, the IC-CPD closing operation shall be initiated.

The test switch S2 is closed and the residual current is steadily increased, starting from a value not higher than 0,2 $I_{\Delta n}$, to try to attain the value of $I_{\Delta n}$ within 30 s. The tripping current is measured each time.

All five measured values shall be between $I_{\Delta no}$ and $I_{\Delta n}$.

Test is repeated with test switch S3 in position 2.

All five measured values shall be between $I_{\Delta no}$ and $I_{\Delta n}$.

9.7.3.3 Verification of the correct operation at closing on residual current

The test circuit is calibrated at each value of the residual current specified in Table 2. Test switch S2 being in the closed position, test switch S1 in the closed position and test switch S3 in position 1, the IC-CPD is closed on the circuit so as to simulate service conditions as closely as possible.

The IC-CPD may close but shall trip within the relevant specified time and not re-close.

The break-time is measured five times. No measurement shall exceed the relevant specified limiting value.

9.7.3.4 Verification of the correct operation in case of the sudden appearance of residual current

The test circuit is calibrated at each value of the residual current specified in Table 2. Test switches S1 being in the closed position, test switch S2 in the open position, test switch S3 in position 1 and the IC-CPD in the closed position, the residual current is suddenly established by closing the test switch S2.

The IC-CPD shall trip during each test. Five tests are made at each value of the residual current with measurement of break-time.

No value shall exceed the relevant specified limiting values.

9.7.3.5 Verification of correct operation in case of sudden appearance of residual currents between 5 A and 100 A

The test circuit is calibrated successively to the following values of residual current:

5 A, 10 A, 20 A, 50 A and 100 A.

The test switch S1 and the IC-CPD being in the closed position, the test switch S3 in position 1, the residual current is established by closing the test switch S2.

The IC-CPD shall trip during each test The break times shall not exceed the times given in Table 2.

The test is made on one pole only taken at random.

9.7.3.6 Verification of the correct operation with load at the reference temperature

The tests of 9.7.3.3 and 9.7.3.4 are repeated, the IC-CPD being loaded with rated current as in normal service for a sufficient time so as to reach steady-state conditions.

In practice, these conditions are reached when the variation of temperature rise does not exceed 1 K/h.

9.7.3.7 Tests at the temperature limits

The IC-CPD shall perform the tests specified in 9.7.3.4 under the following conditions, successively:

a) ambient temperature: –5 °C off-load;

b) ambient temperature: +45 °C, the IC-CPD having been previously loaded, with the rated current, at any convenient voltage, until it attains thermal steady-state conditions.

   In case footnote h, Table 5, applies, the test shall be performed at the maximum temperature of the plug.

In practice these conditions are reached when the variation of temperature rise does not exceed 1 K/h.

Preheating may be made at reduced voltage.

9.7.3.8 Verification of the correct operation at low ambient air temperatures of –25 °C

The IC-CPD, connected as for normal use, is brought into a suitable test chamber with an ambient air temperature of +23 °C ± 2 °C and a relative humidity of 93 % ± 3 %.

The volume ratio of the test chamber to the test samples (including enclosures) shall be greater than 50.

The IC-CPD is in the ON-position without load.

Five test cycles are performed (see Figure 27).

Within 6 h the ambient air temperature is reduced to −25 °C ± 2 °C without any supply of humidity and is kept at this value for 6 h. Within the next 6 h the temperature is increased to +23 °C ± 2 °C and the relative humidity is increased to 93 % ± 3 %.

These values are again kept for 6 h (end of first cycle).

This cycle is performed five times. During these cycles the IC-CPD shall not trip.

Prior to the end of the last 6 h period at −25 °C a residual current is passed through one pole of the IC-CPD.

The IC-CPD shall trip within 0,3 s

– at an alternating residual current of 1,25 $I_{\Delta n}$, and
– at a pulsating residual current (one-way rectification, α = 0°el) of 1,25 × 1,4 $I_{\Delta n}$ for

IC-CPDs with $I_{\Delta n}$ > 6 mA and by a factor 2 for IC-CPDs with $I_{\Delta n}$ = 6 mA.

9.7.4 Verification of the correct operation with residual currents having a d.c. component

9.7.4.1 General

The test conditions of 9.7.1 apply, except that the test circuits shall be those shown in Figures 10a), 10b), 10c), or in Figures 11a), 11b), 11c), as applicable.

9.7.4.2 Verification of the correct operation in case of a continuous rise of a residual pulsating direct current

The IC-CPD shall be tested according to Figures 10a), 10b) or 10c), as applicable.

The auxiliary switches S1 and S2 and the IC-CPD under test are in the closed position. The relevant thyristor shall be controlled in such a manner that current delay angles α of 0°, 90° and 135° are obtained. Each pole of the IC-CPD shall be tested twice at each of the current delay angles, twice in position I and twice in position II of the auxiliary switch S3.

At each test the current, starting from zero, shall be steadily increased within 30 s to

– 1,4 $I_{\Delta n}$ for IC-CPDs with $I_{\Delta n}$ > 6 mA;
– 2 $I_{\Delta n}$ for IC-CPDs with $I_{\Delta n}$ = 6 mA.

The tripping current shall be in accordance with Table 11.

Table 11 – Tripping current ranges for IC-CPDs in case of pulsating d.c. current

Angle α	Tripping current A	
	Lower limit (for all values of $I_{\Delta n}$)	Upper limit for all values of α
0°	For $I_{\Delta n} \leq$ 6 mA: 0,35 $I_{\Delta n}$ For $I_{\Delta n}$ > 6 mA: 4,5 mA	For $I_{\Delta n} \leq$ 6 mA: 2 $I_{\Delta n}$ [a] For $I_{\Delta n}$ > 6 mA: 1,4 $I_{\Delta n}$
90°	For $I_{\Delta n} \leq$ 6 mA: 0,25 $I_{\Delta n}$ For $I_{\Delta n}$ > 6 mA: 6,3 mA	
135°	0,11 $I_{\Delta n}$	

[a] In the USA, the value 30 mA is accepted for $I_{\Delta n}$ < 6 mA.

9.7.4.3 Verification of the correct operation in case of suddenly appearing residual pulsating direct currents with or without being superimposed by a smooth direct current

The following tests shall be performed to verify the correct operation in case of suddenly appearing residual pulsating direct currents

a) Test without superimposed smooth direct current

   The IC-CPD shall be tested according to Figures 10a), 10b), 10c), as applicable.

   The circuit is successively calibrated at the values of I_{Δ} given in Table 2 multiplied by

   – 1,4 $I_{\Delta n}$ for IC-CPDs with $I_{\Delta n} > 6$ mA;

   – 2 $I_{\Delta n}$ for IC-CPDs with $I_{\Delta n} = 6$ mA.

   Two measurements of the break time are made at each of those values at a current delay angle $\alpha = 0°$, with the auxiliary switch S_3 in position I for the first measurement and in position II for the second measurement.

   No value shall exceed the specified limiting values given in Table 2.

b) Test with superimposed smooth direct current of 6 mA

   After that, the IC-CPD shall be tested according to Figures 11a), 11b), 11c), as applicable.

   Two measurements of the break time are made at each of those values specified in 9.7.4.3a) at a current delay angle $\alpha = 0°$, superimposed by a smooth direct current of 6 mA, with the auxiliary switch S3 in position I for the first measurement and in position II for the second measurement.

   No value shall exceed the specified limiting values given in Table 2.

9.7.4.4 Verification at the reference temperature of the correct operation with load

The tests of 9.7.3.2 are repeated, the IC-CPD being loaded with the rated current, this current being established shortly before the test.

NOTE The loading with rated current is not shown in Figure 10.

9.7.5 Verification of behaviour in case of composite residual current

9.7.5.1 General

All tests shall be carried out with the IC-CPD supplied at U_e, with the rated frequency and without load.

Unless otherwise specified tests are made according to Figure 30.

9.7.5.2 Verification of the correct operation in case of a steady increase of composite residual current

Table 12 provides frequency component values for calibration purposes as well as the starting current values to verify the IC-CPD operation in case of a steady increased residual current.

Table 13 provides the limit operating values of the composite residual current.

The test frequency has a tolerance of ± 2 %.

Table 12 – Different frequency component values of test currents and starting current values (I_{Δ}) for verifying the operating in case of steady increased residual current

Different frequency component values of test currents for calibration (r.m.s)		Composite starting current value (r.m.s.)
$I_{\text{at rated frequency}}$	$I_{1\ \text{kHz}}$	I_{Δ}
0,141 $I_{\Delta n}$	0,141 $I_{\Delta n}$	0,2 $I_{\Delta n}$
NOTE 1 $I_{\Delta n}$ corresponds to the rated residual operating current of the device at the rated frequency. NOTE 2 For the test purposes the values of rated frequency and 1 kHz have been used for the output and clock frequency respectively representing the most severe condition.		

To verify the operation of the IC-CPD in the presence of composite currents, the starting composite residual current value given in Table 12 shall be increased at a linear rate. The IC-CPD shall trip within the limits of Table 13.

In any case the ratios of the different frequencies shall be maintained from the initial value up to the operating value.

Table 13 – Operating current ranges for composite residual current

Operating current (r.m.s.)	
Lower limit	Upper limit
0,5 $I_{\Delta n}$	1,4 $I_{\Delta n}$
NOTE 1 $I_{\Delta n}$ corresponds to the rated residual operating current of the device at the rated frequency. NOTE 2 Operating currents are composed of the ratio of frequency components given in Table 12.	

The test switches S1 and S2 and the IC-CPD being in the closed position, the residual current is steadily increased, starting from a value not higher than the starting composite value given in Table 12 trying to attain the upper limit of residual operating current given in Table 16 within 30 s.

The test is repeated three times through one pole chosen at random. Operating values shall be within the limits of Table 13.

9.7.5.3 Verification of the correct operation in case of the sudden appearance of composite residual current

Tests are carried out to verify the break time of the IC-CPD, the test current being calibrated at 5 times the upper limit value given in Table 13.

The test switch S1 and the IC-CPD being in the closed position, the residual current is suddenly established by closing the test switch S2.

Three measurements of the break time are made.

The break times shall be less than 0,04 s.

Each of the three applications of residual current shall be separated from the previous one by an interval of at least 1 min.

9.7.6 Verification of the correct operation in case of smooth d.c. residual current

The test shall be performed according to Figure 29.

a) The test switches S1 and S2 and the IC-CPD being in the closed position, the smooth d.c. residual current is steadily increased, starting from 0, trying to attain the value of 6 mA within 30 s, the tripping current being measured. If the device has not tripped before, the current is kept at the value of 6 mA for at least 10 s.

   One pole of the IC-CPD, chosen at random as shown in Figure 29, is tested twice at each position 1 and 2 of S3.

   The IC-CPD shall trip at a value between 3 mA and 6 mA.

b) A second series of tests is made to verify the break time.

   The test circuit being successively calibrated at each residual current value given in Table 3, the test switch S1 and the IC-CPD being in the closed position, the residual current is suddenly established by closing the test switch S2. The test switch S3 is in position 1 or 2 chosen at random.

   Two measurements of the break time are made on one pole chosen at random at each residual current.

   The break times shall be in compliance with the values given in Table 3.

9.7.7 Miswiring and supply failure tests

9.7.7.1 General

The verification of hazardous live protective conductor conditions only apply to IC-CPDs classified according to 4.4.2.

Each test is made at the following values of the line voltage applied to the relevant terminals: 1,1 times and 0,85 times the rated voltage.

The IC-CPD shall be connected in accordance with Tables 14 or 15 respectively and shall satisfy the characteristics of 5.1.

NOTE In the following countries: US, a switched equipment grounding conductor that extends to the vehicle connector is permissible provided the construction complies with the following:

a) the device is intended for use on a supply circuit not exceeding 150 V to ground;

b) a grounding monitor interrupter (GM/I) is provided integrally with the CCID;

c) the switching device in the equipment grounding conductor shall close before the line switching contacts when the output is energized;

d) the switching device in the equipment grounding conductor shall open after the line switching contacts when the output is deenergized; and

e) the construction shall comply with the tests for switched equipment grounding conductor tests.

Table 14 – Supply failure and hazardous live protective conductor (PE) connections for test with reference to correct supply connections for LNSE / LNE and LLSE / LLE types

Type LNSE / LNE			Type LLSE / LLE			Test clause and comments
IC-CPD input terminal connections						
L	N	PE	L_1	L_2	PE	Correct supply and terminal marking NOTE Types classified under 4.1.
L	N	PE	L_1	L_2	PE	Normal connection 9.7.2 See Figure 2a) LNSE / LNE types, Figure 2b) LLSE / LLE types
N	L	PE				Normal connection 9.7.2 See Figure 2a) LNSE and LNE types
L_1	L_2	PE	L	N	PE	Verification of correct operation in the case of LNSE / LNE and LLSE / LLE types plugged into not compatible supply system. See 9.7.7.4, Figure 3a) LLSE / LLE types, Figure 3b) LNSE / LNE types.
N	L	L	L_1	L_2	L_1	Hazardous live protective conductor (see 3.3.3.18), 9.7.7.2 Figure 4a) LNSE types, Figure 4b) LLSE types This test is considered to cover situations where a hazardous live protective conductor exists due to a miswired supply (only for IC-CPD classified to 4.4.2) See Annex D, Figure D.2, Example 2, LNSE types See Annex D, Figure D.1, Example 11, LLSE types
L	N	L	L_1	L_2	L_2	Hazardous live protective conductor (see 3.3.3.18), 9.7.7.2 Figure 4c) LNSE types, Figure 4d) LLSE types This test is considered to cover situations where a hazardous live protective conductor exists due to a miswired supply (only for IC-CPD classified to 4.4.2) See Annex D, Figure D.2, Example 10, LNSE types See Annex D, Figure D.1, Example 10, LLSE types
L	O	PE				Open neutral: see 9.7.7.3 See Figure 6a) See Annex D, Figure D.2, Example 3
			O L_1	L_2 O	PE PE	Open Line: see 9.7.7.3 See Figure 6b) See Annex D, Figure D.1, Example 3.
L	N	O	L_1	L_2	O	Open protective conductor see 9.7.7.5 (only for IC-CPD classified to 4.5.2) See Figure 12a) LNSE types, Figure 12b) LLSE types, See Annex D, Figure D.2, Example 4, LNSE types See Annex D, Figure D.1, Example 4, LLSE types
NOTE 1 For certain LLSE types a supply neutral terminal connection can be available. NOTE 2 The reversal of the supply neutral and protective conductor (R_x and $< U_e$ for TT systems (see Annex D, Figure D.2, Example 3)) is covered by the tests of 9.14.2.						

Table 15 – Supply failure and hazardous live protective conductor (PE) connections for test with reference to correct supply connections for LLLNSE / LLLNE types

Type LLLNSE / LLLNE					Test clause and comments
L_1	L_2	L_3	N	PE	Correct supply and terminal marking NOTE Types classified under 4.1.
L_1	L_2	L_3	N	PE	Normal connection 9.7.2 See Figure 2c) LLLNSE / LLLNE
L_1	L_2	L_3	N	PE	Verification of correct operation in the case of LLLNSE / LLLNE types plugged into an incompatible supply system. See 9.7.7.4, Figure 3c) and 3d) LLLNSE / LLLNE types.
N	L_2	L_3	L_1	L_1 L_2 L_3	Hazardous live protective conductor (see 3.3.3.18), 9.7.7.2 Figure 4h), Figure 4i), Figure 4j) LLLNSE types This test is considered to cover situations where a hazardous live protective conductor exists due to a miswired supply (only for IC-CPD classified to 4.4.2)
L_1	L_2	L_3	N	L_1 L_2 L_3	Hazardous live protective conductor (see 3.3.3.18), 9.7.7.2 Figure 4e), Figure 4f), Figure 4g) LLLNSE types This test is considered to cover situations where a hazardous live protective conductor exists due to a miswired supply (only for IC-CPD classified to 4.4.2)
L_1	L_2	L_3	O	PE	Open neutral: see 9.7.7.3 See Figure 6c)
L_1	L_2	L_3	N	O	Open PE: see 9.7.7.5 (only for IC-CPD classified to 4.5.2) See Figure 12c)

9.7.7.2 Verification of correct performance in the case of hazardous live protective conductor

Subclause 9.7.7.2 is only applicable for IC-CPDs classified according to 4.4.2.

The IC-CPDs shall comply if the following conditions are fulfilled:

– they do not close if the protective conductor is hazardous live, or
– if they do close they shall re-open in a time not exceeding 300 ms, either automatically, or when closed on the rated residual current flowing in any terminal which is live.

IC-CPDs shall be connected in turn as in Figures 4a) to 4j), as applicable.

With S1 in closed position, the IC-CPD initiating the closing shall be operated in each position.

If the contacts do not close, the unit complies.

If the contacts close then by use of S2, a further test is made with a resistor connected from the protective conductor load terminal to the supply protective conductor.

The resistor value shall be adjusted to produce rated residual current ($U_e/I_{\Delta n}$ for LNSE types, $U_e/I_{\Delta n}$ or $U_e/2$ divided by $I_{\Delta n}$ for LLSE dependant on the connection).

9.7.7.3 Verification of correct performance in case of open neutral (LNSE / LNE and LLLNSE / LLLNE) and open line (LLSE / LLE)

The required performance of IC-CPDs should take place under the following conditions:

- for LNSE / LNE types
  - do not close even momentarily if the neutral is open;
  - open within 1 s if closed and then the neutral is opened.
- for LLSE / LLE types
  - do not close even momentarily if one line is open;
  - open within 1 s if closed and then one line is opened.
- for LLLNSE / LLLNE types
  - do not close even momentarily if the neutral is open;
  - open within 1 s if closed and then the neutral is opened.

Depending on its classification, the correct operation of the IC-CPD in case of open neutral or open line shall be verified by the following tests

a) For IC-CPDs classified according to 4.1.2 (LNSE / LNE)

   The contacts shall not close even momentarily. The IC-CPD shall be connected as per Figure 6a).

   With S4 closed, S2 open, the IC-CPD initiating the closing shall be operated.

   The contacts shall not close with an open neutral.

b) For IC-CPDs classified according to 4.1.3 (LLSE / LLE)

   The contacts shall not close when either line of the supply is opened, even momentarily.

   The IC-CPD shall be connected as per Figure 6b).

   With S1 closed, S2 open, S3 closed, the IC-CPD initiate closing shall be operated.

   Repeat with S2 closed and S3 open.

   The contacts shall not close with an open line.

c) For IC-CPDs classified according to 4.1.4 (LLLNSE / LLLNE)

   The contacts shall not close even momentarily. The IC-CPD shall be connected as per Figure 6c).

   With S1 closed, S2 open, the IC-CPD initiating the closing shall be operated.

   The contacts shall not close with an open neutral.

d) For IC-CPDs classified according to 4.1.2 (LNSE / LNE)

   The contacts shall open when the supply neutral is opened.

   The IC-CPD shall be connected as per Figure 6a).

   With S1 closed, S2 closed, the IC-CPD shall be in the closed position; then open S2 (neutral).

e) For IC-CPDs classified according to 4.1.3 (LLSE / LLE)

   The contacts shall open when either line of the supply is opened.

   The IC-CPD shall be connected as per Figure 6b).

   With S1 closed, S2 closed, S3 closed, the IC-CPD shall be in the closed position; then open S2 (line 1).

f) For IC-CPDs classified according to 4.1.4 (LLLNSE / LLLNE)

   The contacts shall open when the supply neutral is opened.

   The IC-CPD shall be connected as per Figure 6c).

   With S4 closed, S2 closed, the IC-CPD shall be in closed position; then open S2 (neutral).

9.7.7.4 Behaviour in case of an IC-CPD connected to an incompatible supply system

In cases where the IC-CPD is not intended to operate on more than one of the supply systems (LNSE or LLSE), the IC-CPD shall protect against use on an incompatible supply system.

NOTE In the following countries an IC-CPD shall be able to function properly in both LNE and LLE configurations, provided the correct voltage is available: BE.

The contacts under the following test conditions shall not close.

IC-CPDs shall be connected as in Figures 3a), 3b), 3c) or Figure 3d), as applicable.

The IC-CPD shall be connected in accordance with Table 14 and shall satisfy the characteristics of 5.1.

9.7.7.5 Verification of correct performance in the case of an open protective conductor

These test are only applicable for IC-CPD classified according to 4.5.2.

IC-CPDs classified according to 4.1.2 (LNSE) shall be connected as in Figure 12a) where at supply S, the protective conductor is connected to the neutral (N) with a resistor of an impedance equal to 1 600 Ω.

IC-CPDs classified according to 4.1.3 (LLSE) shall be connected as in Figure 12b) where at supply S, the protective conductor is connected to L2 with a resistor of an impedance equal to 1 600 Ω.

IC-CPDs classified according to 4.1.4 (LLLNSE) shall be connected as in Figure 12c) where at supply S, the protective conductor is connected to the neutral (N) with a resistor of an impedance equal to 1 600 Ω.

With S1 closed, S2 open, the IC-CPD initiating the closing shall be operated.

The IC-CPD contacts shall not close, even momentarily.

9.7.8 Verification of protective conductor contact behaviour

9.7.8.1 Verification of protective conductor contact coupling when closing

The tests, by changing the pilot status from state B to state C, shall verify that the protective conductor does not close later than L or N contacts close. The tests are made at 0,85 times and 1,1 times of rated voltage.

9.7.8.2 Verification of protective conductor contact coupling when opening

The tests shall verify, by changing the pilot status from state C to state B, that the protective conductor does not open earlier than L and N open. The tests are made at 0,85 times and 1,1 times of rated voltage and when the supply voltage is slowly reduced down to 50 V a.c. The protective conductor contact function should be verified.

One sample of IC-CPD shall be prepared that will not open the L contact again after closing (thus simulating a welded L contact).

The test is performed as follows:

The contacts are activated by using the control pilot transition from B to C. The protective conductor contact shall be verified to be closed. The contacts are then initiated to open by the control function transition from C to B.

The result shall be that the L contact remains closed (simulated welded L contact) and that the protective conductor contact does not open.

9.7.9 Verification that the protective conductor is connected to the electric vehicle

The IC-CPD shall be installed as for normal use. The device under test is supplied by a power source, according to Figure 28, and is powered at 1,1 times the rated voltage. The following test procedure is applied.

a) The switch S2 being in closed position, the switch S1 is closed. The contacts of the IC-CPD shall close.

b) The switched S2 being in opened position, the switch S1 is closed. The contacts of the IC-CPD shall not close.

c) The switch S1 and S2 being in the closed position, the contacts of the IC-CPD shall be closed. If the switch S2 is suddenly opened, the contacts of the IC-CPD shall open in less than 0,1 s. After closing of S1, some time may elapse before closing of the IC-CPD.

Afterwards, the test is repeated but with the device being supplied at 0,85 U_e.

9.7.10 Verification of standing current in the protective conductor connection in normal service

IC-CPDs shall be connected as in Figure 7, as applicable.

A resistor (R_1) of 1 Ω ± 1 %, with an r.m.s. voltmeter connected across it, is connected between the supply protective conductor and the input protective conductor terminal of the IC-CPD.

A resistor (R) of 1 Ω ± 1 % is connected between the supply neutral and the input neutral terminal of the IC-CPD.

The applied voltage is 1,1 U_e.

The IC-CPD initiating the closing shall be operated and the voltage drop across the resistor R_1 measured.

The IC-CPD is opened and the voltage drop across the resistor measured.

The current in the protective conductor is calculated by use of the known resistance value and r.m.s. voltage measurement. The resultant r.m.s. protective conductor current value shall not exceed 1 mA r.m.s. at 1,1 U_e in the open and 1,5 mA r.m.s. in the closed positions.

9.7.11 Verification of the correct operation in case of residual direct currents which may result from rectifying circuits supplied from two phases

This test applies only for IC-CPDs operating on two-phase supply, according to 4.1.3.

a) The test shall be performed according to Figure 15.

   The test switches S1 and S2 and the IC-CPD being in the closed position, the residual pulsating direct current is steadily increased, starting from a value not higher than 2 mA, trying to attain the value of 7 mA within 30 s, the tripping current being measured.

   The test circuit is connected to the IC-CPD at two-line terminals chosen at random.

   The IC-CPD is tested five times at each positions I and II of S3.

   The IC-CPD shall trip within the limits of 3,5 mA to 7 mA.

b) A second series of tests is made to verify the break time.

The test circuit being successively calibrated at each current value given in Table 4, the test switch S1 and the IC-CPD being in the closed position, the residual current is suddenly established by closing the test switch S2.

With the IC-CPD connected at two-line terminals chosen at random, five measurements of the break time are made at each value of residual current given in Table 4 at each position I and II of S3.

The break times shall be in compliance with the values given in Table 4.

9.7.12 Verification of the correct operation in case of residual direct currents which may result from rectifying circuits supplied from three phases

This test applies only for IC-CPDs operating on three-phase supply (according to 4.1.4).

a) The test shall be performed according to Figure 16 (see below).

   The test switches S1 and S2 and the IC-CPD being in the closed position, the residual pulsating direct current is steadily increased, starting from a value not higher than 2 mA, trying to attain the value of 6,2 mA within 30 s, the tripping current being measured.

   The IC-CPD is tested five times at each positions I and II of S3.

   The IC-CPD shall trip within the limits of 3,1 mA to 6,2 mA.

b) A second series of tests is made to verify the break time.

   The test circuit being successively calibrated at each current value given in Table 4, the test switch S1 and the IC-CPD being in the closed position, the residual current is suddenly established by closing the test switch S2.

   Five measurements of the break time are made at each value of residual current given in Table 4 at each position I and II of S3.

   The break times shall be in compliance with the values given in Table 4 of this standard.

9.8 Verification of mechanical and electrical endurance

9.8.1 Endurance of plug and vehicle connector part

Plug and vehicle connector shall be tested in accordance with the relevant IEC standard or according to national standard.

9.8.2 Endurance of the residual current function of the IC-CPD

9.8.2.1 General

The IC-CPD is prepared according to 9.2. The test is made in a test circuit as shown in Figure 31.

Endurance tests are made at the rate of four operating cycles per minute, if the conditioning of the IC-CPD does not allow this, the test shall be made at the shortest possible time, given by the manufacturer. Switching of S2 shall not be synchronized with the phase angle of the supply. The ON period shall have a duration of 1,9 s to 2,1 s.

IC-CPDs are subjected to a total number of 10 000 operating cycles, each operating cycle consisting of a closing operation followed by an opening operation.

The test is made at rated operational voltage.

Calibration of the test circuit:

a) the current is recorded through the current sensor A;

b) when supplied at the test voltage the following adjustments are made;

1) calibration of inrush current (R3 and C1): The IC-CPD is replaced by a link BC having negligible impedance compared with that of the test circuit. S3 and S4 are in open position. R3 and C1 are adjusted so that after closing S1 at a phase angle of 90° the current through the current sensor reaches a peak value of 200 A ± 10 A with a rise time t_r (10 % to 90 % of the peak value) of maximum 20μs and declines to a value of 66 A ± 3 A at 30 μs + 20μs after the peak;
2) calibration of rated current (X1): With BC removed, S1, S2 and S3 in closed position and S4 in open position, X1 is adjusted so that the current through the current sensor equals the rated current. X1 consists of resistors and reactors in series (X1). If air-core reactors are used, a resistor taking approximately 0,6 % of the current through the reactors is connected in parallel with each reactor. If iron-core reactors are used, the iron-power losses of these reactors shall not appreciably influence the recovery voltage. The current shall have substantially sine-wave form and the power factor shall be at least 0,95;
3) calibration of pre-charge current (R2) if the rated current of the device is lower than 30 A: With the IC-CPD replaced by link BC, having negligible impedance compared with that of the test circuit and S1, S2, S3 and S4 in closed position, R2 is adjusted so that the current through the current sensor equals 30 A r.m.s. If the rated current of the device is higher than 30 A, R2 is replaced by an open circuit.

The inrush current consists of two superimposed components, both starting at the same time at the closing of the contactors in the IC-CPD:

– The resulting test current has a peak of maximum 230 A and corresponds to the Event 1 of ISO 17409:–, 8.8.2.
– This peak value decay to 30 A r.m,s. This (sinusoidal) current remains up to 1 s and corresponds to the Event 2 of ISO 17409:–, 8.8.2.

A principal wave shape is shown in Figure 33.

9.8.2.2 Test procedure for on-load test

The opening operations shall be effected as follows:

a) 1 000 operations are carried out by closing S4 and S3, applying the supply voltage to the IC-CPD by closing S1, closing S2, and opening S4 1 s ± 100 ms after closing of the main circuit by the IC-CPD. 2 s ± 100 ms after closing of the main circuit by the IC-CPD the opening operation is initiated by opening S2. After that the new operation cycle is started. After 1 000 operations have been carried out S1 shall be opened.
b) 1 500 operations are carried out by closing S4 and S3, applying the supply voltage to the IC-CPD by closing S1, closing S2, and opening S4 1 s ± 100 ms after closing of the main circuit by the IC-CPD. 2 s ± 100 ms after closing of the main circuit by the IC-CPD the opening operation is initiated by passing a residual operating current of $I_{\Delta n}$ through one pole (not shown in Figure 31). After that the new operation cycle is started.

During the tests of a) and b), it is considered that the protective conductor contact is also verified but without load.

9.8.2.3 Test procedure for making without breaking test

The remaining operating cycles between the required 10 000 operating cycles and the operating cycles are done by closing S4 and S3, applying the supply voltage to the IC-CPD by closing S1, and closing S2 1 s ± 100 ms after closing of the main circuit by the IC-CPD the switches S4 and S3 shall be opened. 2 s ± 100 ms after closing of the main circuit by the IC-CPD the opening operation is initiated by opening S2. After that the new operation cycle is started. After the full 10 000 operations have been carried out S1 shall be opened.

9.8.2.4 Condition of the IC-CPD after the tests

Following the tests of 9.8.2.2 and 9.8.2.3, the IC-CPD shall not show during inspection

– undue wear;
– damage of the enclosure permitting access to live parts by the standard gauge of Figure 9;
– loosening of electrical or mechanical connections;
– seepage of the sealing compound, if any.

Under the test condition of 9.7.3.4, the IC-CPD shall trip with a test current of 1,25 $I_{\Delta n}$. One test only shall be made with measurement of break time. The break time shall not exceed 0,3 s.

The IC-CPD shall then perform satisfactorily for the dielectric strength test specified in 9.5.3, but at a voltage equal to 900 V for 1 min and without previous humidity treatment.

9.9 Verification of the behaviour of the IC-CPD under overcurrent conditions

9.9.1 List of the overcurrent tests

The various tests to verify the behaviour of the IC-CPD under overcurrent conditions are shown in Table 16.

Table 16 – Tests to verify the behaviour of IC-CPDs under overcurrent conditions

Verification	Subclause
Rated making and breaking capacity I_m	9.9.2.2
Rated residual making and breaking capacity $I_{\Delta m}$	9.9.2.3
Coordination at 250 A and at the rated conditional short-circuit current I_{nc}	9.9.2.4 a)
Coordination at the rated making and breaking capacity I_m	9.9.2.4 b)
Coordination at 250 A and at the rated conditional residual short-circuit current $I_{\Delta c}$	9.9.2.4 c)
Making and breaking capacity of the plug and socket-outlet(s) separate or incorporated in integral items of the IC-CPD	9.9.3

9.9.2 Short-circuit tests

9.9.2.1 General conditions for test

The conditions of 9.9.2.1 are applicable to any test intended to verify the behaviour of the IC-CPD under short-circuit conditions.

a) Test circuit

Figure 8, as applicable, gives the diagrams of the circuit to be used for the tests.

The supply feeds a circuit including a resistor R, a reactor X, an SCPD, the IC-CPD under test and the additional resistors R_1, R_2, R_3 or R_4, as applicable.

The resistor R and reactor X are inserted between the supply source S and the IC-CPD under test.

The reactors X shall be air-cored. They shall always be connected in series with the resistor R, and their value shall be obtained by series coupling of individual reactors. Parallel connecting of reactors is possible if these reactors have practically the same time-constant.

Since the transient recovery voltage characteristics of test circuits including large air-cored reactors are not representative of normal service conditions, the air-cored reactor shall be shunted by a resistor R taking approximately 0,6 % of the current through the reactor, unless otherwise agreed between manufacturer and user.

The SCPD is inserted on the supply side of the IC-CPD under test.

The additional resistors R_2, R_3 and R_4, shall be inserted on the load side of the IC-CPD under test as shown in Figure 8.

IC-CPDs according to 4.2.2 and 4.2.3 shall be tested in the assembly as manufactured.

IC-CPDs according to 4.3.3 shall be fitted with cables at the discretion of manufacturer and test house.

The diagram of the test circuit shall be given in the test report. It shall be in accordance with the relevant Figure 8 of this standard.

There shall be one and only one point of the test circuit which is directly earthed. This may be the short-circuit link of the test circuit or the neutral point of the supply or any other convenient point. The method of earthing shall be stated in the test report.

For the purpose of verifying the minimum I^2t and I_p values to be withstood by the IC-CPD as given in Table 17, tests have to be performed. The SCPD, if any, shall be adjusted and shall be embodied either by a silver wire or by a fuse or by any other means. The manufacturer shall specify the type of SCPD to be used in the tests. The type of SCPD shall be mentioned in the test report.

For the purpose of this test, verification of the correctly selected and adjusted SCPD (I^2t and I_p) is made prior to testing, the IC-CPD being replaced by a temporary connection having a negligible impedance.

The minimum values of let-through energy I^2t and peak current I_p, based on an electrical angle of 45°, are given in Table 17.

Table 17 – Minimum values of I^2t and I_p

		I_n A			
I_{nc} and $I_{\Delta c}$ A		≤ 16	≤ 20	≤ 25	≤ 32
1 500	I_p (kA)	1,02	1,1	1,25	1,5
	I^2t (kA^{2}s)	2,5	3,0	3,6	6,0

At the request of the manufacturer higher values of I^2t and I_p may be used. The verification of the minimum I^2t and I_p values is not needed if the manufacturer has stated for the IC-CPDs values higher than the minimum ones in which case the stated values shall be verified.

All the conductive parts of the IC-CPD under test normally earthed in service, including the metal support on which the IC-CPD is mounted or placed or any metal enclosure (see 9.9.2.1 f)), shall be connected to the neutral point of the supply or to a substantially non-inductive artificial neutral permitting a prospective fault current of at least 100 A.

This connection shall include a copper wire F of 0,1 mm diameter and not less than 50 mm in length for the detection of the fault current and, if necessary, a resistor R_1.

Voltage sensors V shall record the supply voltage and the recovery voltage. Current sensor A shall record the test current.

Other sensors may be fitted to give indications of operation, for example voltage across the poles carrying test current or voltage from the L (or L_1) load terminal to neutral.

Unless otherwise stated in the test report, the resistance of the measuring circuits shall be at least 100 Ω /V of the power frequency recovery voltage.

b) Tolerances on test quantities

All the tests concerning the verification of rated making and breaking capacity and of the correct coordination between IC-CPD and SCPD shall be performed at values of influencing quantities and factors as stated by the manufacturer in accordance with Table 5 of this standard, unless otherwise specified.

The tests are considered as valid if the quantities as recorded in the test report are within the following tolerances for the specified values:

– current: $^{+5}_{0}$ %;

– frequency: ±5 %;

– power factor: $^{0}_{-0,05}$;

– voltage: ±5 % (including power frequency recovery voltage).

c) Power factor of the test circuit

The power factor of the test circuit shall be determined according to a recognized method which shall be stated in the test report.

Two examples are given in Annex G.

The power factor shall be between 0,93 and 0,98.

d) Power frequency recovery voltage

The value of the power frequency recovery voltage shall be equal to a value corresponding to 105 % of the rated voltage of the IC-CPD under test.

NOTE 1 The value of 105 % of the rated voltage is deemed to cover the effects of the variations of the system voltage under normal service conditions. The upper limit value can be increased with the approval of the manufacturer.

After each arc extinction, the power frequency recovery voltage shall be maintained for not less than 0,1 s.

e) Calibration of the test circuit

The current is recorded through the current sensor A.

When supplied at the test voltage, recorded by voltage sensor V, the following adjustments are made:

– R and X: The SCPD is replaced by link B_L and IC-CPD by links B_c having a negligible impedance compared with that of the test circuit. The load side connections of the IC-CPD under test are short-circuited by the link B_d of negligible impedance. The resistor R and the reactor X are adjusted so as to obtain a current equal to the rated conditional short-circuit current at the prescribed power factor.

– R_2, R_3, R_4: The SCPD is replaced by link B_L and IC-CPD by links B_c having a negligible impedance compared with that of the test circuit (B_d is removed).

  R_2: a residual current of 10 $I_{\Delta n}$ when S_1 is closed (for the residual current during the test of $I_{m)}$.

  R_3: the rated making and breaking current (for the test coordination of I_m, $I_{\Delta m}$ and $I_{m)}$ The value is the highest of 100 A or 10 I_n.

  R_4: 250 A current (for tests of I_{nc} and $I_{\Delta c}$).

f) Condition of the IC-CPD for test

In case the IC-CPD is fitted with an integral fuse the following applies:

– a first set of samples is tested with a linked fuse;

– a second set of samples is tested with the non-replaceable integral fuse.

The IC-CPD shall be assembled and connected according to the manufacturer's instructions and, as far as applicable, laid on a metal support in free air.

For the opening operation (O) only, a clear polyethylene sheet (0,05 ± 0,01) mm thick of a size of at least 50 mm larger in each direction than the overall dimensions of the front face of the device, but not less than 200 mm × 200 mm, is fixed and reasonably stretched in a frame, placed at a distance of 10 mm from

– either the maximum projection of the operating means of a device without recess for the operating means; or

– the rim of a recess for the operating means of a device with recess for the operating means.

The foil should have the following physical properties:

– density at 23 °C (0,92 ± 0,05) g/cm3;

– melting point 110 °C to 120 °C.

The control mechanism for the switching operations shall simulate as closely as possible the normal manual operation.

It shall be verified that the IC-CPD under test operates correctly on no-load when it is operated under the specified conditions.

g) Sequence of operations

The test procedure consists of a sequence of operations. The following symbols are used for defining the sequence of operations:

O represents an ‘open’ operation, with the IC-CPD in the closed position the short-circuit is established by closing the switch S_2;

t represents the time interval between two successive short-circuit operations which shall be 3 min or such longer time as may be required for resetting or renewing the SCPD, if any;

CO represents a ‘close – open’ operation: with the switch S_2 in the closed position the short-circuit is initiated by closing the IC-CPD. The opening is by operation of the IC-CPD or the SCPD (in the case of a SCPD, see 9.9.2.4).

NOTE 2 If the IC-CPD is of the type which automatically closes when the voltage is applied, the test switch S_3 is closed to initiate the ‘CO’ operation.

h) Behaviour of the IC-CPD during tests

During tests, the IC-CPD under test shall not endanger the operator.

Furthermore, there shall be no permanent arcing, no flashover between poles or between poles and exposed conductive parts, nor operation of the device F.

A non-replaceable integral fuse, if any, may operate during the test.

i) Condition of the IC-CPD after tests

The IC-CPD samples are considered as having passed the test if at least one of the following conditions are fulfilled:

– no damage impairing its further use, as follows:

  - the IC-CPDs shall be capable of satisfying the tests of 9.14;
  - the IC-CPD shall be capable, without maintenance of making and breaking its rated current at its rated voltage;
  - under the test conditions of 9.7.3.3, the IC-CPD shall trip at a test current of 1,25 $I_{\Delta n}$. One test only is made on one pole taken at random, without measurement of break-time;
  - for an IC-CPD according to 4.4.2 (SPE), opening of the PE contact shall be ensured.

– opening of the non-replaceable integral fuse within the phase(s) and / or neutral current path, if any, the control pilot signal shall disable the charging and the PE contact, if any, is in closed position,

– a fault is indicated by a visual or audible signal, the control pilot signal shall disable the charging and the PE contact, if any, is in closed position;

In addition the following conditions shall be fulfilled:

– there shall be no access to live parts which are normally not accessible in normal use, even if the standard test finger is applied with a force not exceeding 5 N;

– the polyethylene foil shall show no holes visible with normal or corrected vision without additional magnification;

– without maintenance the IC-CPD shall comply with the requirements of 9.5.3 but at a voltage equal to twice its rated voltage for 1 min and without previous humidity treatment;
– the continuity of the PE path with sufficient low impedance shall be maintained and checked by appropriate means.

9.9.2.2 Verification of the rated making and breaking capacity (I_m)

This test is intended to verify the ability of the IC-CPD to make, to carry for a specified time and to break short-circuit currents, while a residual current causes the IC-CPD to operate.

a) Test conditions

The IC-CPD is tested in a circuit according to the general test conditions prescribed in 9.9.2.1.

A link B_L is connected across the SCPD so that there is no external SCPD in the circuit.

R_2 is connected by closing S_1.

R_3 is connected to the switch S_2 line terminal. The switch S_2 load terminal is connected to the IC-CPD neutral load terminal of a type LNSE.

b) Test procedure

The following sequence of operation is performed:

CO – t – CO – t – CO

9.9.2.3 Verification of the rated residual short-circuit making and breaking capacity ($I_{\Delta m}$)

This test is intended to verify the ability of the IC-CPD to make, to carry for a specified time and to break residual short-circuit currents.

a) Test conditions

For unpoled plug and socket-outlet systems the test shall be performed at a random position of the plug inserted into the socket-outlet.

The IC-CPD is tested in a circuit according to the general test conditions prescribed in 9.9.2.

A link B_L is connected across the SCPD so that there is no external SCPD in the circuit.

S_1 is opened to disconnect R_2.

R_3 is connected to the switch S_2 line terminal. The switch S_2 load terminal is connected to the protective conductor load terminal.

b) Test procedure

The following sequence of operations is performed:

O – t – CO – t – CO

9.9.2.4 Verification of the coordination between the IC-CPD and the SCPD

These tests are intended to verify that the IC-CPD protected by the SCPD is able to withstand without damage short-circuit currents up to its rated conditional short-circuit current (see 5.3.9 and 5.3.10) and at its rated making and breaking rating.

The short-circuit current is interrupted by the association of the IC-CPD and the SCPD.

During the test either the IC-CPD or the SCPD or both may open. However, if only the IC-CPD opens, the test is also considered as satisfactory.

The SCPD is renewed or reset, as applicable, after each operation.

The following tests are made under the general conditions of 9.9.2.1 and as stated in a), b) or c) as appropriate.

For the 'O' operation, the closing of switch S_2 is synchronized with respect to the voltage wave so that the point of initiation is (45 ± 5)°.

a) Verification of the coordination at 250 A and at the rated conditional short-circuit current (I_{nc})

A test is made without establishing any residual current up to the rated conditional short-circuit current I_{nc}.

1) Test conditions

For unpoled plug and socket-outlet systems the test shall be performed at a random position of the plug inserted into the socket-outlet.

The link BL across the SCPD is opened so that the SCPD is in the test circuit.

R_2 is not connected and S_1 is open.

For the 250 A test, R_4 is connected to the switch S_2 line terminal. The switch S_2 load terminal is connected to the IC-CPD neutral load terminal of a type LNSE.

For the I_{nc} test the IC-CPD load terminal L_t is connected to the switch S_2 line terminal. The switch S_2 load terminal is connected to the IC-CPD neutral load terminal of a type LNSE.

2) Test procedure

The following sequence of operations is performed:

O – t – CO at 250 A,

O – t – CO at rated I_{nc} .

A new sample may be used for each test sequence.

b) Verification of the coordination at the rated making and breaking capacity (I_m)

A test is made, without establishing any residual current, at 100 A.

1) Test conditions

The link B_L across the SCPD is opened so that the SCPD is in the test circuit.

R_2 is not connected and S_1 is open.

R_3 is connected to the switch S_2 line terminal. The switch S_2 load terminal is connected to the IC-CPD neutral load terminal of a type LNSE.

2) Test procedure

The following sequence of operations is performed:

O – t – CO – t – CO.

c) Verification of the coordination at 250 A and at the rated conditional residual short-circuit current ($I_{\Delta c}$)

A test is made with a residual current up to the rated conditional short-circuit current $I_{\Delta c}$ through the IC-CPD protective conductor circuit.

1) Test conditions

The link B_L across the SCPD is opened so that the SCPD is in the test circuit.

R_2 is not connected and S_1 is open.

For the 250 A test R_4 is connected to the switch S_2 line terminal. The switch S_2 load terminal is connected to the IC-CPD protective conductor load terminal.

For the $I_{\Delta c}$ test the IC-CPD load terminal L_t is connected to the switch S_2 line terminal. The switch S_2 load terminal is connected to the IC-CPD protective conductor load terminal.

2) Test procedure

The following sequence of operations is performed:

O – t – CO at 250 A,

O – t – CO at rated $I_{\Delta c}$.

A new sample may be used for each test sequence.

9.9.3 Verification of the making and breaking capacity of the plug of the IC-CPD

Compliance is checked according to Clause 20 of IEC 60884-1:2002 and IEC 60884-1:2002/AMD2:2013.

9.10 Verification of resistance to mechanical shock and impact

9.10.1 General

IC-CPDs shall have adequate mechanical strength to withstand the stresses imposed during normal use.

Compliance of each integral item is checked by the appropriate tests in accordance with Table 18.

Table 18 – List of tests of resistance to mechanical shock and impact

Item to be tested	Test subclause
For devices classified under 4.3.2, 4.3.3, 4.3.4	9.10.2 and 9.10.4
For screwed glands of IC-CPDs	9.10.3

Compliance for plugs and connectors not incorporating the function box, is checked by the appropriate tests of the applicable product standard.

9.10.2 Drop test

The IC-CPD is prepared such as an assembly of the function box with less than 100 mm length of cable on each side, if applicable, for the test.

The drop test shall be performed according to IEC 60068-2-31 with the following parameters:

– number of devices: 3;
– number of falls per device: 2 in each axis x, y, z;
– drop height: 1 m;
– impact surface: concrete ground or steel plate;
– orientation: first fall of each device at a different dimensional axis, second fall with the given device at the same dimensional axis but on the opposite side of the housing;
– operation mode: not operating.

After completion of the above test the IC-CPD enclosure shall show no visible damage that would mitigate touch protection. The IC-CPD should then be powered up and successfully pass a self test.

NOTE 1 This test covers wrong handling of the user who can drop the device when carrying it.

NOTE 2 The test description is taken from 4.3.2 of ISO 16750-3:2012.

9.10.3 Test for screwed glands of IC-CPDs

Screwed glands are fitted with a cylindrical metal rod having a diameter equal to the nearest whole number, in millimetres, below the internal diameter of the packing.

The glands are then tightened by means of a suitable spanner, the torque shown in Table 19 being applied to the spanner for 1 min.

Table 19 – Torque applied to the spanner for the test

Diameter of test rod mm	Torque Nm	
	Metal glands	Glands or moulded material
Up to and including 14	6,25	3,75

After the test, the glands and the enclosures of the samples shall show no damage within the meaning of this standard.

9.10.4 Mechanical strength test on IC-CPDs provided with cords

Non-rewirable (according to 4.3.2) or pluggable IC-CPD (according to 4.3.4) samples are tested as delivered.

The IC-CPD is arranged with 2,25 m of flexible cord from the pivot point to the support point as shown in Figure 19.

The sample is held so that the cable or cord is horizontal and is then allowed to fall onto a concrete floor eight times (in various orientations).

After the test, the samples shall show no damage within the meaning of this standard. In particular, no part shall have become detached or loosened.

NOTE Small chips and dents which do not adversely affect the protection against electric shock are neglected.

If applicable, the IC-CPD shall operate when a residual current of 1,25 $I_{\Delta n}$ is applied to one pole chosen at random, no measurement of break-time being made.

After this test the protection against electric shock shall not be affected and the sample shall comply with the requirements of 9.4.

9.11 Test of resistance to heat

9.11.1 General

The tests are made according to 9.11.2, 9.11.3 and 9.11.4 as applicable.

The tests of 9.11.2 and 9.11.3 are not made on parts of ceramic material.

If two or more of the insulating parts referred to in 9.11.2 and 9.11.3 are made of the same material, the test is carried out only on any one of these parts, according to 9.11.2 or 9.11.3, as applicable.

9.11.2 Temperature test in heating cabinet

The samples, without removable covers, if any, are kept for 1 h in a heating cabinet at a temperature of (100 ± 2) °C.

Removable covers, if any, are kept for 1 h in the heating cabinet at a temperature of (70 ± 2) °C.

During the test, the samples shall not undergo any change impairing their further use, and the sealing compound, if any, shall not flow to such an extent that live parts are exposed.

After the test and after the samples have been allowed to cool down to approximately room temperature, there shall be no access to live parts which are normally not accessible in normal use, even if the standard test finger is applied with a force not exceeding 5 N.

Under the test condition of 9.7.3.3, the IC-CPD shall trip with a test current of 1,25 $I_{\Delta n}$. Only one test is made, on one pole taken at random, without measurement of break-time.

After the test, the marking shall still be legible.

NOTE Discoloration, blisters or a slight displacement of the sealing compound are disregarded, provided that safety is not impaired within the meaning of this standard.

9.11.3 Ball pressure test for insulating material necessary to retain in position current-carrying parts

Parts of IC-CPDs made of insulating material necessary to retain in position current-carrying parts or parts of the protective circuit, and parts retaining the terminals or terminations in position are subjected to a ball pressure test by means of the apparatus shown in Figure 14.

When it is not possible to carry out the test on the specimens, the test should be carried out on a piece at least 2 mm thick which is cut out of the specimen. If this is not possible, up to and including four layers, each cut out of the same specimen may be used, in which case the total thickness of the layers should be not less than 2,5 mm.

Parts of the front surface zone of thermoplastic material of 2 mm width surrounding the phase and neutral pins entry holes of socket-outlets are also to be subjected to this test.

The part under test shall be placed on a steel plate at least 3 mm thick and in direct contact with it.

The part is placed on the steel support with the appropriate surface to be tested in the horizontal position. A steel ball of 5 mm diameter is pressed against this surface with a force of 20 N.

The test load and the supporting means shall be placed within the heating cabinet for a sufficient time to ensure that they have attained the stabilized test temperature before the test commences.

The test is made in a heating cabinet at a temperature of (125 ± 2) °C.

After 1 h, the ball is removed from the sample which is then immersed 10 s in cold water to cool it to approximately room temperature.

The diameter of the impression caused by the ball is measured and shall not exceed 2 mm.

9.11.4 Ball pressure test for insulating material not necessary to retain in position current-carrying parts

External parts of IC-CPDs made of insulating material not necessary to retain in position current-carrying parts and parts of the protective circuit, even though they are in contact with them, are subjected to a ball pressure test in accordance with 9.11.3, but the test is made at a

temperature of (70 ± 2) °C or (45 ± 2) °C plus the highest temperature rise determined for the relevant part during the test of 9.6, whichever is the highest.

In case in Table 5 footnote h) applies, the test is made at a temperature of (70 ± 2) °C or (40 ± 2) °C plus the highest temperature rise determined for the relevant part during the test of 9.6, whichever is the highest.

9.12 Resistance of insulating material to abnormal heat and to fire

The glow-wire test is performed according to IEC 60695-2-10 and IEC 60695-2-11 under the following conditions:

– for parts of insulating material necessary to retain in position current-carrying parts and parts of the protective circuit, by the test made at a temperature of 750 °C ± 15 °C;
– for all other parts made of insulating material, by the test made at a temperature of 650 °C ± 10 °C.

If the tests specified have to be made at more than one place on the same sample, care shall be taken to ensure that any deterioration caused by previous tests does not affect the result of the test to be made.

Small parts, such as washers, are not subjected to the test of 9.12.

The tests are not made on parts of ceramic material.

If possible, the sample should be a complete IC-CPD.

If the test cannot be made on a complete IC-CPD, a suitable part may be cut from it for the purpose of the test.

The test is made on one sample.

In case of doubt, the test shall be repeated on two further samples.

The test is made by applying the glow-wire once.

The sample shall be positioned during the test in the most unfavourable position of its intended use (with the surface tested in a vertical position).

The tip of the glow-wire shall be applied to the specified surface of the sample taking into account the conditions of the intended use under which a heated or glowing element may come into contact with the sample.

The sample is considered as having passed the glow-wire test if one of the following conditions is met:

– there is no visible flame and no sustained glowing;
– flames and glowing at the sample extinguish within 30 s after the removal of the glow-wire.

There shall be no ignition of the tissue paper or scorching of the board.

9.13 Verification of the self test

Each IC-CPD is initially supplied at rated voltage as for normal use.

During the self test procedure it shall be verified that the protective conductor on the supply side does not become live and the contacts to the load side shall not be closed.

The IC-CPD shall be caused to trip under the conditions of 9.7.3.4 with a residual current of $I_{\Delta n}$. It shall not be possible to reclose the IC-CPD without performing a self test.

Before each starting of the charging process, the IC-CPD shall be tested by an automatic initiated self test.

The correct operation of the IC-CPD shall result in starting the charging of the EV.

An IC-CPD sample shall be prepared by shorting the line and neutral contacts. In case of non-mechanically coupled contacts, another one is prepared with only one contact shorted, chosen at random. For the test this current path is connected to the line.

The IC-CPD is then supplied at its rated voltage. The charging process shall be initiated.

The result shall be that the fault is indicated by a visual or audible signal, the control pilot signal shall disable the charging and the protective conductor contact, if any, is in closed position.

9.14 Verification of the behaviour of IC-CPDs in case of loss of the supply voltage

9.14.1 Verification of correct operation at the minimum operating voltage (U_x)

A voltage equal to U_e is applied to any two current paths of the IC-CPD chosen at random and the voltage is gradually reduced to U_x and then progressively lowered at a rate of approximately 5 V/s until automatic opening occurs.

The opening voltage is measured.

Five measurements are made on each sample.

All the opening voltage values measured shall not exceed 0,85 times the minimum rated voltage and be higher than U_x, if applicable.

At the end of these measurements the voltage is set to U_e and then the voltage is reduced to a value 5% above the maximum measured opening voltage. Under this condition it shall be verified that the IC-CPD operates in accordance with Table 2 at $I_{\Delta n}$.

If any of the measured opening voltages is greater than 85 V the above test in accordance with Table 2 at $I_{\Delta n}$ is repeated at a supply voltage just above the lowest measured opening voltage.

9.14.2 Verification of the automatic opening in case of loss of the supply voltage

The IC-CPD is supplied on the line side with the rated voltage (or, if relevant, with a voltage having a value within its range of rated voltages) and is closed.

The line voltage is then switched off.

The time interval between the switching off and the opening of the main contacts is measured.

Five measurements are made.

The opening time for the IC-CPD shall be less than or equal to 1 s.

9.14.3 Verification of the reclosing function

The IC-CPD is in open position due to automatic opening. A slowly rising supply voltage is applied so as to obtain the rated voltage or, in the case of a range of rated voltages, the lowest rated voltage starting from zero within 30 s. The IC-CPD shall reinitiate the charging process before or at the latest when the voltage reaches 0,85 times the rated voltage. The increase of the voltage shall be stopped at the moment of automatic reclosing of the IC-CPD.

At that voltage or 85 V, whichever is the highest, it shall be verified that the IC-CPD operates in accordance with Table 2 at $I_{\Delta n}$. The supply voltage is removed and then re-applied after 30 s and the IC-CPD shall not reclose automatically as long as there was no manual reset.

9.15 Verification of the limiting values of the non-operating current under overcurrent conditions

The IC-CPD is connected as for normal use with a substantially non-inductive load corresponding to a current equal to 4 I_n.

IC-CPDs are supplied on the line side with the rated voltage (or, if relevant, with a voltage having any value within its range of rated voltages).

The load is switched on by a two-pole test switch and then switched off after 1 s.

The IC-CPD shall not open.

The test is repeated three times, the interval between two successive closing operations being at least 1 min.

If relevant, an integral fuse may be replaced by a link.

9.16 Verification of resistance against unwanted tripping due to surge currents to earth resulting from impulse voltages

The IC-CPD is tested using a surge generator capable of delivering a damped oscillatory current as shown in Figure 23. An example of circuit diagram for the test of the IC-CPD is shown in Figure 24. One pole of the IC-CPD, chosen at random, is submitted to 10 applications of the surge current. The polarity of the surge current wave shall be inverted after every two applications. The interval between two consecutive applications shall be about 30 s.

The current impulse shall be measured by appropriate means and adjusted using an additional sample of an IC-CPD of the same type to meet the following requirements:

– peak value: 25 A $^{+10}_{0}$ %;
– virtual front time: 0,5 μs ± 30 %;
– period of the following oscillatory wave: 10 μs ± 20 %;
– each successive peak: about 60 % of the preceding peak.

During the tests, the IC-CPD shall not trip.

9.17 Verification of reliability

9.17.1 Climatic test

9.17.1.1 General

The test is based on IEC 60068-3-4 taking into account the tests of IEC 60068-2-30.

9.17.1.2 Test chamber

The chamber shall be constructed as stated in IEC 60068-3-4. Condensed water shall be continuously drained from the chamber and shall not be used again until it has been purified. Only distilled water shall be used for the maintenance of chamber humidity.

Before entering the chamber, the distilled water shall have a resistivity of not less than 500 Ωm and a pH value of 7,0 ± 0,2. During and after the test the resistivity should be not less than 100 Ωm and the pH value should remain within 7,0 ± 1,0.

9.17.1.3 Severity

The cycles are effected under the following conditions:

– upper temperature: (55 ± 2) °C;
– number of cycles: 28.

9.17.1.4 Testing procedure

The test procedure shall be in accordance with IEC 60068-3-4 and IEC 60068-2-30.

a) Initial verification

An initial verification is made by submitting the IC-CPD to the test according to 9.7.3.4, but only at $I_{\Delta n}$.

b) Conditioning

1) The IC-CPD connected as for normal use is introduced into the chamber.

It shall be in the closed position. IC-CPDs shall be supplied at rated voltage or, in the case of more than one rated voltage, at any one rated voltage.

2) Stabilizing period (see Figure 20).

The temperature of the IC-CPD shall be stabilized at (25 ± 3) °C:

– either by placing the IC-CPD in a separate chamber before introducing it into the test chamber, or
– by adjusting the temperature of the test chamber to (25 ± 3) °C after the introduction of the IC-CPD and by maintaining it at this level until temperature stability is attained.

During the stabilization of temperature by either method, the relative humidity shall be within the limits prescribed for standard atmospheric conditions for testing (see Table 5).

During the final hour, with the IC-CPD in the test chamber, the relative humidity shall be increased to not less than 95 % at an ambient temperature of (25 ± 3) °C.

3) Description of the 24 h cycle (see Figure 21).

i) The temperature of the chamber shall be progressively raised to the appropriate upper temperature prescribed in 9.17.1.3. The upper temperature shall be achieved in a period of 3 h ± 30 min and at a rate within the limits defined by the shaded area of Figure 21. During this period, the relative humidity shall be not less than 95 %. Condensation shall occur on the IC-CPD during this period.

NOTE The condition that condensation occurs implies that the surface temperature of the IC-CPD is below the dew point of the atmosphere. This means that the relative humidity is higher than 95 %, if the thermal time-constant is low. Care is taken so that no drops of condensed water can fall on the sample.

ii) The temperature shall then be maintained at a substantially constant value, within the prescribed limits of ±2 °C for the upper temperature, for 12 h ± 30 min from the beginning of the cycle.

During this period the relative humidity shall be (93 ± 3) %, except for the first and the last 15 min when it shall be between 90 % and 100 %.

Condensation shall not occur on the IC-CPD during the last period of 15 min.

iii) The temperature shall then fall to (25 ± 3) °C within 3 h to 6 h. The rate of fall for the first 1 h 30 min shall be such that, if maintained as indicated in Figure 20, it would result in a temperature of (25 ± 3) °C being attained in 3 h ± 15 min. During the temperature fall period, the relative humidity shall be not less than 95 %, except for the first 15 min when it shall be not less than 90 %.

iv) The temperature shall then be maintained at (25 ± 3) °C with a relative humidity not less than 95 %, until the 24 h cycle is completed.

9.17.1.5 Recovery

At the end of the cycles, the IC-CPD shall not be removed from the test chamber.

The door of the test chamber shall be opened and the temperature and humidity regulation is stopped.

A period of 4 h to 6 h shall then elapse to permit the ambient conditions (temperature and humidity) to be re-established before making the final measurement.

During the 28 cycles, the IC-CPD shall not trip.

9.17.1.6 Final verification

Under the conditions of the tests specified in 9.7.3.4, the IC-CPD shall trip with a test current of 1,25 $I_{\Delta n}$ and shall not trip with a current of $I_{\Delta no}$. One test only is made on one pole taken at random, without measurement of break-time.

9.17.2 Test at a temperature of 45 °C

The IC-CPD is placed as for normal use on a dull black painted plywood support, about 20 mm thick.

IC-CPDs are tested as supplied by the manufacturer.

The assembly is placed in a heating cabinet.

Non-rewirable IC-CPDs are tested as delivered.

The IC-CPD is loaded with a current equal to the rated current at any convenient voltage and is subjected, at a temperature of (45 ± 2) °C, to 28 cycles, each cycle comprising 21 h with current passing and thereafter 3 h without current. The current is interrupted by an auxiliary switch, the IC-CPD not being operated.

In case in Table 5 footnote h) applies, the test shall be performed at the maximum temperature of the plug.

IC-CPDs are supplied at the rated voltage or, in the case of more rated voltages, at any one rated voltage. At the end of the last period of 21 h with current passing, the temperature rise of the terminals is determined by means of fine wire thermocouples. This temperature rise shall not exceed 50 K.

After this test the IC-CPD is allowed to cool down in the cabinet to approximately room temperature without current passing.

Under the conditions of tests specified in 9.7.3.4, the IC-CPD shall trip with a test current of 1,25 $I_{\Delta n}$. One test only is made on one pole taken at random without measurement of break-time.

9.18 Resistance to ageing

The IC-CPD and its electronic components, if any, shall comply with the two following tests, as relevant.

a) Resistance to ageing

Parts intended for decorative purposes only, such as certain lids, are to be removed before the test.

IC-CPDs are tested after having been mounted and assembled as for normal use, in a heating cabinet with an atmosphere having the composition and pressure of the ambient air and ventilated by natural circulation.

The temperature in the cabinet shall be (70 ± 2) °C.

The samples are kept in the cabinet for 7 days (168 h).

The use of an electrically heated cabinet is recommended.

Natural circulation may be provided by holes in the walls of the cabinet.

After the treatment the samples are removed from the cabinet and kept at room temperature and relative humidity between 45 % and 55 % for at least 4 days (96 h).

The samples shall show no crack visible with normal or corrected vision without additional magnification, nor shall the material have become sticky or greasy, this being judged as follows.

With the forefinger wrapped in a dry piece of rough cloth, the sample is pressed with a force of 5 N. No traces of the cloth shall remain on the sample and the material of the sample shall not stick to the cloth.

After the test, the samples shall show no damage which would lead to non-compliance with this standard.

The force of 5 N can be obtained in the following way.

The samples are placed on one of the pans of a balance and the other pan is loaded with a mass equal to the mass of the sample plus 500 g.

Equilibrium is then restored by pressing the sample with the forefinger wrapped in a dry piece of rough cloth.

b) Ageing of electronic components

The IC-CPD is placed in an ambient temperature of (45 ± 2) °C and loaded with the rated current for a period of 168 h. The voltage on the electronic parts shall be 1,1 times the voltage corresponding to the rated voltage of the IC-CPD or in case of more than one rated voltage, at the voltage corresponding to the highest rated voltage. After this test, the IC-CPD in the cabinet is allowed to cool down to approximately room temperature without current passing.

In case in Table 5 footnote h) applies, the test shall be performed at the maximum temperature of the plug.

Under the test conditions specified in 9.7.3.4, the IC-CPD shall trip at a test current of 1,25 $I_{\Delta n}$ and shall not trip with a current of $I_{\Delta no}$. One test only is made on one pole taken at random without measurement of break-time.

NOTE An example of a test circuit for this verification is given in Figure 22.

9.19 Resistance to tracking

Ceramic materials and materials having a comparative tracking index (CTI) higher than 400 are not tested.

For other materials, compliance is checked by the test of IEC 60112 with the following parameters:

– *a flat surface of the part to be tested, if possible at least 15 mm × 15 mm, is placed in the horizontal position;*
– *the material under test shall show a proof-tracking index of 175 V using test solution A with the interval between drops of 30 s ± 5 s;*
– *no burning, no flashover or breakdown between electrodes shall occur before a total of 50 drops has fallen.*

NOTE 1 Care is taken that the electrodes are clean, correctly shaped and correctly positioned before each test is started.

NOTE 2 In case of doubt, the test is repeated, if applicable, on a new set of samples.

9.20 Test on pins provided with insulating sleeves

Compliance of pins of IC-CPDs is checked according to Clause 30 of IEC 60884-1:2002, IEC 60884-1:2002/AMD1:2006 and IEC 60884-1:2002/AMD2:2013.

9.21 Test of mechanical strength of non-solid pins of plugs

Compliance is checked according to IEC 60884-1:2002, 14.2.

9.22 Verification of the effects of strain on the conductors

The flexible cable or cord is connected to the IC-CPD in such a way that the current-carrying conductors are led from the strain relief to the corresponding terminals along the shortest possible path.

After they are connected, the core of the earthing conductor is led to its terminal and cut off at a distance 8 mm longer than necessary for its correct connection.

The earthing conductor is then connected to the terminal as well. It shall then be possible to house the loop, which is formed by the earthing conductor owing to its surplus length, freely in the wiring space without squeezing or pressing the core when the shell or cap of the IC-CPD is remounted and fixed correctly

9.23 Checking of the torque exerted by IC-CPDs on fixed socket-outlets

NOTE In the following countries this test is not required: JP.

The IP-CPD is wired as manufactured or intended for normal use and fitted with a relevant plug.

The equipment is inserted into a fixed socket-outlet complying with the relevant standard at a height of 1,5 m, the socket-outlet being pivoted about a horizontal axis through the axis of the live socket-outlet contacts at a distance of 8 mm behind the engagement face of the socket-outlet and parallel to this engagement face.

The torque exerted by the plug and the cable on a socket-outlet when installed such that the engagement face is vertical shall not exceed 0,25 Nm, if relevant for the plug and socket-outlet system.

During the test care should be taken that the flexible cable of the IC-CPD hang freely.

9.24 Tests of the cord anchorage

The effectiveness of the retention is checked by the following test by means of an apparatus as shown in Figure 17.

The function box of IC-CPDs according to 4.3.2 and 4.3.3 is tested as delivered.

The sample is placed in the test apparatus so that the axis of the cable or cord is vertical where it enters the sample.

The cable or cord is then subjected 100 times to a pull of

– 60 N for 6 A < I_n ≤ 16 A and U_e ≤250 V;
– 80 N for 6 A < I_n ≤ 16 A and U_e >250 V;
– 100 N for I_n > 16 A.

The pulls are applied each time for 1 s without jerks.

Care should be taken to exert the same pull simultaneously on all parts (core, insulation and sheath) of the flexible cable or cord.

Immediately afterwards, the cable or cord is subjected for 1 min to a torque of 0,25 Nm.

After the tests, the cable or cord shall not have been displaced by more than 2 mm with the cable subjected to the test pull. For rewirable accessories by the manufacturer, the end of the conductors shall not have moved noticeably in the terminals. For non-rewirable accessories, there shall be no break in the electrical connections.

For the measurement of the longitudinal displacement, a mark is made on the cable or cord while it is subjected to the pull, at a distance of approximately 2 cm from the end of the sample or the cord guard, before starting the tests. If, for non-rewirable accessories, there is no definite end to the cord-connected part of the IC-CPD an additional mark is made on the body of this part.

9.25 Flexing test of non-rewirable IC-CPDs

A flexing test is made by means of an apparatus as shown in Figure 18.

The sample is fixed to the oscillating member of the apparatus so that, when this is at the middle of its travel, the axis of the flexible cable or cord, where it enters the sample, is vertical and passes through the axis of oscillation.

Samples with flat cords are mounted so that the major axis of the section is parallel to the axis of oscillation.

The sample shall be fixed in the test apparatus in an appropriate way.

The IC-CPD is so positioned, by variation of the distance between the fixing part of the oscillating member and the axis of oscillation, that the cord makes the minimum lateral movement when the oscillating member of the test apparatus is moved over its full travel.

In order to have the possibility of finding easily by experiment the mounting position with the minimum lateral movement of the cord during the test, the flexing apparatus should be built in such a way that the different supports for the accessories mounted on the oscillating member can be readily adjusted.

It is recommended that the test apparatus has provisions (e.g. a slot or a pin) making it possible to see whether the cord makes the minimum lateral movement.

The cable or cord is loaded with a mass such that the force applied is

– 20 N for IC-CPDs with cables or cords having a nominal cross-sectional area not exceeding 2,5 mm^2;

– 25 N for IC-CPDs with cables or cords having a nominal cross-sectional area exceeding 2,5 mm^2, but not exceeding 6 mm^2.

A current equal to the rated current of the IC-CPD or to the following current, whichever is the lowest, is passed through the conductors:

– 16 A for IC-CPDs with cables or cords having a nominal cross-sectional area exceeding 1,5 mm^2;
– 10 A for IC-CPDs with cords having a nominal cross-sectional area of 1,5 mm^2.

The voltage between the conductors shall be the rated voltage of the IC-CPD or, in the case of more than one rated voltage, the highest rated voltage.

The oscillating member is moved through an angle of 90° (45° on either side of the vertical*)*. The number of flexing operations is 10 000 at the rate of 60 per minute.

NOTE 1 A flexing operation is one movement, either backwards or forwards.

Samples with circular section cables or cords are turned through 90° in the oscillating member after 5 000 flexing operations. Samples with flat cords are only bent in a direction perpendicular to the plane containing the axes of the conductors.

During the flexing test, there shall be

– no interruption of the current;
– no short-circuit between conductors.

NOTE 2 A short-circuit between the conductors of the flexible cable or cords is considered to occur if the current attains a value equal to twice the test current of the IC-CPD.

The voltage drop between each contact and the corresponding conductor loaded with the test current shall not increase by more than 10 mV.

After the test the guard, if any, shall not have become separated from the body and the insulation of the flexible cable or cord shall show no sign of abrasion or wear. Broken strands of the conductor shall not have pierced the insulation so as to become accessible.

NOTE 3 The revision of this test is under consideration.

9.26 Verification of the electromagnetic compatibility (EMC)

EMC tests shall be performed according to IEC 61543 as follows:

– Tests listed in Table 20 are covered and need not to be repeated:

Table 20 – Tests already covered for EMC by this standard

Reference to Tables 4 and 5 of IEC 61543:1995, IEC 61543:1995/AMD1:2004 and IEC 61543:1995/AMD2:2005	Electromagnetic phenomena	Tests of IEC 62752
T 1.3	Voltage amplitude variations	9.7 and 9.14
T 1.4	Voltage unbalance	9.7 and 9.14
T 1.5	Power frequency variations	9.2
T 1.8	Magnetic fields	9.9 and 9.15
T 2.4	Current oscillatory transients	9.16

The remaining tests in Tables 4, 5 and 6 of IEC 61543:1995, IEC 61543:1995/AMD1:2004 and IEC 61543:1995/AMD2:2005 shall be done according to the test sequences H, I and J listed in Annex A of this standard.

For devices containing a continuously operating oscillator, the test of the CISPR 14 series shall be carried out on the samples prior to the tests of IEC 61543.

NOTE The on-going work in TC 69 will be considered for a future amendment.

9.27 Tests replacing verifications of creepage distances and clearances

9.27.1 General

The following tests replace verifications of creepage distances and clearances for electronic circuits connected between active conductors (phases and neutral) and/or between active conductors and the earth circuit when the contacts are in the closed position.

IC-CPDs shall not create fire and/or shock hazards under abnormal conditions likely to occur in service.

The conditions under which a component is used within an IC-CPD shall be in accordance with the operating characteristics marked on the component and/or given in the data provided by the manufacturer.

9.27.2 Abnormal conditions

When IC-CPDs are exposed to abnormal conditions, no part shall reach temperatures likely to cause danger of fire to the surroundings of the IC-CPDs and no live parts shall become accessible.

Compliance is checked by subjecting the IC-CPDs to a heating test under fault conditions as described in 9.27.3 and to a verification of protection against electric shock as prescribed in 9.4.

9.27.3 Temperature rise resulting from fault conditions

Unless otherwise specified, the tests are made on IC-CPDs while they are mounted, connected and loaded as specified in 9.6.

Examination of the IC-CPD and its circuit diagram shows the fault conditions which shall be applied.

Generally, one separate sample is submitted for each fault condition to be tested.

Each of the following fault conditions a) to e) shall be applied in turn. Only one test is carried out for each of the following fault conditions.

a) Short-circuit across clearances and creepage distances, if smaller than those given by curve A of Figure 25 with the following exception:

   In the requirements for clearances and creepage distances between conductors (one of which may be connected to one pole of the supply mains), which are on a printed board complying with the pull-off and peel strength requirements specified in the IEC 61249-2 series, the values given by Figure 25 are replaced by the values calculated from the following formula:

$$\log d = 0{,}78 \log \frac{V}{300} \text{ with a minimum of } 0{,}2 \text{ mm}$$

   where

   d is the distance in mm;

   V is the peak value of the voltage in V.

   NOTE 1 These distances can be determined by reference to Figure 26.

NOTE 2 The above reduced values apply to the conductors themselves, but not to mounted components or associated soldered connections. A lacquer coating or the like on printed boards is ignored when calculating the distances.

Clearances and creepage distances complying with the requirements of Table 7 and printed boards with type 2 coating complying with IEC 60664-3 are excluded from this test.

b) Short-circuit across insulation consisting of lacquer or enamel coatings

c) Short-circuit or interruption of semiconductors

For integrated circuits and other semiconductor devices with more than two terminals the number of tests implied make it impracticable to apply the open-circuiting and/or shorting of all combinations of terminals. In this case, it is permissible first to analyse in detail, by a desk study, all the possible mechanical, thermal and electrical faults which may develop in the IC-CPD due to the malfunction of the electronic device or other circuit components. Only the combinations corresponding to faults that, on the basis of this analysis, are considered to be likely to cause the non-compliance of the IC-CPD with the requirements of the last two paragraphs of 9.27.3 have to be investigated by this method.

d) Short-circuit of electrolytic capacitors

e) Short-circuit or disconnection of resistors, inductors or capacitors

NOTE 4 Condition e) need not be applied if these components comply with the requirements of 9.28.

The temperatures resulting from the fault conditions are measured for the parts mentioned in Table 21 after steady state has been reached or after 4 h (whichever is the shorter time) under each of the fault conditions a) to e).

These temperatures shall not exceed the values given in Table 21 in the tests b) and c). They may exceed those values in the test a).

After the tests a) to e) the IC-CPDs may no longer be capable of meeting all their performance requirements, but they shall comply with the requirements of protection against electric shock according to 9.4.

9.28 Verifications for single electronic components used in IC-CPDs

9.28.1 General

The following verifications shall be performed for capacitors and specific resistors and inductors used in electronic circuits connected between active conductors (phases and neutral) and/or between active conductors and the earth circuit when the contacts are in the closed position.

9.28.2 Capacitors

Capacitors shall comply with the requirements of the IEC 60384-14 series.

The relevant types are

– X_1 or X_2 when relating to interference;

– Y_1 or Y_2 when relating to shock hazard.

These capacitors shall be marked with their rated voltage in V, their rated capacitance in µF and their reference temperature in °C, or the manufacturer may provide data sheets.

9.28.3 Resistors and inductors

Resistors and inductors, whose short-circuiting or disconnection is likely to cause unsatisfactory results in the tests of 9.27, shall comply with the relevant safety requirements of IEC 60065. Tests already carried out on resistors and inductors complying with IEC 60065 are not required to be repeated.

Table 21 – Maximum permissible temperatures under abnormal conditions

Parts of the IC-CPD	Maximum permissible temperature under specific abnormal conditions °C
Accessible parts	
Knobs, handles, accessible surfaces, enclosures, if:	
– metallic	100
– non-metallic[a]	100
Internal surfaces of insulating enclosures	135[b]
Supply cords and wiring insulation with [c, f]:	
– polyvinyl chloride or synthetic rubber	135
– natural rubber	
Other insulations[c]:	
– thermoplastic materials[d]	[e]
– non-impregnated paper	105
– non-impregnated cardboard	115
– impregnated cotton, silk, paper and textile	125
– laminates based on cellulose or textile, bonded with	
• phenol-formaldehyde, melamine-formaldehyde, phenol-furfural or polyester	145
• epoxy	185
– mouldings of	
• phenol-formaldehyde, or phenol-furfural, melamine and melamine phenolic compounds with	
– cellulose fillers	165
– mineral fillers	185
• thermosetting polyester with mineral fillers	185
• alkyd with mineral fillers	185
– composite materials of:	
• polyester with fibre glass reinforcement	185
• epoxy with fibre glass reinforcement	185
– silicone rubber	225
Parts of thermoplastic materials[d] acting as support or as a mechanical barrier	[e]
Winding wires insulated with[c, f]	
• non-impregnated silk cotton, etc.	110
• impregnated silk cotton, etc.	135
• oleoresinous materials	170
• polyvinyl-formaldehyde or polyurethane resins	185
• polyester resins	190
• polyesterimid resins	215
Core laminations	As for the relevant windings
Terminals and parts which may come into contact with cable insulation when installed	135

a	If this temperature is higher than that allowed by the class of the relevant insulating material, the nature of the material is the governing factor.
b	The admissible temperatures for the internal part of insulating enclosures are those indicated for the relevant insulating materials.
c	In this standard, the permissible temperatures are based on service experience in relation to the thermal stability of the materials. The materials quoted are examples. For materials for which higher temperature limits are claimed and for materials other than those listed, the maximum temperatures should not exceed those which have been proved to be satisfactory.
d	Natural rubber and synthetic rubbers are not considered as being thermoplastic materials.
e	Due to their variety, it is not possible to specify permissible temperatures for thermoplastic materials. The matter is under consideration.
f	The possibility of raising the values for wires and cables insulated with heat-resistant polyvinyl chloride is under consideration.

9.29 Chemical loads

The tests for chemical loads are performed according to ISO 16750-5:2010, Table 1 required for “luggage compartment” and “mounting on the exterior” (columns C and D).

9.30 Heat test under solar radiation

The test shall be carried out in accordance with IEC 60068-2-5, test Sa, procedure B.

The conditions are under consideration.

9.31 Resistance to ultra-violet (UV) radiation

This test applies only to enclosures and external parts of the IC-CPD which are constructed of synthetic materials or metals that are entirely coated with synthetic material. Representative samples of such parts shall be subjected to the following test:

The UV test is according to ISO 4892-2, method A, cycle 1, providing a total test period of 500 h. For enclosures constructed of synthetic materials compliance is checked by verification that the flexural strength (according to ISO 178) and Charpy impact (according to ISO 179-1) of synthetic materials have 70 % minimum retention.

The test shall be made on six test specimens of standard size according to ISO 178 and on six test specimens of standard size according to the ISO 179 series. The test specimens shall be made under the same conditions as those used for the manufacture of the enclosure concerned.

For the test carried out in accordance with ISO 178, the surface of the sample exposed to UV shall be turned face down and the pressure applied to the non-exposed surface.

For the test carried out in accordance with ISO 179-1 for materials whose impact bending strength cannot be determined prior to exposure because no rupture has occurred, not more than three of the exposed test specimens shall be allowed to break.

For compliance of enclosures constructed of metals entirely coated by synthetic material, the adherence of the synthetic material shall have a minimum retention of category 3 according to ISO 2409.

Samples shall not show cracks or deterioration visible to normal or corrected vision without additional magnification.

This test need not be carried out if the original manufacturer can provide data from the synthetic material supplier to demonstrate that material of the same type and thickness or thinner complies with this requirement.

9.32 Damp and salt mist test for marine and coastal environments

9.32.1 Test for internal metallic parts

This test is applicable to internal metallic parts of the IC-CPD but not the pins of the plug.

The test consists of:

– 6 cycles of 24 h each for the damp heat cycling test according to IEC 60068-2-30 (test Db) at (40 ± 3) ºC and relative humidity of 95 %, and
– 2 cycles of 24 h each for the salt mist test according to IEC 60068-2-11 (test Ka: salt mist), at a temperature of (35 ± 2) ºC.

9.32.2 Test for external metallic parts only

This test is applicable to external metallic parts of the IC-CPD.

The test comprises two identical 12-day periods.

Each 12-day period comprises:

– 5 cycles of 24 h each for the damp heat cycling test according to IEC 60068-2-30 (test Db) at (40 ± 3) ºC and relative humidity of 95 % and,
– 7 cycles of 24 h each for the salt mist test according to IEC 60068-2-11 (test Ka: salt mist), at a temperature of (35 ± 2) ºC.

9.32.3 Test criteria

After the test, the enclosure or samples shall be washed in running tap water for 5 min, rinsed in distilled or demineralised water then shaken or subjected to air blast to remove water droplets. The specimen under test shall then be stored under normal service conditions for 2 h.

Compliance is checked by visual inspection to determine that:

– *there is no evidence of iron oxide, cracking or other deterioration more than that allowed by ISO 4628-3 for a degree of rusting Ri1. However surface deterioration of the protective coating is allowed. In case of doubt associated with paints and varnishes, reference shall be made to ISO 4628-3 to verify that the samples conform to the specimen Ri1;*
– *the mechanical integrity is not impaired;*
– *seals are not damaged.*

9.33 Hot damp test for tropical environments

Under consideration.

9.34 Vehicle drive-over

9.34.1 General

This test does not apply to the household plugs complying with the relevant national standards or IEC 60884-1. It also does not apply to industrial plugs complying with IEC 60309-1.

Function boxes intended for, or connected to, a length of cord greater than 0,3 m between the plug and the function box shall have adequate resistance to damage from being driven over by a vehicle.

Compliance is checked by the test mentioned in 9.34.2 and 9.34.3.

9.34.2 Test at crushing force 5 000 N

The function box wired with the minimum size cable of a type recommended by the manufacturer shall be placed on a concrete floor in any normal position of rest. A crushing force of (5 000 ± 250) N shall be applied by a conventional automotive tyre, P225/75R15 or an equivalent tyre suitable for the load, mounted on a steel rim and inflated to a pressure of (2,2 ± 0,1) bar. The wheel is to be rolled over the function box at a speed of (8 ± 2) km/h. The function box is to be oriented in a natural resting position before applying the force in a different direction for each sample. The function box under test shall be held or blocked in a fixed position so that it does not move substantially during the application of the applied force. For function boxes integrated into the plug, in no case is the force to be applied to the projecting pins.

9.34.3 Test at crushing force 11 000 N

The procedure described in 9.34.2 is to be repeated on additional samples, with an applied crushing force of (11 000 ± 550) N using a conventional automotive tyre suitable for the load, and inflated to its rated pressure.

9.34.4 Performance after the tests

After the test in 9.34.2, the following conditions shall apply:

There shall be no severe cracking, breakage, or deformation to the extent that:

- live parts, other than exposed wiring terminals, or internal wiring are made accessible to contact by the standard test finger shown in Figure 34 (see 9.4);
- the integrity of the enclosure is defeated so that an acceptable mechanical or environmental (degree of) protection is not afforded to the internal parts of the function box, or polarisation of the function box is defeated;
- there is interference with the operation, function or installation of the function box;
- the function box does not provide adequate strain relief for the flexible cable;
- the creepage distances and clearances between live parts of opposite polarity, live parts and accessible dead or earthed metal are reduced below the values in 8.24;
- other evidence of damage that could increase the risk of fire or electric shock occurs;
- the function box does not comply with a repeated dielectric test in accordance with 9.5.

As a result of the test in 9.34.3, the IC-CPDs shall either comply with the requirements described above for 9.34.2 or be damaged or broken to the extent that the function box is obviously damaged.

9.35 Low storage temperature test

The test shall be performed according to IEC 60068-2-1, test A, at a temperature of –40 °C for a duration of 24 h.

During the storage the IC-CPD is not under operation.

After this test the IC-CPD is allowed to warm up in the cabinet to approximately room temperature.

Under the conditions of tests specified in 9.7.3.4, the IC-CPD shall trip with a test current of 1,0 $I_{\Delta n}$. One test only is made on one pole taken at random without measurement of break-time.

9.36 Vibration and shock test

Conformity shall be tested according to IEC 60068-2-64 random vibration.

The test shall be applied for 8 h for each plane of the IC-CPD. PSD shall be applied according to Table 22.

The r.m.s. acceleration value shall be 2 G.

Table 22 – PSD value depending on frequency for vibration testing

Frequency	Power spectral density	
Hz	$(m/s^2)^2/Hz$	G^2/Hz
10	9,909	0,103 2
55	3,224 5	0,033 6
180	0,123 8	0,001 3
300	0,123 8	0,001 3
360	0,069 5	0,000 7
1 000	0,069 5	0,000 7

NOTE 1 The test description is taken from 5.1.1.1 of ISO 16750-4:2010 with a modified profile.

After this test, the shock test shall be performed according to IEC 60068-2-27 with the following test parameters:

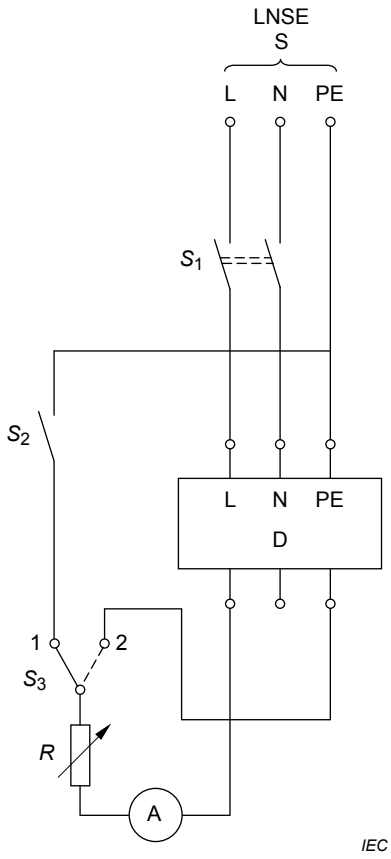
- number of shocks: 10;
- pulse shape: half sinusoidal waveform;
- acceleration: 100 m/s²;
- curation: 16 ms.

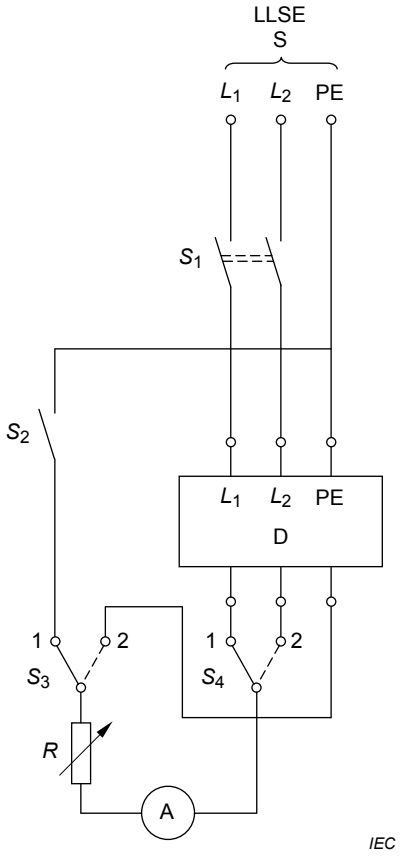
NOTE 2 This covers shocks which are being absorbed in a car such as when driving over curbstones.

NOTE 3 The test description is taken from 4.2.3 of ISO 16750-3:2012 with a modified test profile.

After the test the IC-CPD shall operate when a residual current of 1,25 $I_{\Delta n}$ is applied to one pole chosen at random, no measurement of break-time being made.

After this test the protection against electric shock shall not be affected and the sample shall comply with the requirements of 9.4.





NOTE The position of L and N from the supply voltage S is chosen at random.

Figure 2a) – Type LNSE / LNE

Figure 2b) – Type LLSE / LLE

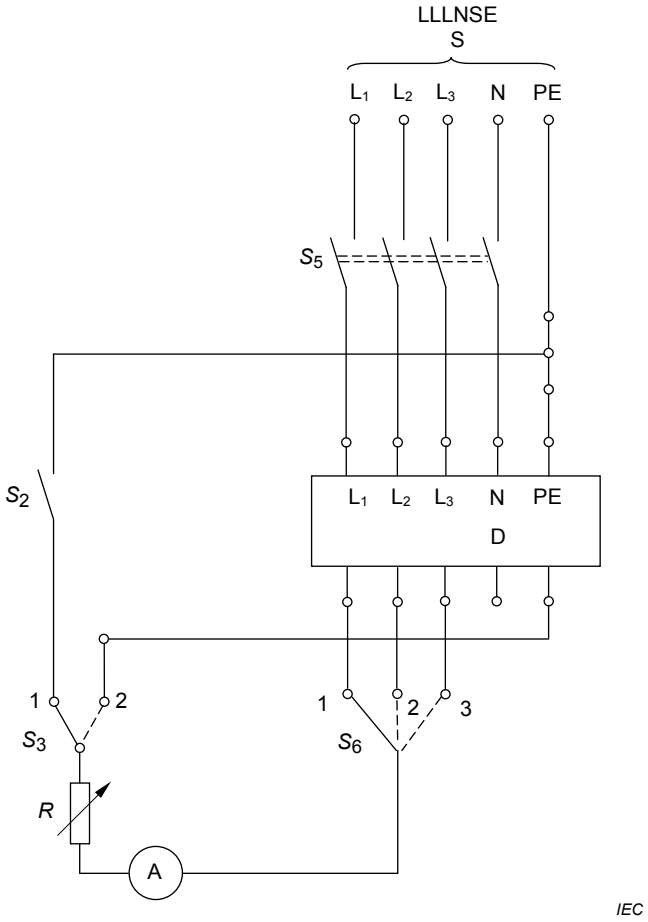


Figure 2c) – Type LLLNSE / LLLNE

PE	protective conductor
L	line
N	neutral
R	variable resistor
D	device under test
S	supply (for LNSE types line and neutral)
A	ammeter
S_1	two-pole switch
S_2	single-pole switch
$S_{3,4}$	two-way switch
S_5	four-pole switch
S_6	three-way switch

Figure 2 – Test circuit for the verification of operating characteristic (9.7.3), reduced supply voltage (9.14)

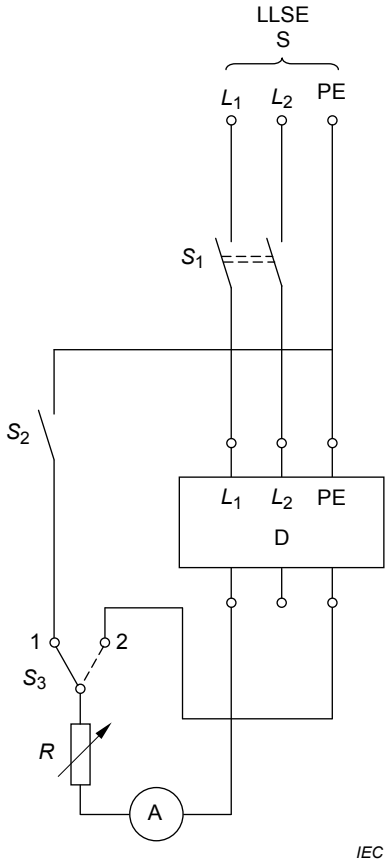


Figure 3a) – Type LLSE / LLE

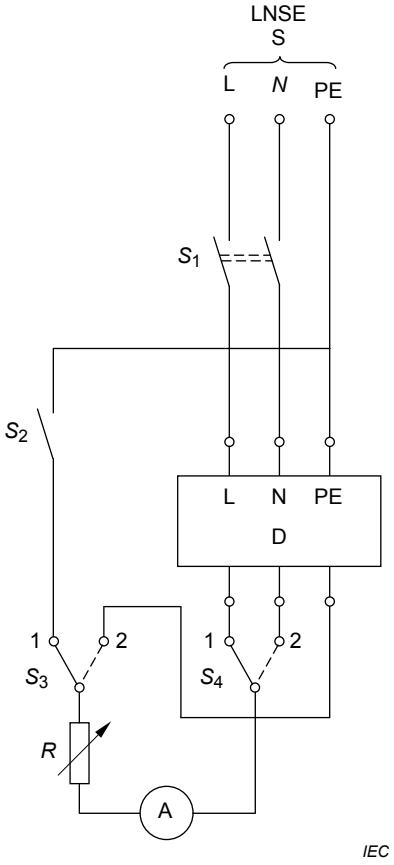


Figure 3b) – Type LNSE / LNE

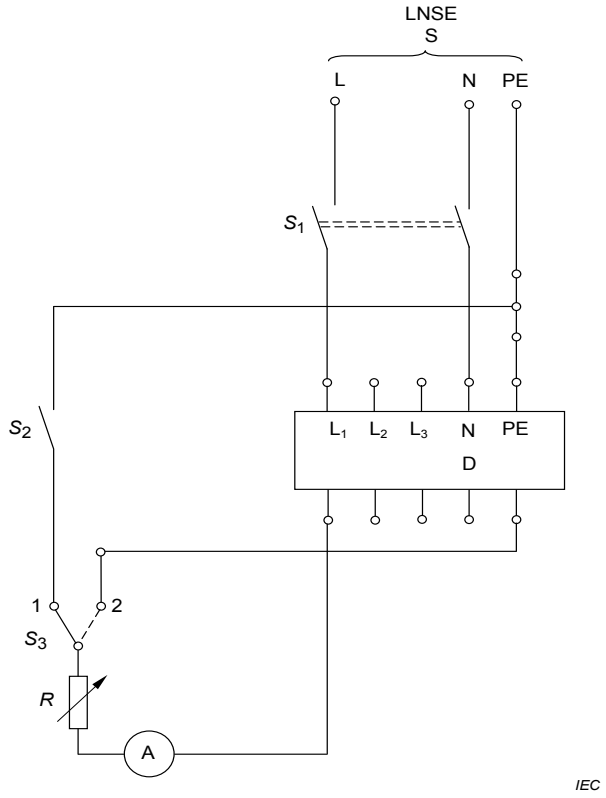


Figure 3c) – Type LLLNSE / LLLNE on LNSE supply

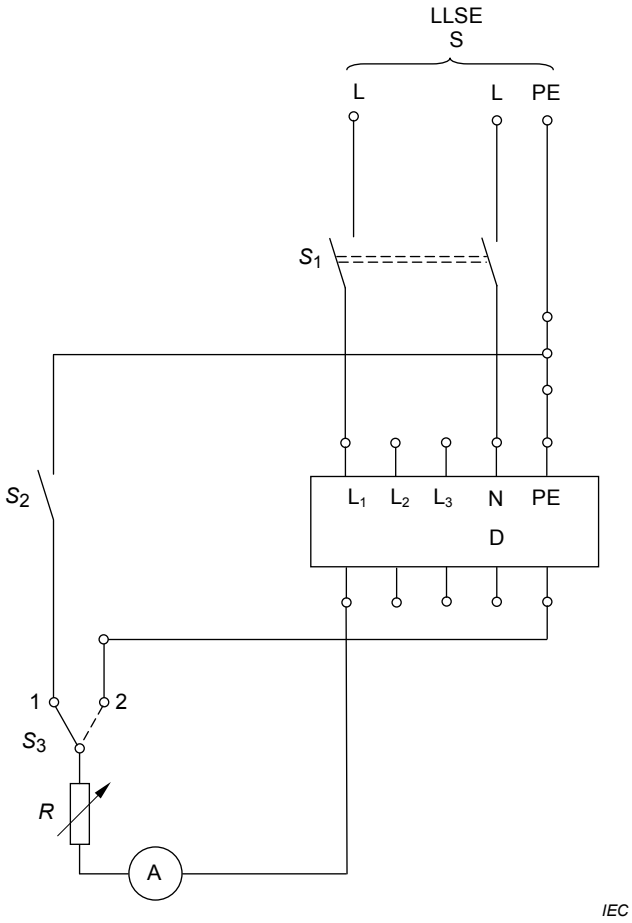


Figure 3d) – Type LLLNSE / LLLNE on LLSE supply

PE	protective conductor
L	line
N	neutral
R	variable resistor
D	device under test
S	supply (for LNSE types line and neutral)
A	ammeter
S_1	two-pole switch
S_2	single-pole switch
S_3,S_4	two-way switch

Figure 3 – Test circuit for the verification when plugged in incompatible supply systems (9.7.7.4)

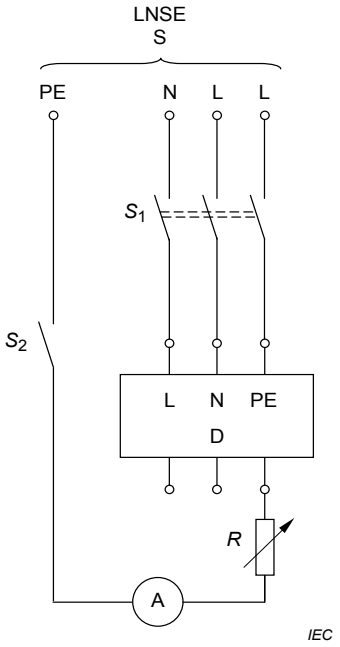


Figure 4a) – Type LNSE

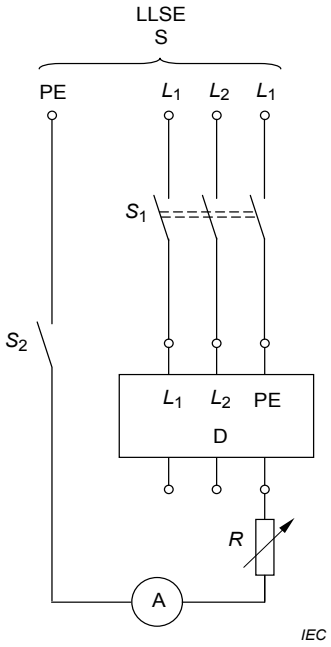


Figure 4b) – Type LLSE

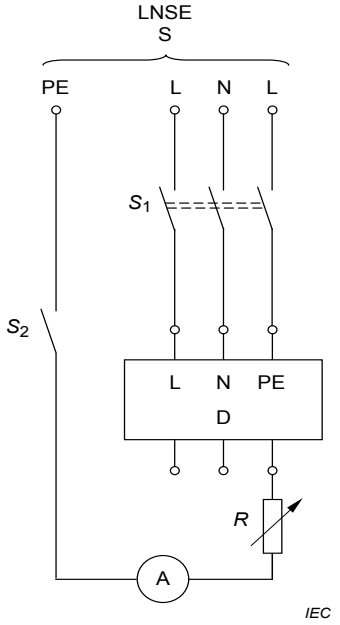


Figure 4c) – Type LNSE

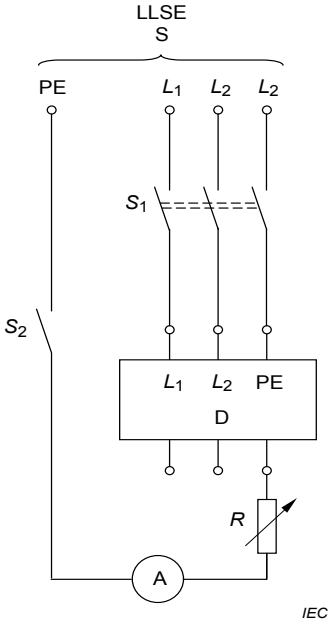


Figure 4d) – Type LLSE

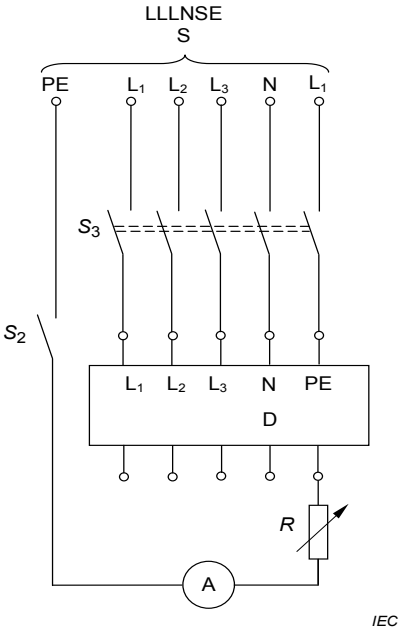


Figure 4e) – Type LLLNSE

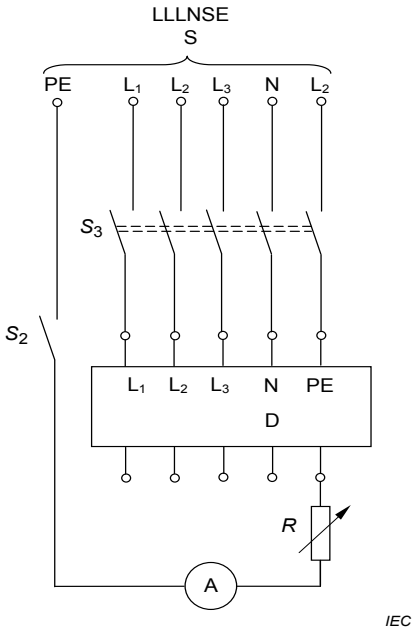


Figure 4f) – Type LLLNSE

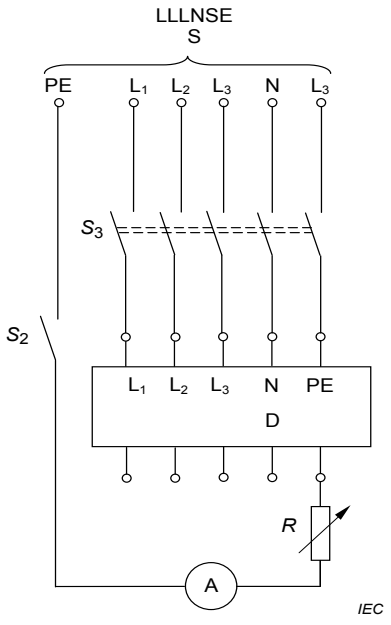


Figure 4g) – Type LLLNSE

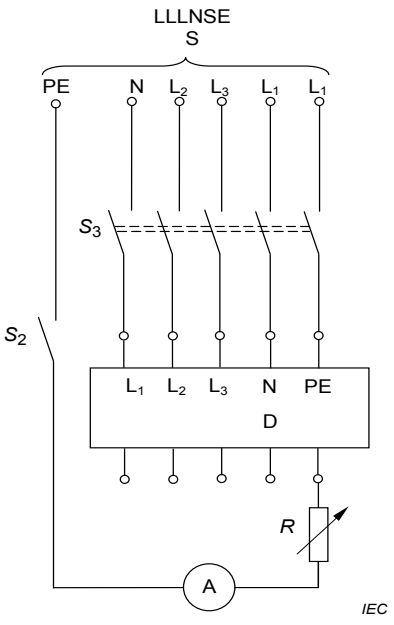


Figure 4h) – Type LLLNSE

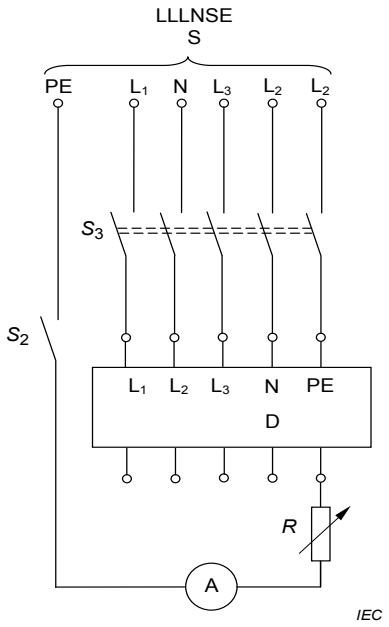


Figure 4i) – Type LLLNSE

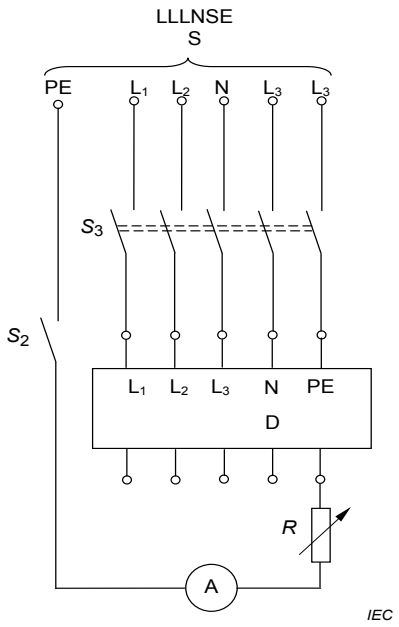


Figure 4j) – Type LLLNSE

PE protective conductor
L line
N neutral
R variable resistor (adjust for $I_{\Delta n}$)
D device under test
S supply (for LNSE types line and neutral)
A ammeter
S_1 three-pole switch
S_2 single-pole switch momentary
S_3 five-pole switch

LNSE types: For Figures 2a) and 2c), see 9.7.7.2.

Figure 4 – Verification of correct operation for hazardous live PE (see Table 14 and Table 15)

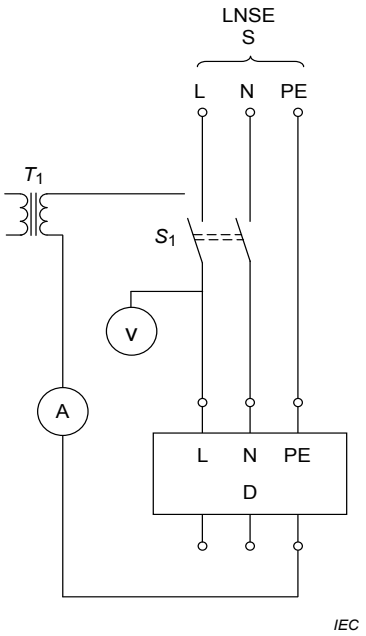


Figure 5a) – Type LNSE / LNE

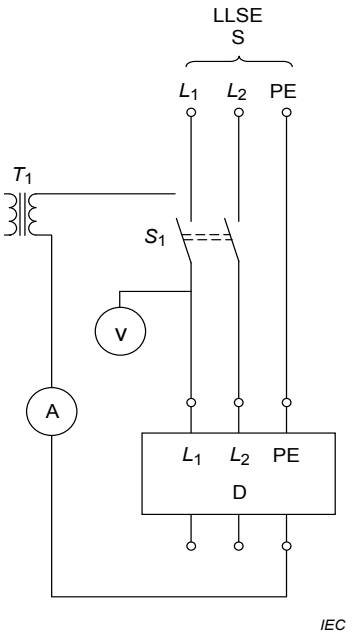


Figure 5b) – Type LLSE / LLE

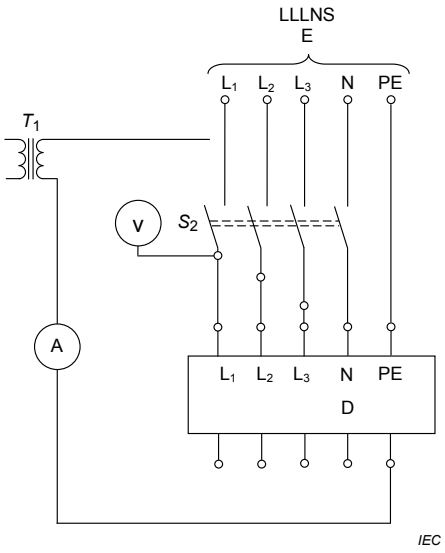


Figure 5c) – Type LLLNSE / LLLNE

PE protective conductor
L line
N neutral
D device under test
T_1 variable current injection transformer 0 A to 20 A
A AC ammeter 0 A to 20 A
V voltmeter
S_1 two-pole switch
S_2 four-pole switch momentary
S supply (for LNSE types line and neutral)

See 9.6.3.

Samples with the trip circuit disabled may be required for this test.

Figure 5 – Verification of temperature rise of the protective conductor

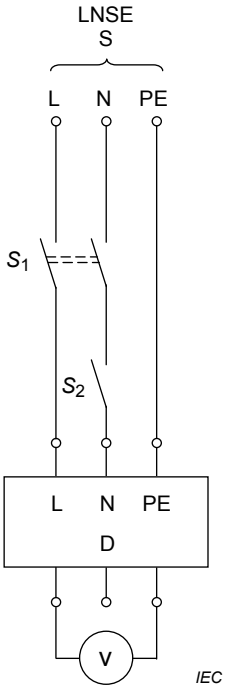


Figure 6a) – Type LNSE / LNE

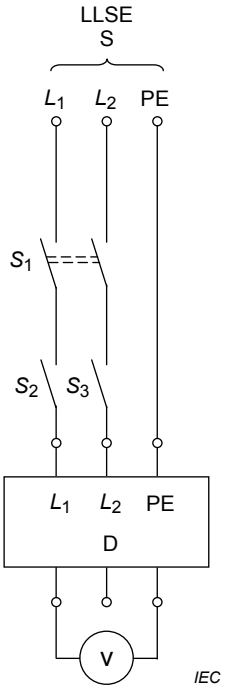
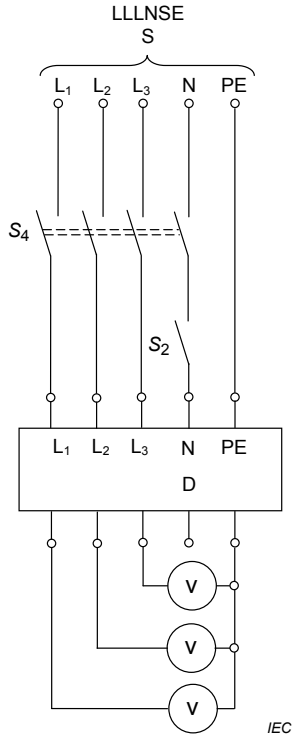


Figure 6b) – Type LLSE / LLE



PE protective conductor
L line
N neutral
D device under test
S supply (for LNSE types line and neutral)
S_1 two-pole switch
$S_{2, 3}$ single-pole switch
S_4 Four-pole switch
V voltmeter(s)

See 9.7.4.2

Figure 6c – Type LLLNSE / LLLNE

Figure 6 – Verification of open neutral for LNSE types, and open line for LLSE types

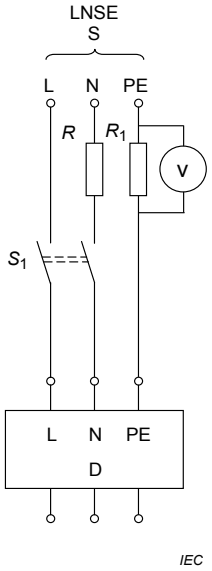


Figure 7a) – LNSE / LNE type

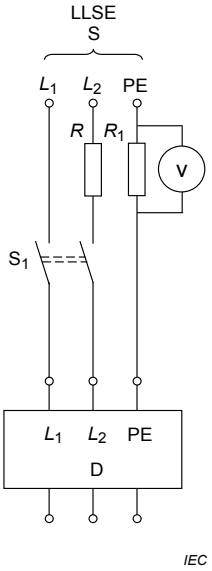


Figure 7b) – LLSE / LLE type

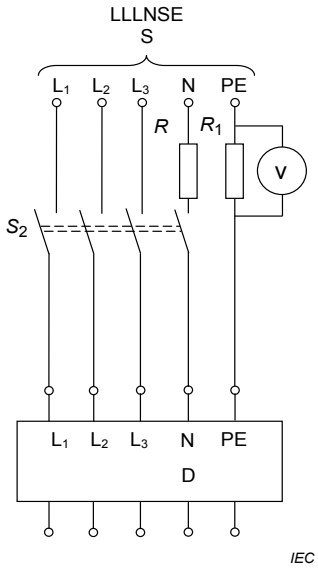


Figure 7c) – LLLNSE / LLLNE type

PE protective conductor
L line
N neutral
S_1 two-pole switch
S_2 four-pole switch
D device under test
S supply (for LNSE types line and neutral)
V voltmeter r.m.s.
R, R_1 1,0 Ω ± 1 %
See 9.7.10.

Figure 7 – Verification of a standing current in the protective conductor in normal service

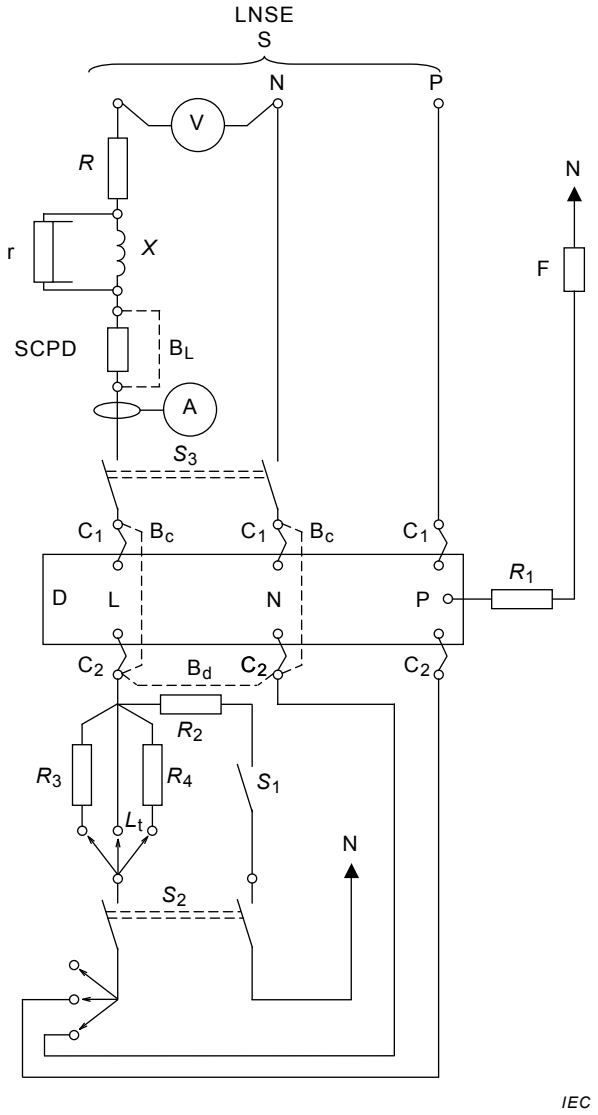


Figure 8a) – LNSE / LNE types

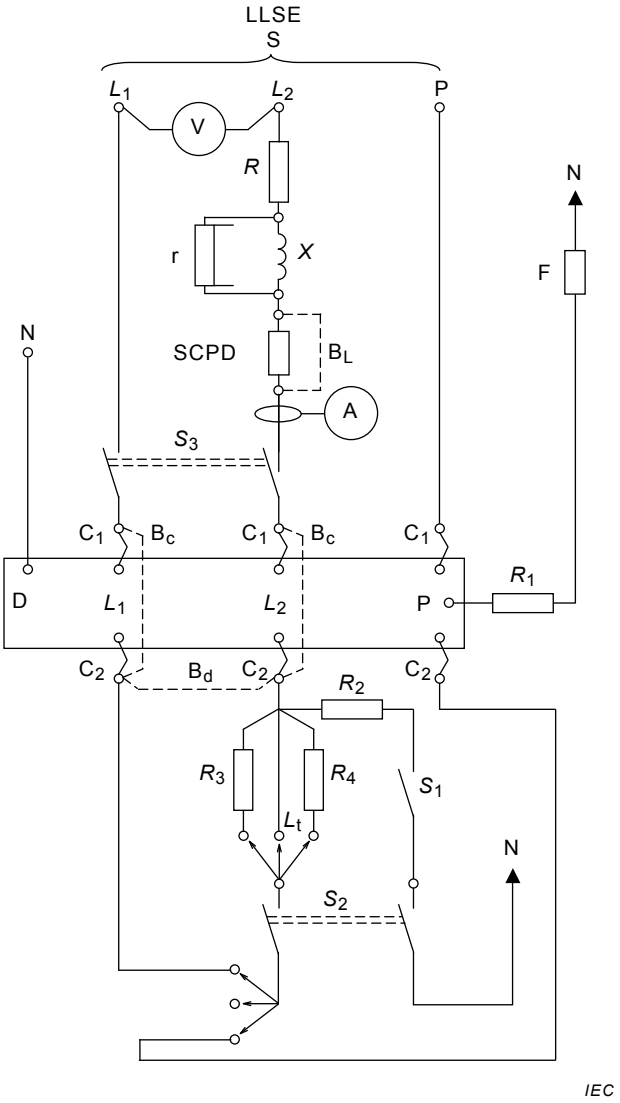


Figure 8b) – LLSE / LLE types

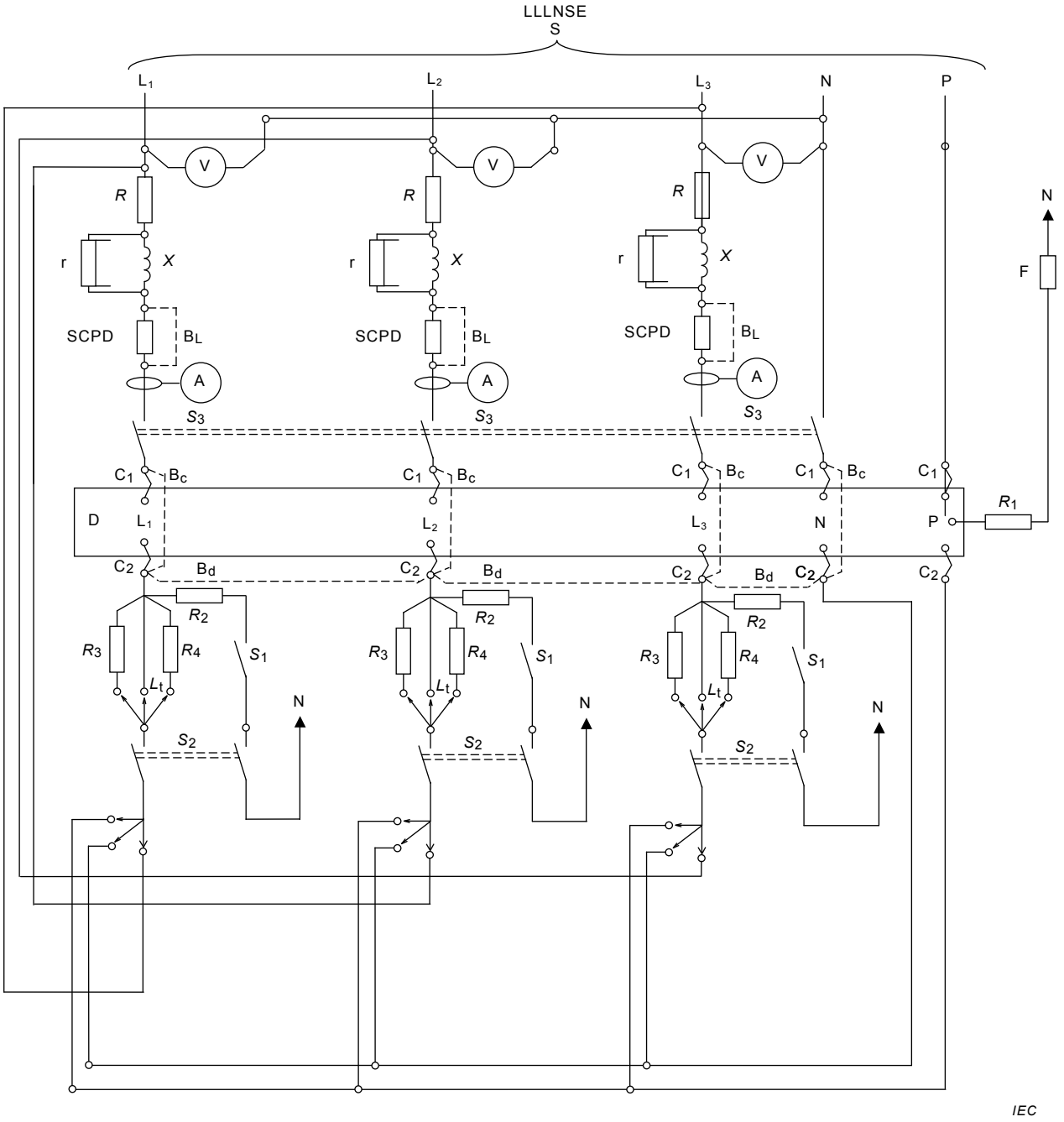
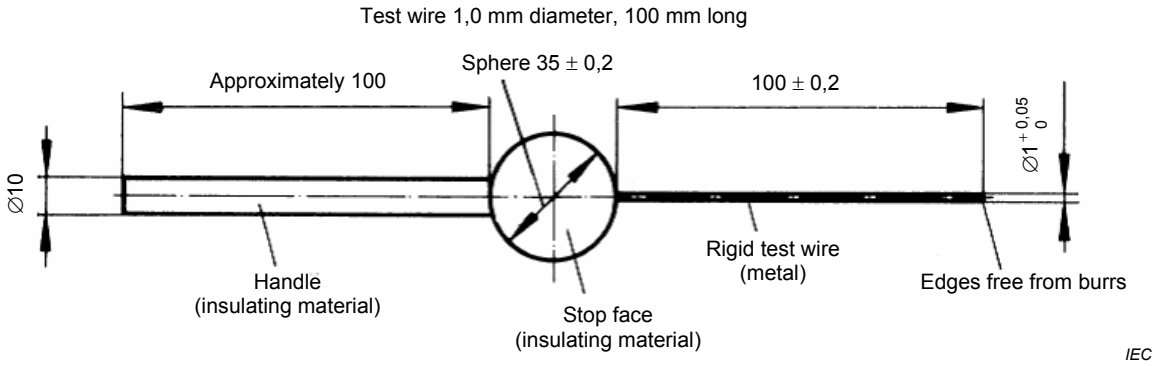


Figure 8c) – LLLNSE / LLLNE type

PE	protective conductor
L	line
N	neutral
S	test supply for rated voltage
V	oscillogram element to record voltage
R and X	resistor and reactor, adjusted to I_{nc}
r	shunt resistor
SCPD	silver wire, fuse or circuit breaker
BL	bridging link for SCPD (closed during calibration and I_m, $I_{\Delta m}$ tests; open during I_{nc}, $I_{\Delta c}$, I_m conditional tests)
A	oscillogram element to record current
S_3	switch for making the CO test of a unit with automatic closing
C1 and C2	IC-CPD flexible cord, total length 0,75 m
D	device under test
R_1	resistor to give approximately 100 A
F	fine wire fuse
B_C	temporary IC-CPD bridging connections for calibration

B_d temporary IC-CPD load terminals bridging connections for calibration of I_{nc}
R_2 resistor to give 10 × $I_{\Delta n}$
S_1 switch to insert R_2 for I_m test
R_3 resistor adjusted to I_m (and $I_{\Delta m}$)
R_4 resistor to give 250 A
S_2 switch to initiate O tests, left closed for CO tests
L_t load terminal
Arrows at S2 terminals alternative connections as specified for various test

Figure 8 – Test circuit for the verification of the making and breaking capacity and the short-circuit coordination with an SCPD (see 9.9.2)



Test force: 10 N ± 10 %

Dimensions in millimetres

Figure 9 – Standard test wire 1,0 mm

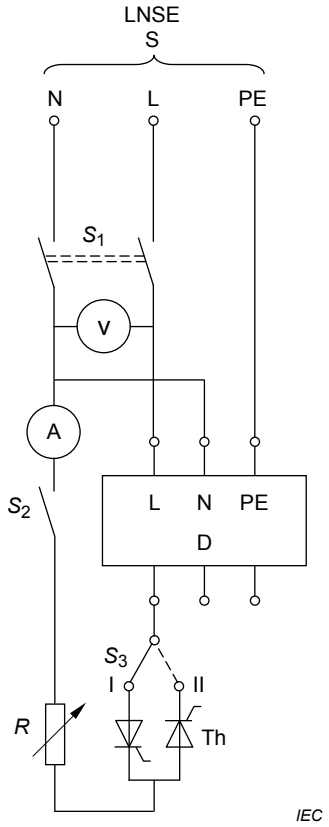


Figure 10a) – LNSE / LNE types

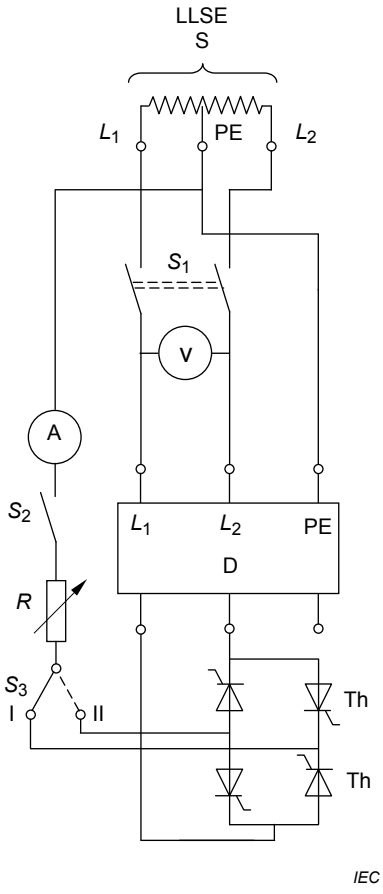


Figure 10b) – LLSE / LLE types

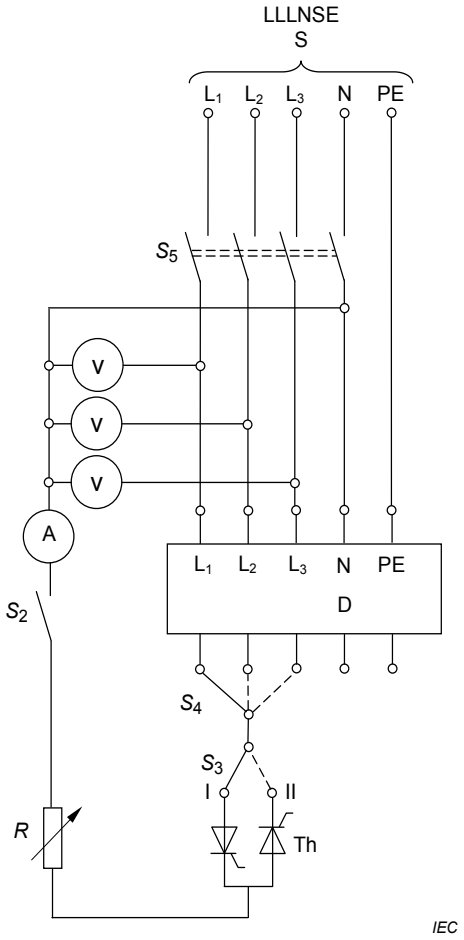


Figure 10c) – LLLNSE / LLLNE types

PE	protective conductor
L	line
N	neutral
S	supply
V	voltmeter
A	ammeter (measuring r.m.s. values)
D	device under test
R	variable resistor
Th	thyristor
S_1	two-pole switch
S_2	single-pole switch
S_3	two-way switch
S_4	three-way switch
S_5	four-pole switch

Figure 10 – Test circuit for the verification of the correct operation in the case of residual pulsating direct currents (see 9.7.4)

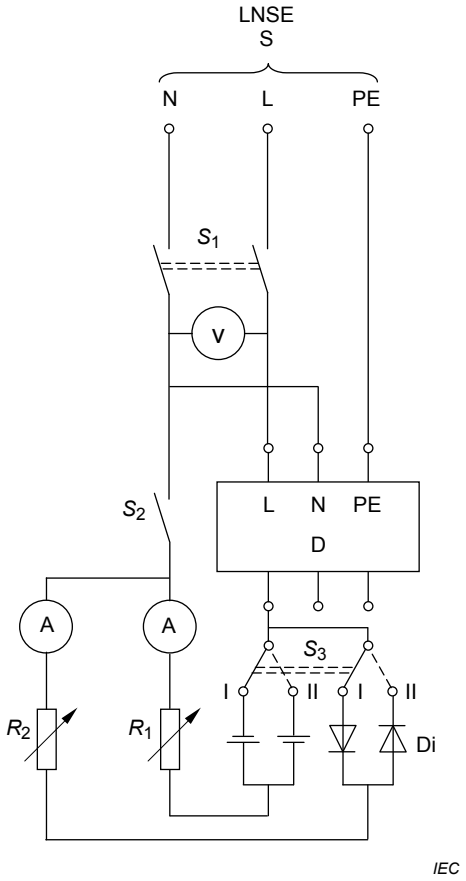


Figure 11a) – LNSE / LNE types

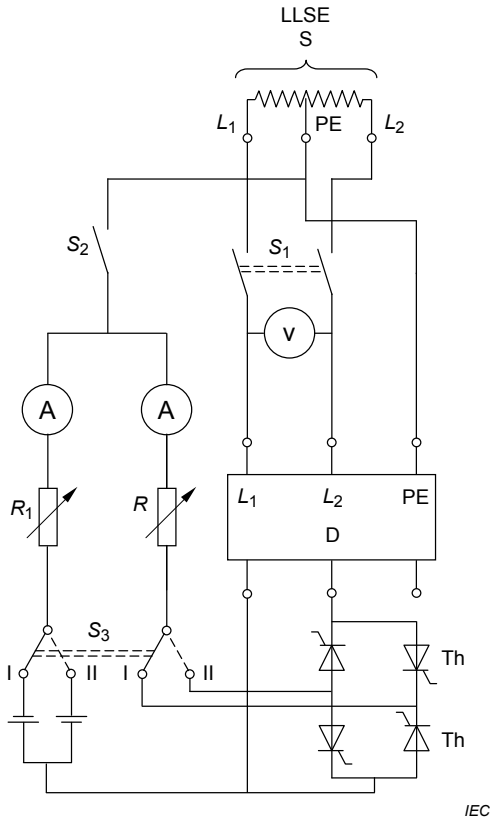


Figure 11b) – LLSE / LLE types

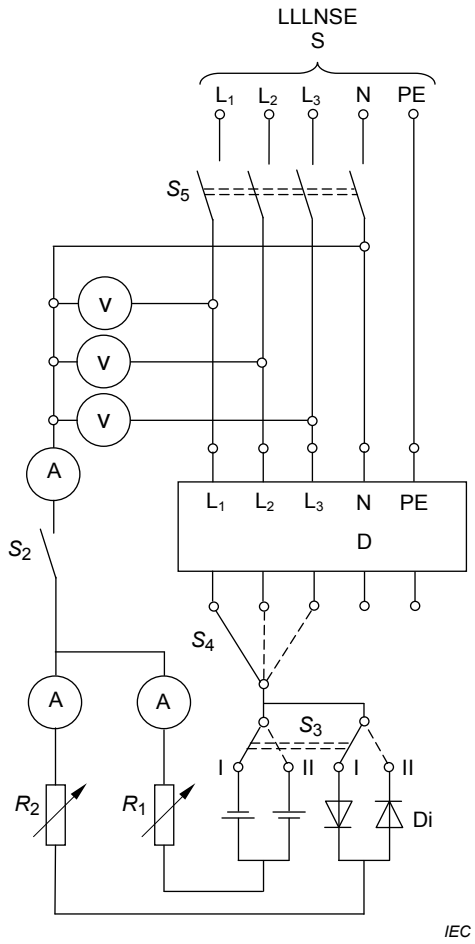


Figure 11c) – LLLNSE / LLLNE types

PE	protective conductor
L	line
N	neutral
S	supply
V	voltmeter
A	ammeter (measuring r.m.s. values)
D	Device under test
R	variable resistor
Di	diode
S_1	two-pole switch
S_2	single-pole switch
S_3	two-pole two-way switch
S_4	three-way switch
S_5	four-pole switch

Figure 11 – Test circuit for the verification of the correct operation in the case of residual pulsating direct currents superimposed by a smooth direct current (see 9.7.4.3)

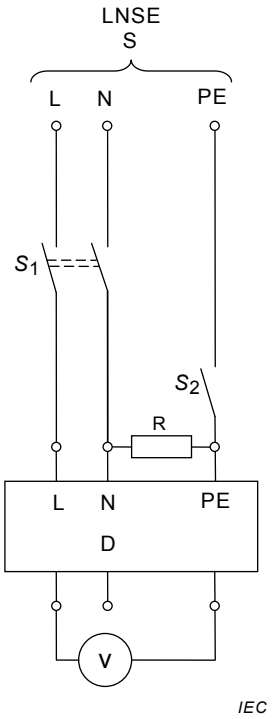


Figure 12a) – Type LNSE

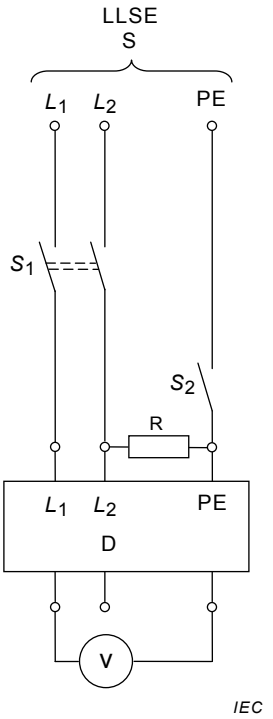


Figure 12b) – Type LLSE

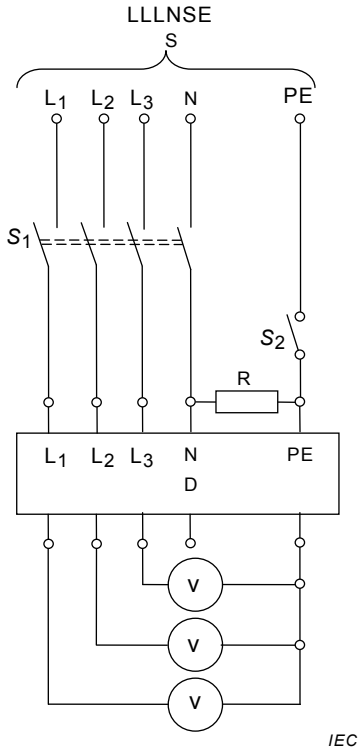


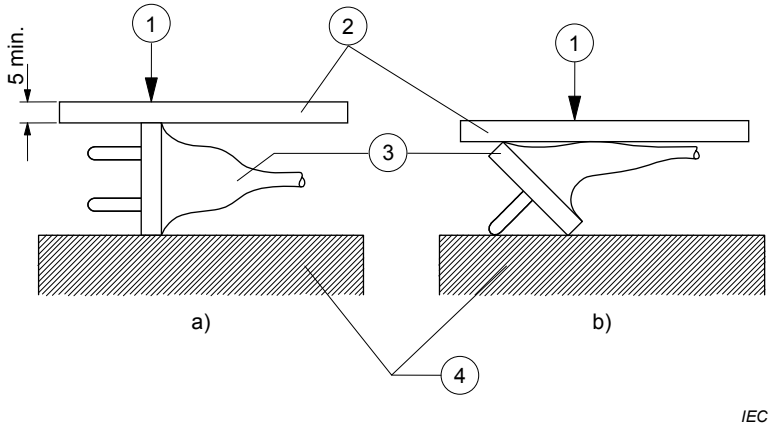
Figure 12c) – Type LLLNSE

PE protective conductor
L line
N neutral
D device under test
S supply
S_1 two-pole switch or four-pole switch, as applicable
S_2 single-pole switch
V voltmeter
R resistor 1600 Ω

NOTE For LLSE types a supply neutral connection can be connected for reference.

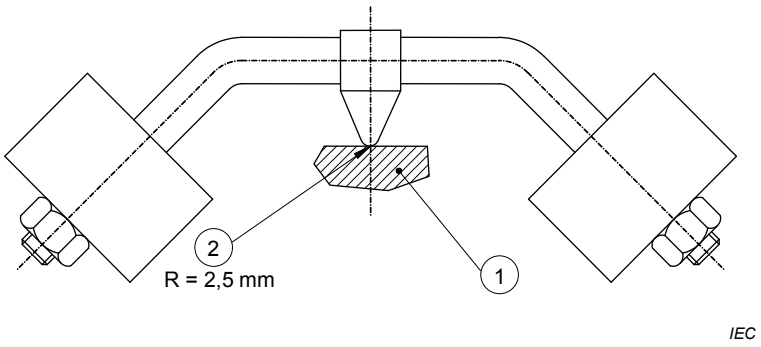
Figure 12 – Verification of open protective conductor (see 9.7.7.5)

Dimensions in millimetres



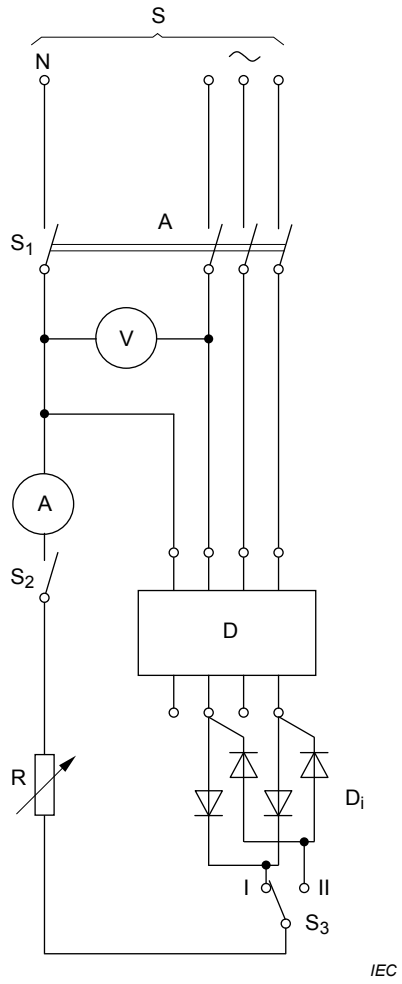
1 force
2 steel pressure plate
3 plug-portion of the sample
4 steel base

Figure 13 – Arrangement for compression test for verification of protection against electric shock



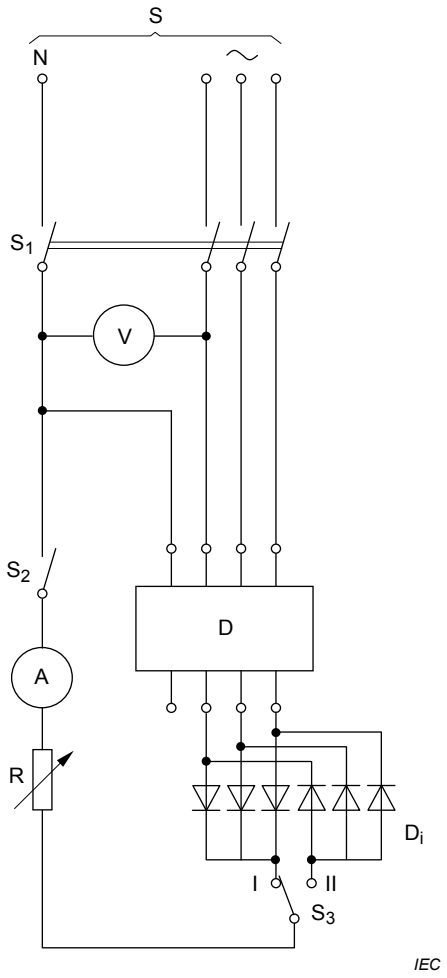
1 sample
2 spherical

Figure 14 – Ball-pressure test apparatus



Point A	supply by 2 phases chosen at random
S	supply
V	voltmeter
A	ammeter (measuring r.m.s. values)
D	device under test
D_i	diodes
R	variable resistor
S_1	multi-pole switch
S_2	single-pole switch
S_3	two-pole switch

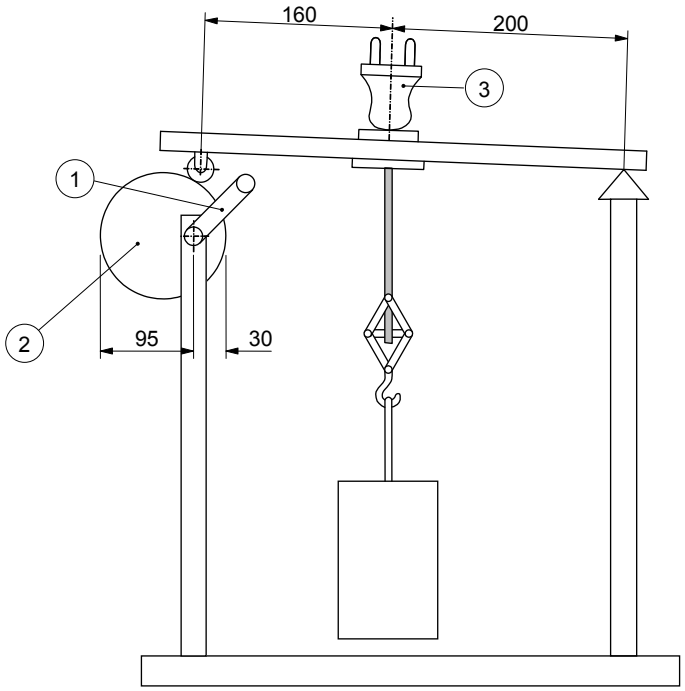
Figure 15 – Test circuit for IC-CPD according to 4.1.3 to verify the correct operation in case of residual pulsating direct currents which may result from rectifying circuits supplied from two phases



S supply
V voltmeter
A ammeter (measuring r.m.s. values)
D device under test
D_i diodes
R variable resistor
S_1 multi-pole switch
S_2 single-pole switch
S_3 two-pole switch

Figure 16 – Tests circuit for IC-CPD according to 4.1.4 to verify the correct operation in case of residual pulsating direct currents which may result from rectifying circuits supplied from three phases

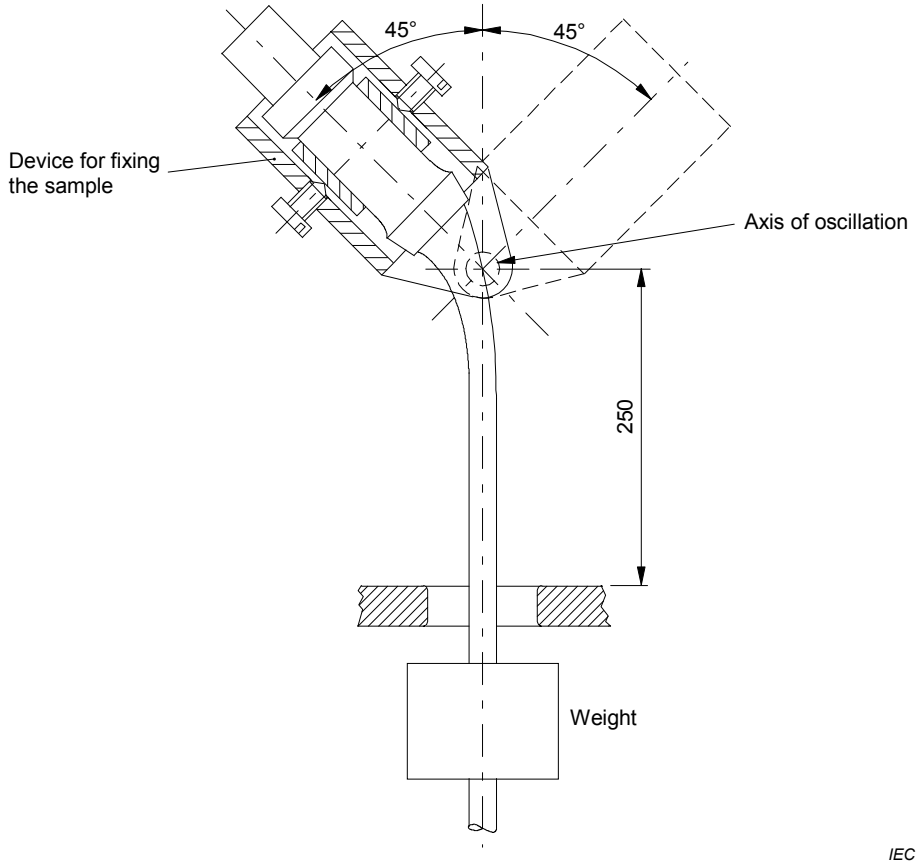
Dimensions in millimetres



1 crank
2 eccentric
3 sample

Figure 17 – Apparatus for testing the cord retention

Dimensions in millimetres



1 device for fixing the sample

2 sample

3 weight

An adjustment of the different supports for the accessories by means of a threaded spindle shall be provided as per the explanation in 9.25.

Figure 18 – Apparatus for flexing test

Dimensions in millimetres

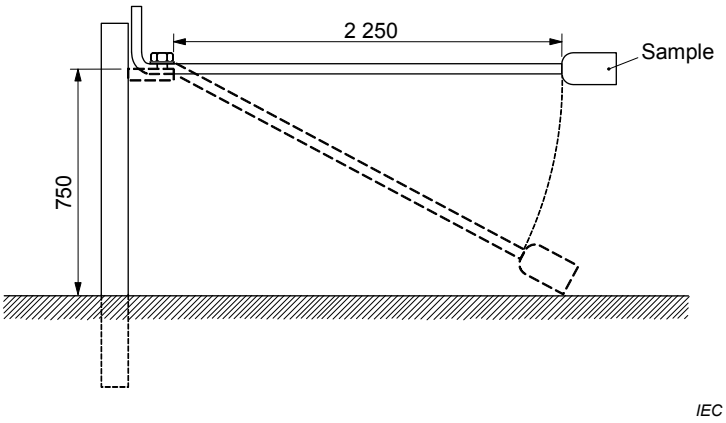


Figure 19 – Arrangement for mechanical strength test on IC-CPDs provided with cords (9.10.4)

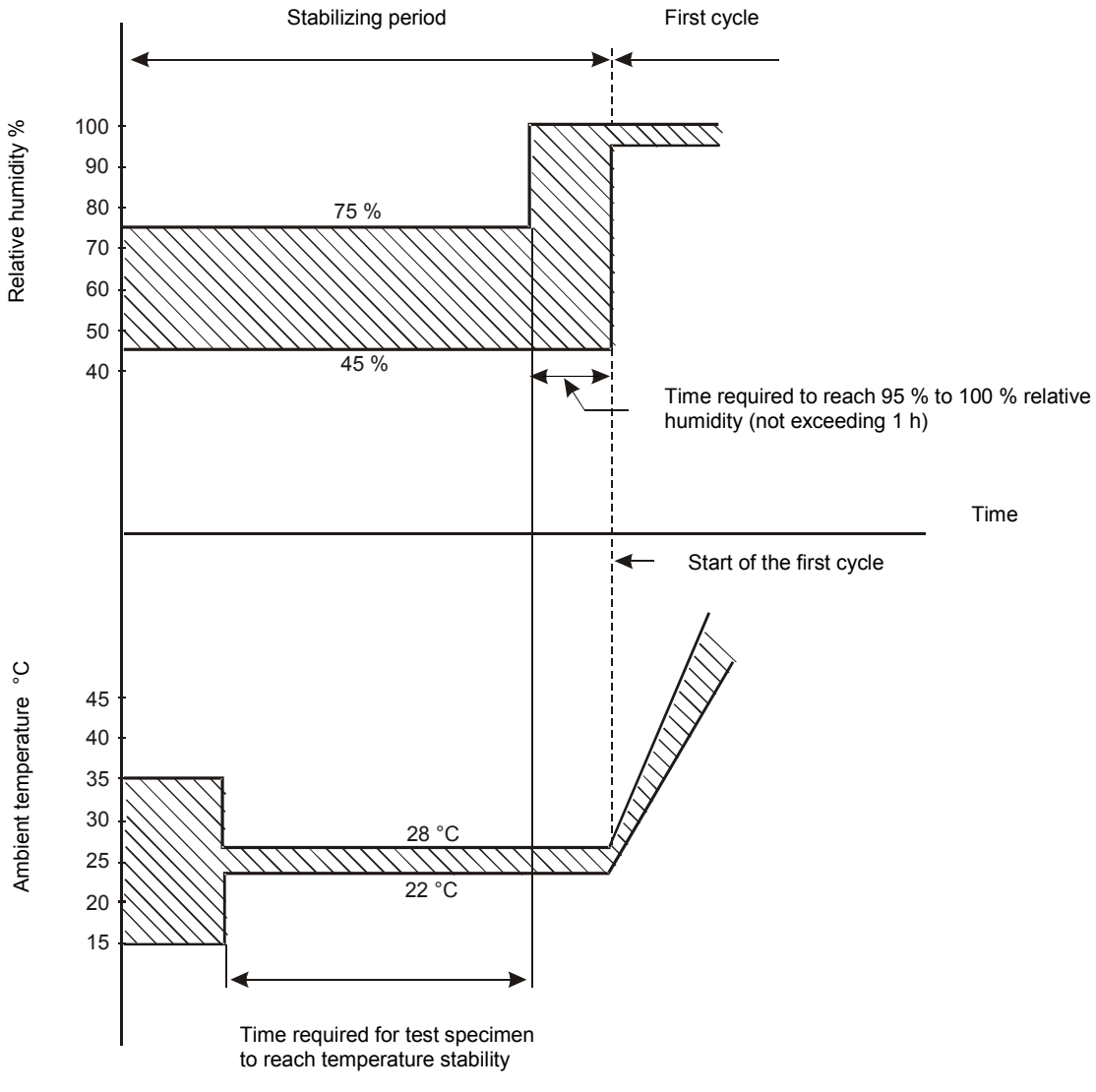


Figure 20 – Stabilizing period for reliability test (9.17.1.4)

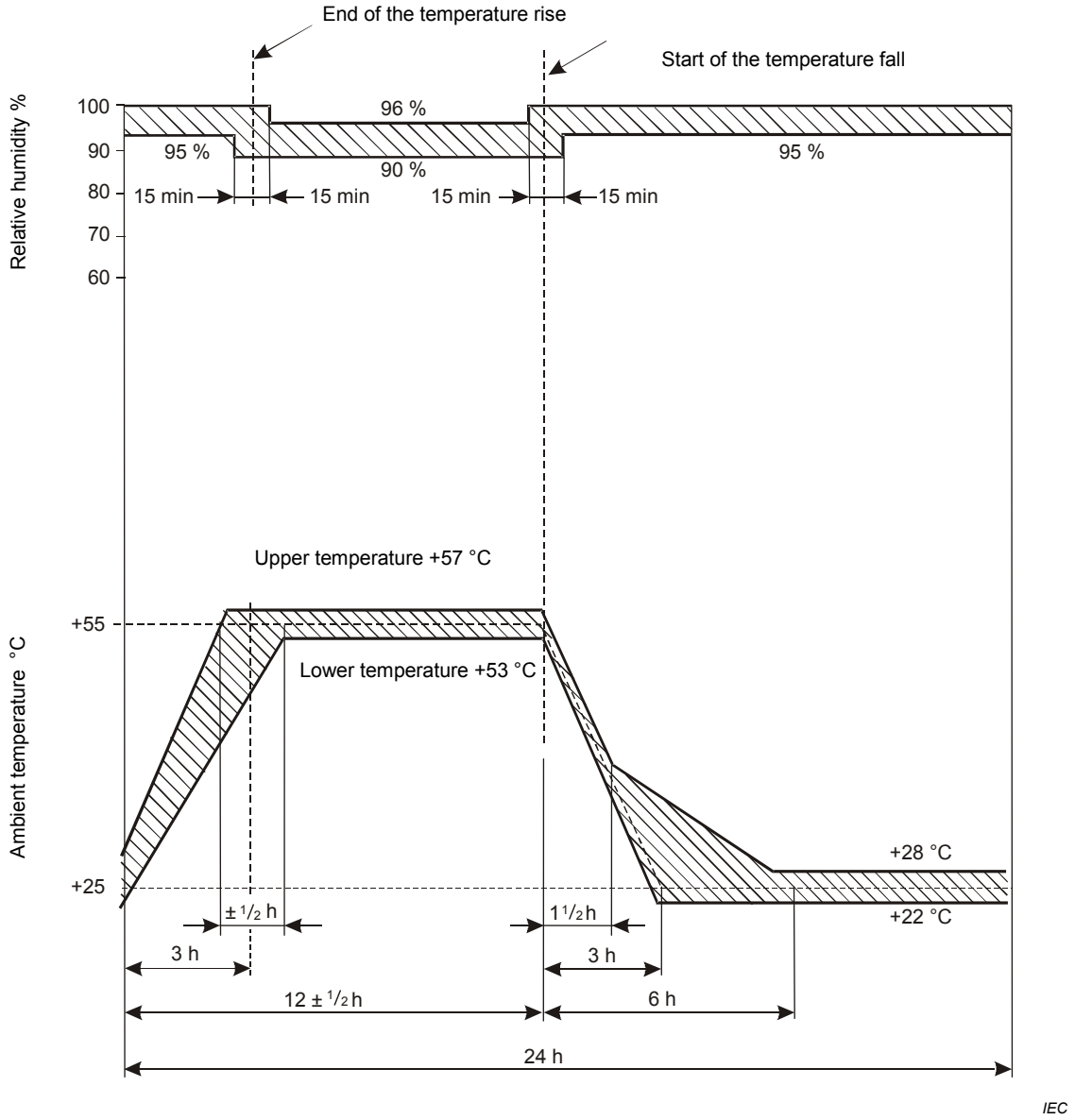
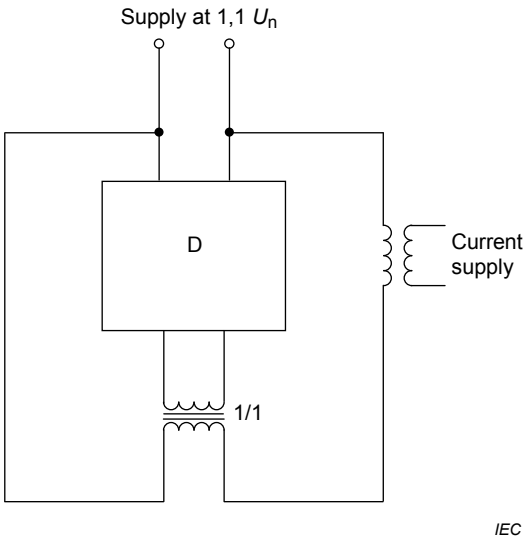


Figure 21 – Reliability test cycle (9.17.1.4)



D IC-CPD under test

Figure 22 – Example for test circuit for verification of ageing of electronic components (9.18)

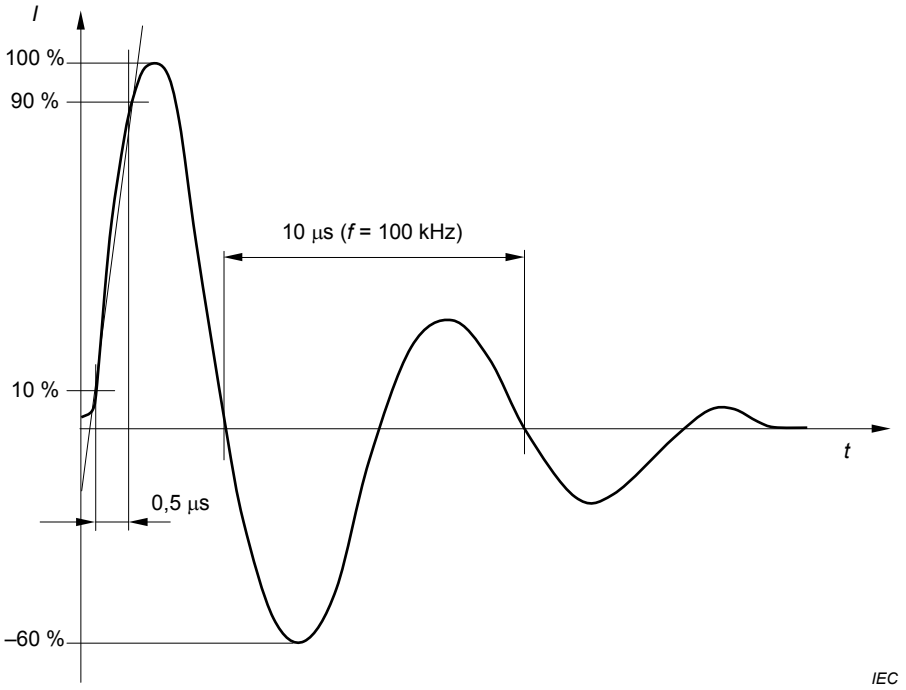
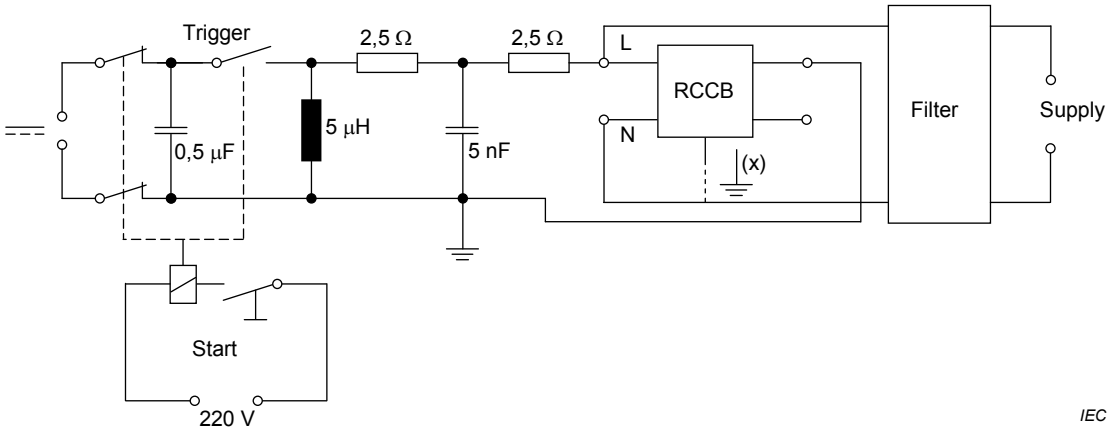
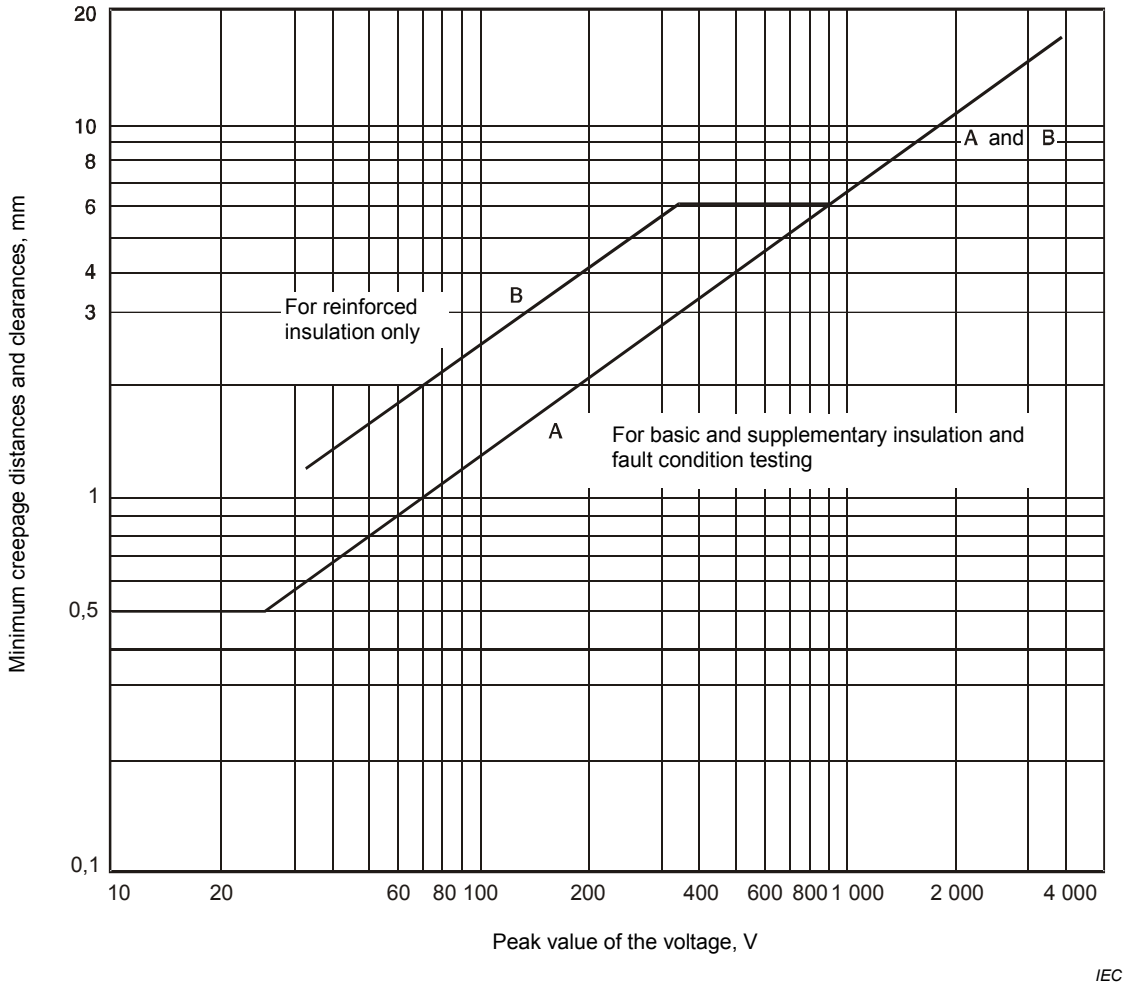


Figure 23 – Current ring wave 0,5 μs/100 kHz



(x) Earthing terminal connected to the neutral conductor if marked on the IC-CPD

Figure 24 – Example of test circuit for the verification of resistance to unwanted tripping



For parts conductively connected to the supply mains with voltages in the range of 220 V and 250 V (r.m.s.), the dimensions are equal to those relating to 354 V, peak:

Curve A: 34 V corresponds to 0,6 mm
354 V corresponds to 3,0 mm

Curve B: 34 V corresponds to 1,2 mm
354 V corresponds to 6,0 mm

Figure 25 – Minimum creepage distances and clearances as a function of peak value of voltage (see 9.27.3 a))

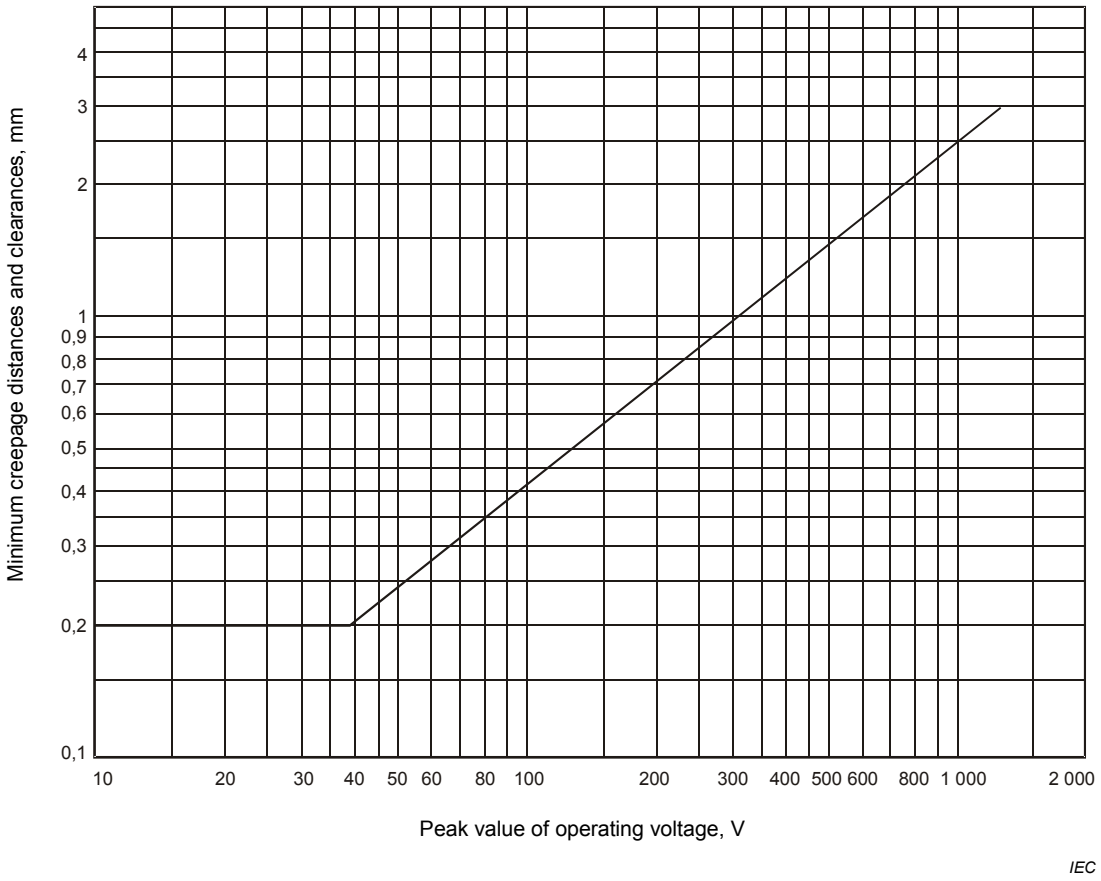


Figure 26 – Minimum creepage distances and clearances as a function of peak value of operating voltage (see 9.27.3 a))

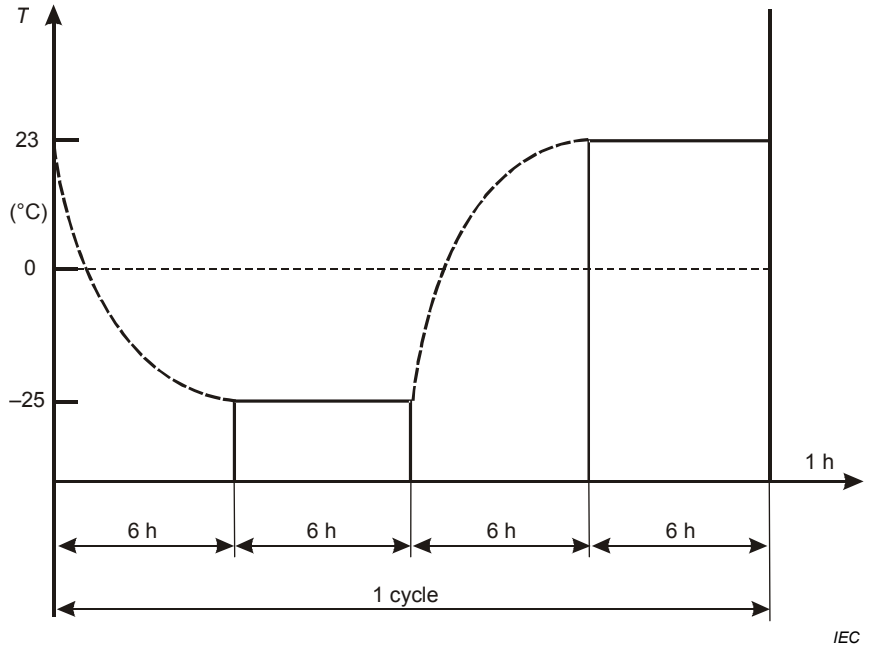
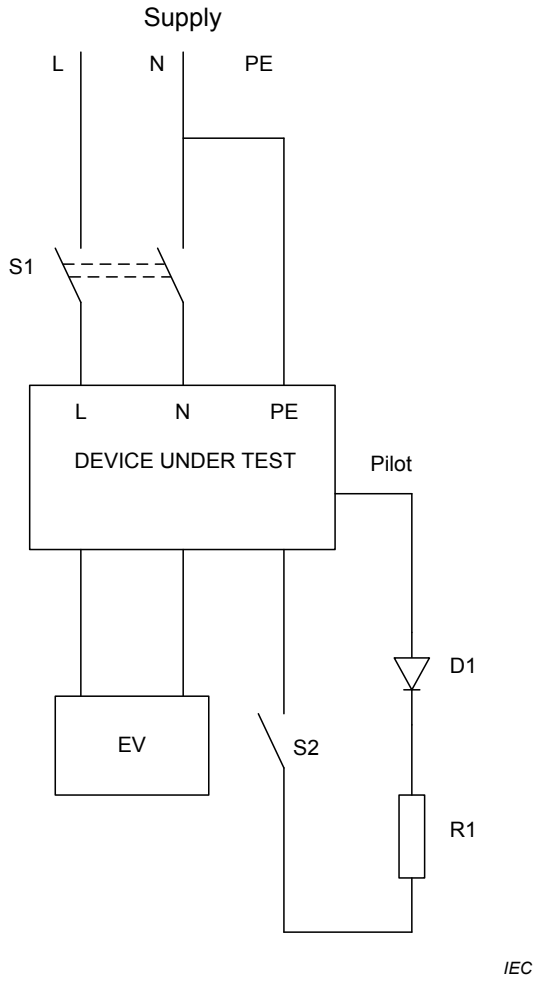


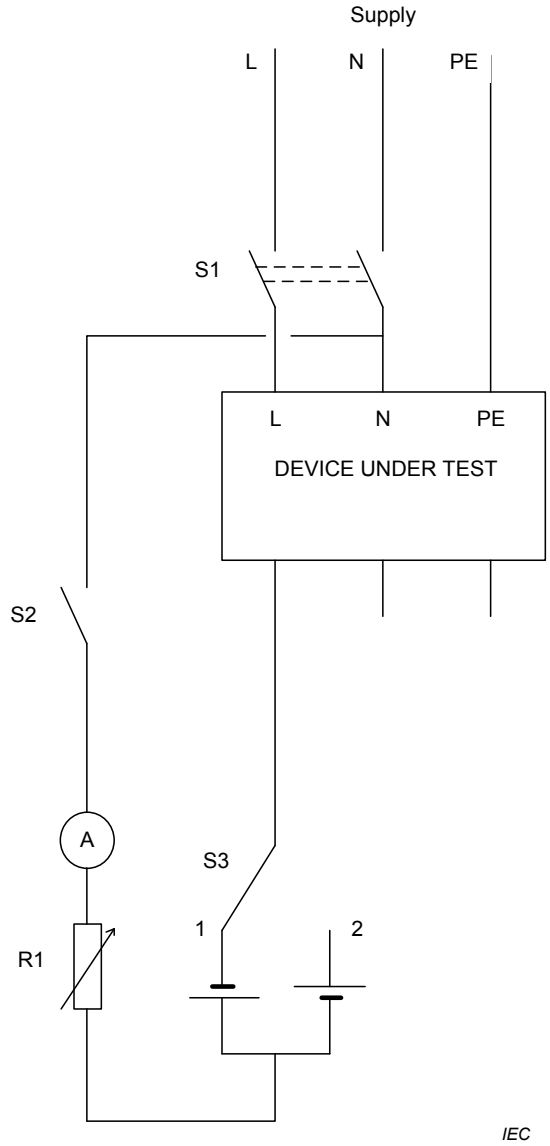
Figure 27 – Test cycle for low temperature test



The figure shows the LNSE-type.
For LLSE type, the connection from the supply is: L1 –L2 – PE.
For LLLNSE type, the connection from the supply is: L1 –L2 –L3–N–PE.

S_1, S_2	switch
S	supply
D	device under test
R_1	resistor value 882 Ω ± 3%
D_1	diode
EV	resistive load simulating electric vehicle at rated current

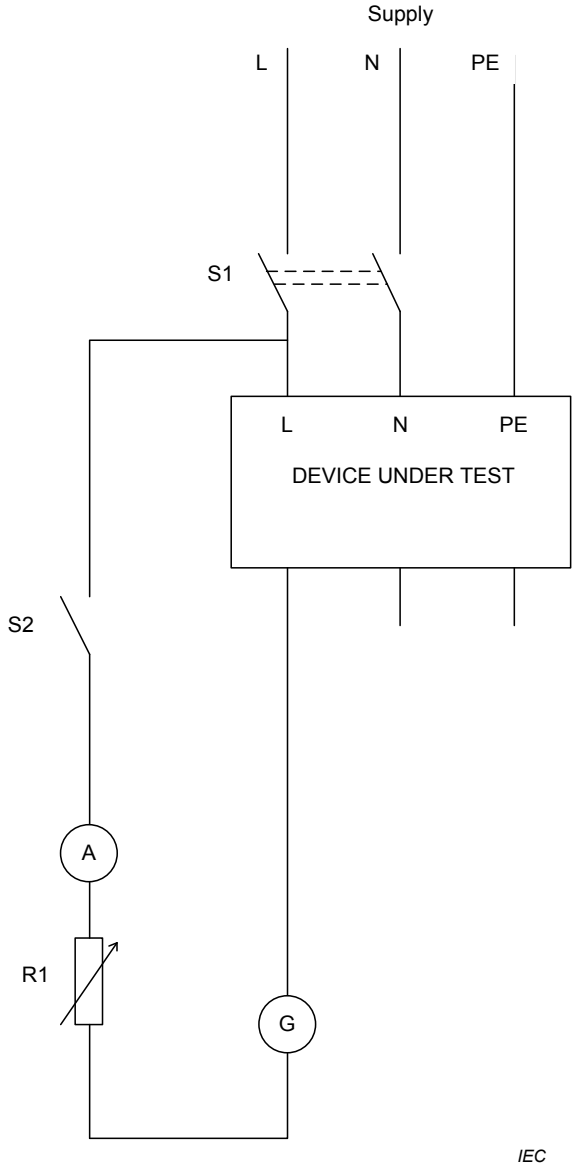
Figure 28 – Test circuit for verification of connection of protective conductor to the EV, according to 9.7.9



The figure shows the LNSE-type.
For LLSE type, the connection from the supply is: L1 –L2 – PE.
For LLLNSE type, the connection from the supply is: L1 –L2 –L3–N–PE.

S_1, S_2, S_3	switch
S	supply
D	device under test
R_1	adjustable resistor

Figure 29 – Verification of correct operation in case of smooth d.c. leakage current, according to 9.7.6



The figure shows the LNSE-type.
For LLSE type, the connection from the supply is: L1 –L2 – PE.
For LLLNSE type, the connection from the supply is: L1 –L2 –L3–N–PE.

S supply

S_1 all-pole switch (optional)

S_2 single-pole switch

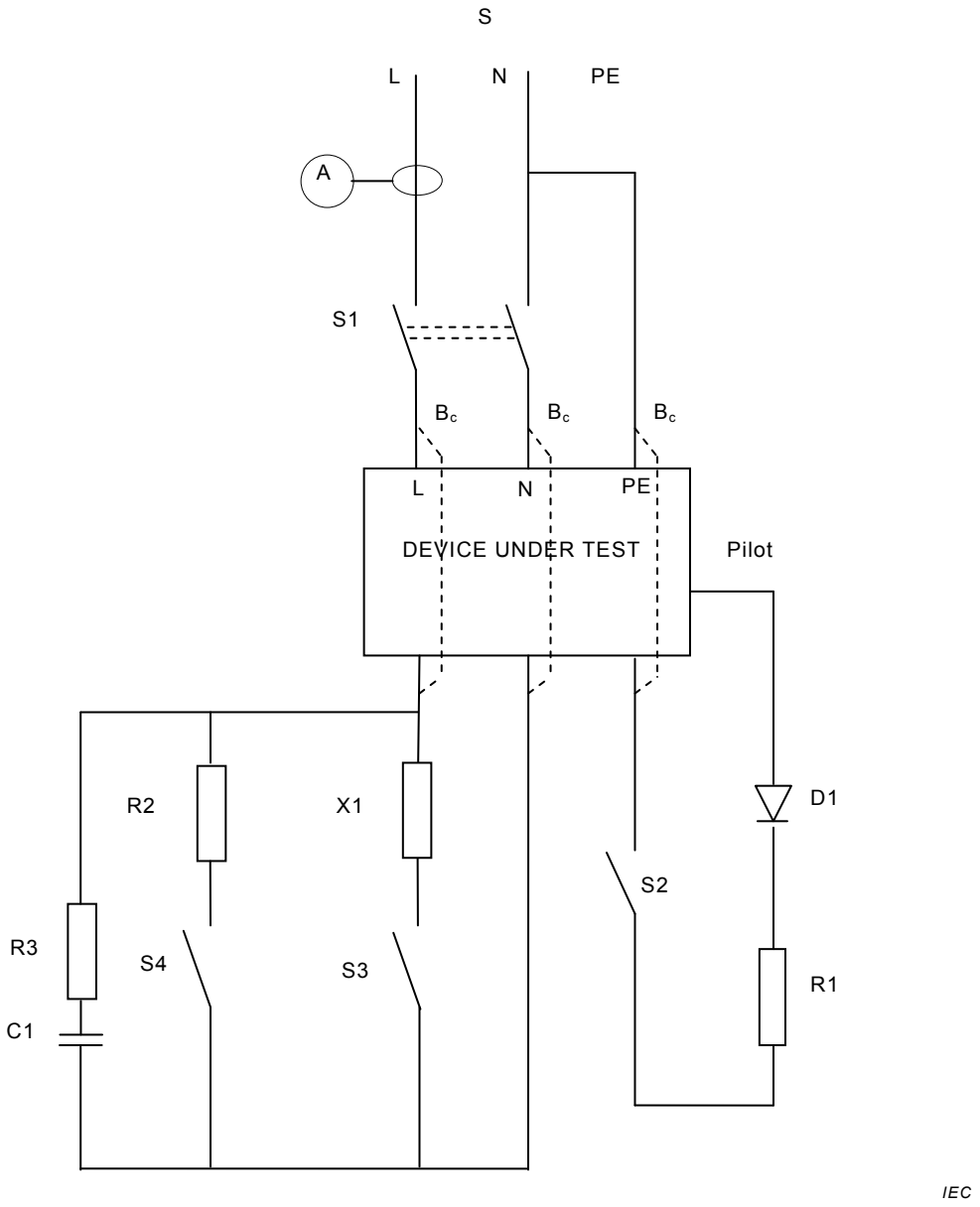
D IC-CPD under test

R_1 e.g. 10 Ω (any suitable value)

G arbitrary waveform generator (combination of, 50 Hz and 1 kHz)

A amperemeter

Figure 30 – Example of a test circuit for the verification of correct operation in case of residual sinusoidal alternating currents composed of multi-frequency components



The figure shows the LNSE-type.
For LLSE type, the connection from the supply is: L1 –L2 – PE.
For LLLNSE type, the connection from the supply is: L1 –L2 –L3–N–PE.

Key

S_1, S_2, S_3, S_4	switch
S	supply
D	device under test
R_1	resistor value 882 Ω ± 3 %
R_2	resistor
R_3	resistor
X_1	resistor and reactor to adjust rated current
C_1	capacitor
D_1	diode

Figure 31 – Test circuit for endurance test according to 9.8

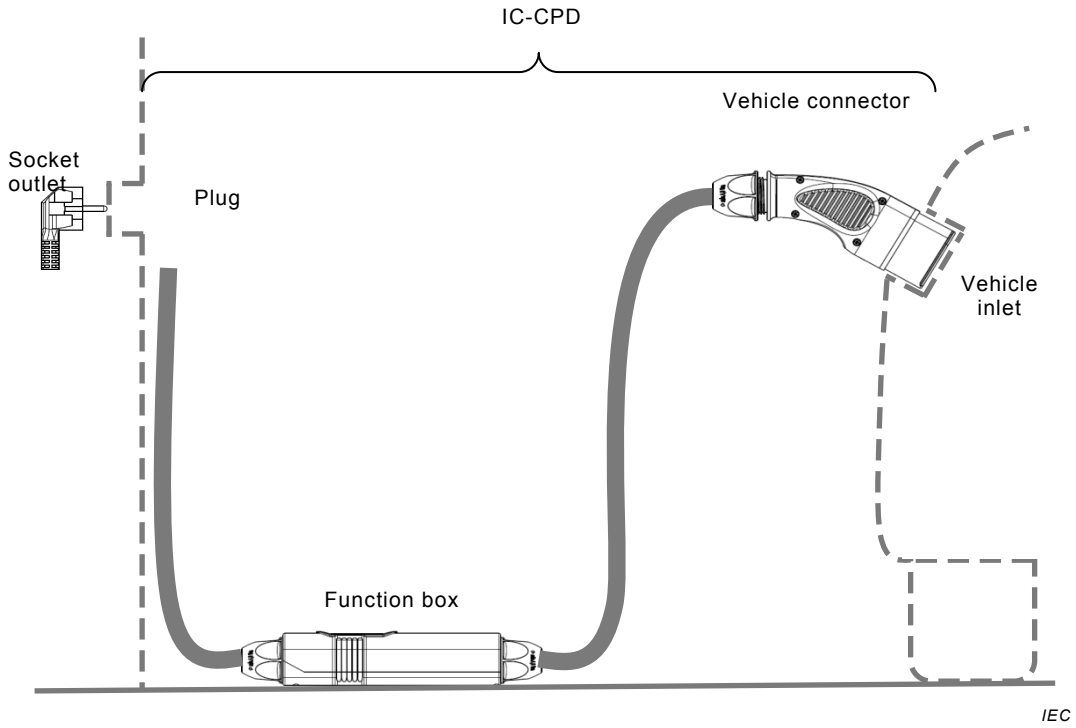
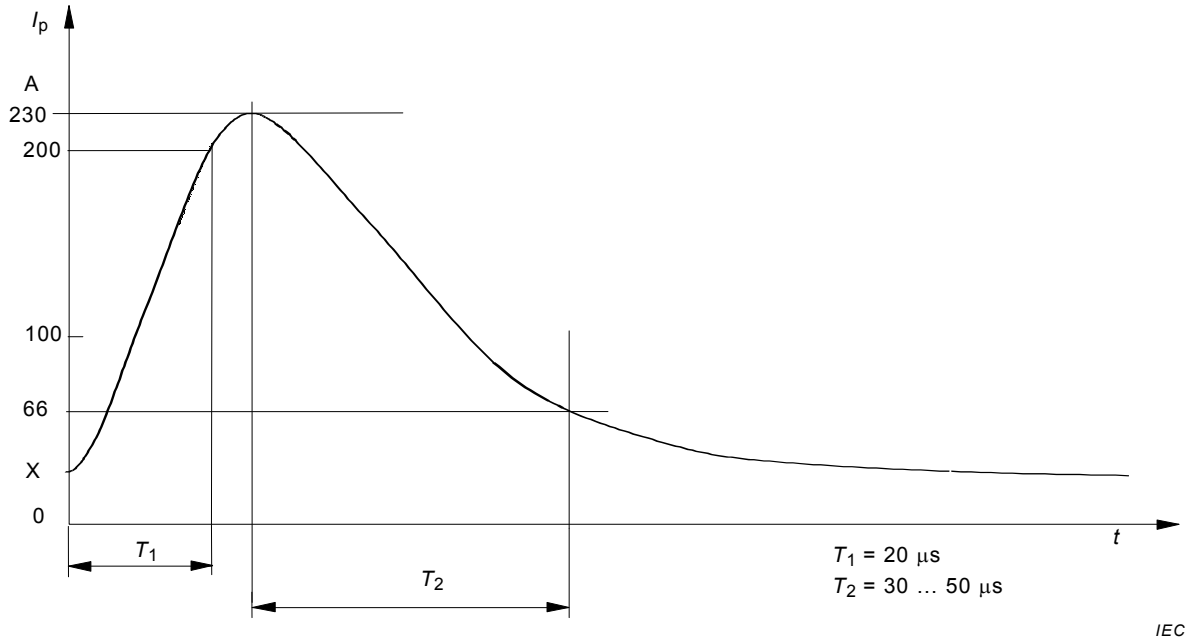


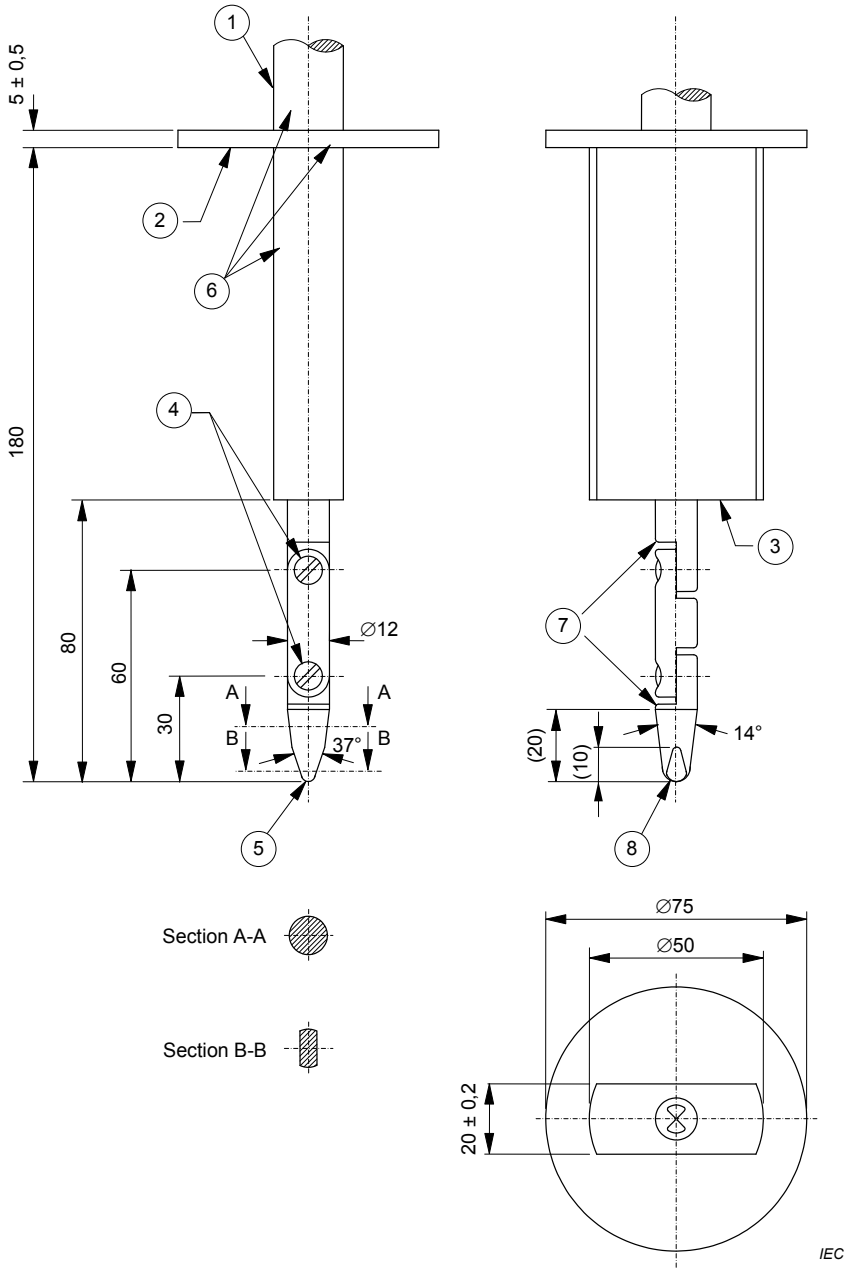
Figure 32 – The use of the IC-CPD



Key

X Starting value for the inrush current (0… 42 A) depending on the phase angle of the sinusoidal current of 30 A r.m.s.

Figure 33 – Informative wave shape of inrush current for tests according to 9.8.2



Key

1 Handle

2 Guard

3 Stop face

4 Joints

5 R2 ± 0,05 cylindrical

6 Insulating material

7 Chamfer all edges

8 R4 ± 0,05 spherical

Material : metal, except where otherwise specified
Tolerances on dimensions without specific tolerance:

on angles: $^{0}_{-10}$

on linear dimensions:

up to 25 mm: $^{0}_{-0,05}$

over 25 mm: ±0,2

Both joints shall permit movement in the same plane and the same direction through an angle of 90° with a tolerance of $^{+10}_{0}$ °.

Figure 34 – Test finger

Annex A
(normative)

Test sequences and number of samples to be submitted for verification of conformity to this standard

A.1 Verification of conformity

The following test sequences can be used:

– by the manufacturer for the purpose of the supplier's declaration;
– by an independent certification body.

For plugs the type tests shall be in accordance with IEC 60884-1, IEC 60309-1, or IEC 60309-2, as applicable.

For vehicle connectors the type tests shall be in accordance with IEC 62196-1.

A type test according to an appropriate national standard is also acceptable

A.2 Test sequences

The tests are made according to Table A.1 where the tests in each sequence are carried out in the order indicated.

Table A.1 – Test sequences

Test sequence		Clause or subclause	Test (or inspection)
A		6	Marking
			General [a]
		9.3	Indelibility of marking
		9.22	Strain on the conductors
		9.23	Torque exerted by IC-CPDs on fixed socket-outlets
		8.5.3	Degree of protection of the function box(es)
		9.4	Protection against electric shock
		9.11	Resistance to heat
		8.4.3	Clearances and creepage distances
		9.19	Resistance to tracking
		9.12	Resistance to abnormal heat and to fire
B		9.5	Test of dielectric properties
		9.6	Temperature rise
		9.17.2	Reliability at 45°C
		9.18	Ageing
		9.20	Test on pins provided with insulating sleeves
		IEC TS 62763:2013 Table 4[e]	Tests of the pilot function
C	C_1	9.9.3	Making and breaking capacity of the plug of the IC-CPD
		9.8	Mechanical and electrical endurance
		9.21	Mechanical strength of non-solid pins of plugs
		9.24	Tests of cord anchorage
		IEC TS 62763:2013, Table 4[e]	One test of the pilot function chosen at random
	C_2[b]	9.24	Tests of cord anchorage
	C_3[b]	9.25	Flexing test of non-rewirable IC-CPDs
D	D_0	9.7	Operating characteristics, 9.7.7 is made at the end of test sequence
	D_1	9.14	Behaviour in the case of failure of the supply voltage
		9.16	Unwanted tripping
		9.9.2.3	Performance at $I_{\Delta m}$
		9.13	Residual current function by self test
		9.10	Resistance to mechanical shock and impact
		9.15	Non-operating current under overcurrent conditions
		9.27	Tests replacing verifications of creepage distances and clearances
		9.28	Verifications for single electronic components used in IC-CPDs
E		9.9.2.4 a)	Coordination at I_{nc}
		9.9.2.2	Performance at I_m
		IEC TS 62763:2013, Table 4[e]	One test of the pilot function chosen at random
F		9.9.2.4 b)	Coordination at I_m
		9.9.2.4 c)	Coordination at $I_{\Delta c}$
		IEC TS 62763, Table 4[e]	One test of the pilot function chosen at random

Test sequence	Clause or subclause	Test (or inspection)
G	9.35 9.17.1 IEC TS 62763:2013, Table 4[e]	Low storage temperature test Reliability (climatic test) One test of the pilot function chosen at random
H [1)]	IEC 61543:1995 and IEC 61543:1995/AMD1:2004, [d] Table 4 -T1.1 IEC 61543:1995 and IEC 61543:1995/AMD1:2004 [d], Table 4 -T1.2 IEC 61543:1995 and IEC 61543:1995/AMD1:2004 [d], Table 5 -T2.3	Harmonics, interharmonics Signalling voltage Conducted unidirectional transients of the ms and μs time scale
I	IEC 61543:1995 and IEC 61543:1995/AMD1:2004 [d], Table 5 -T2.1[c] and T2.5 IEC 61543:1995 and IEC 61543:1995/AMD1:2004[d], Table 5 -T2.2	Conducted oscillatory voltages or currents Conducted unidirectional transients of the ns time scale (burst)
J	IEC 61543:1995 and IEC 61543:1995/AMD2:2005[d], Table 5 – T2.6[c] IEC 61543:1995 and IEC 61543:1995/AMD1:2004 [d], Table 6 -T3.1	Conducted common mode disturbances in the frequency range lower than 150 kHz Electrostatic discharges
K	9.30	Heat test under solar radiation
L	9.31	UV radiation
M	9.32	Damp and salt mist
N	9.34	Vehicle drive-over
O	IEC TS 62763:2013, Table 4[e] 9.29	Control pilot function controller Chemical loads
P	9.36	Shock and vibration test

a "General" consists of inspections and measurements contained in 8.1, 8.2 and 8.3. Individual tests of these subclauses may be performed at any convenient place within the test sequence A.

b Applies to non-rewirable devices.

c Use test levels as for 30 mA IC-CPDs .

d Wherever in IEC 61543" PRCDs / SRCDs" are mentioned it should read as "IC-CPD".

e IEC TS 62763:2013 will be reintroduced in the future edition 3 of IEC 61851-1.

f For devices containing a continuously operating oscillator, the test of the CISPR 14 series shall be carried out on the samples prior to the tests of this sequence.

A.3 Number of samples to be submitted for full test procedure

If only one type of IC-CPD of one current rating and one residual operating current rating is submitted for test, the number of samples to be submitted to the different test series is those indicated in Table A.2 where the minimum performance criteria are also indicated.

If all samples submitted according to the second column of Table A.2 pass the tests, compliance with the standard is met. If only the minimum numbers given in the third column

pass the tests, additional samples, as shown in the fourth column, shall be tested and all shall then satisfactorily complete the test sequence.

NOTE For the temperature-rise tests of 9.6 a specially prepared sample with the trip circuit disabled can be required.

Table A.2 – Number of samples to be submitted for full test procedure

Test sequence [a]	Number of samples	Minimum number of accepted samples [b]	Number of samples for repeated tests [c]
A	1	1	–
B [d, e]	3	2	3
C_1 [k] (9.9.3 and 9.8 only)	3	2	3
C_2 [f]	3	2	3
C_3 [f]	3	2	3
D_0 [f, g, k]	3	2	3
D_1 [h, l]	3	2	3
E [f, i, k, l]	3	2	3
F [f, i, k, l]	3	2	3
G	3	2	3
H [f, j, k]	3	2	3
I [f, j, k]	3	2	3
J [f, j, k]	3	2	3
K	3	2	3
L	3	2	3
M	3	2	3
N	3	2	3
O	3	2	3
P	3	2	3

a In total, a maximum of three test sequences may be repeated.

b It is assumed that a sample which has not passed a test has not met the requirements due to workmanship or assembly defects which are not representative of the design.

c In the case of repeated tests, all tests shall be passed successfully.

d A specially prepared sample with electronics not subject to the impulse is required.

e For the temperature rise tests of the protective conductor, a specially prepared sample with the trip circuit disabled may be required.

f If requested by the manufacturer, the tests shall be done on only one (or two) set(s) of samples.

g An additional sample is required for the −25 °C test.

h If dismantling for test purposes is necessary, one more sample may be necessary. In this case, the manufacturer shall supply samples which may be specially prepared.

i (A) new sample(s) may be used for the I_{nc} tests.

j On request of the manufacturer the same set of samples may be subjected to more than one of these test sequences.

k if an IC-CPD is classified to more than one classification of 4.1 an additional set of samples shall be submitted for each classification. The acceptance criteria apply as given.

l For IC-CPD with a non-replaceable integral fuse a second set of samples is required see 9.9.2.1 f).

A.4 Number of samples to be submitted for simplified test procedures in case of submitting simultaneously a range of IC-CPDs of the same fundamental design

A.4.1 If a range of IC-CPDs of the same fundamental design, or additions to such a range of IC-CPDs, are submitted for conformity assessment, the number of samples to be tested may be reduced according to Table A.3.

NOTE For the purposes of Annex A, the same fundamental design comprises a series of rated currents (I_n) and a series of rated residual operating currents ($I_{\Delta n}$).

IC-CPDs can be considered to be of the same fundamental design if the conditions from a) to j) inclusive are satisfied.

a) They have the same basic design, in particular:
   – fused IC-CPDs and non-fused IC-CPDs shall not occur together in the same range.
b) The residual current operating means have identical tripping mechanisms and identical relays or solenoids except for the variations permitted in l) and m).
c) The materials, finish and dimensions of the internal current-carrying parts are identical other than the variations detailed in k) below.
d) The contact size, material, configuration and method of attachment are identical.
e) The manual operating mechanism, materials and physical characteristics are identical.
f) The moulding and insulating materials are identical.
g) The method, materials and construction of the arc extinction device are identical.
h) The basic design of the residual current sensing device is identical other than the variations permitted in l) and m) below.
i) The basic design of the residual current tripping device is identical except for the variations permitted in m) below.
j) The basic design of the test device, if any, is identical except for the variations permitted in n) below.

The following variations are permitted provided that the IC-CPDs comply in all other respects with the requirements detailed above.

k) Cross-sectional area of the internal current-carrying connecting means.
l) Number of turns and cross-sectional area of the windings and the size and material of the core of the differential transformer.
m) The sensitivity of the relay and/or the associated electronic circuit, if any.

A.4.2 For IC-CPDs of the same fundamental design, having different current rating and rated residual current, the number of samples to be tested may be reduced according to Table A.3.

Table A.3 – Reduction of number of samples

Test sequence	Number of samples [a]	
A	1	max. rating I_n min. rating $I_{\Delta n}$
B	3	max. rating I_n min. rating $I_{\Delta n}$
C_1	3	max. rating I_n min. rating $I_{\Delta n}$
C_2 or C_3	3	of any rating I_n or $I_{\Delta n}$
$D_0 + D_1$	3	max. rating I_n min. rating $I_{\Delta n}$
D_0	1	for all other ratings of $I_{\Delta n}$
E	3	max. rating I_n min. rating $I_{\Delta n}$
F	3	max. rating I_n min. rating $I_{\Delta n}$
	3[b]	min. rating I_n max. rating $I_{\Delta n}$
G	3	max. rating I_n min. rating $I_{\Delta n}$
H	3 [c] any rating I_n , min. rating $I_{\Delta n}$	
I	3 [c] any rating I_n , min. rating $I_{\Delta n}$	
J	3 [c] any rating I_n , min. rating $I_{\Delta n}$	
K	3 any rating I_n , min. rating $I_{\Delta n}$	
L	3 any rating I_n , min. rating $I_{\Delta n}$	
M	3 any rating I_n , min. rating $I_{\Delta n}$	
N	3 any rating I_n , min. rating $I_{\Delta n}$	
O	3 any rating I_n , min. rating $I_{\Delta n}$	
P	3 any rating I_n , min. rating $I_{\Delta n}$	

a If a test is to be repeated according to the minimum performance criteria of Clause A.3, a new set of samples is used for the relevant test. In the repeated test, all test results shall be acceptable.

b If only one value of $I_{\Delta n}$ is submitted, these sets of samples are not required.

c Only the highest number of current paths.

Annex B
(normative)

Routine tests

In general, tests may have to be made to ensure that the IC-CPD conforms with the samples that withstood the tests of this standard, according to the experience gained by the manufacturer.

The choice of the proper tests is left to the manufacturer.

Annex C
(normative)

Determination of clearances and creepage distances

C.1 Overview

In determining clearances and creepage distances, it is recommended that the following points should be considered.

C.2 Orientation and location of a creepage distance

If necessary, the manufacturer shall indicate the intended orientation of the equipment or component in order that creepage distances are not adversely affected by the accumulation of pollution for which they were not designed.

C.3 Creepage distances where more than one material is used

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.

C.4 Creepage distances split by a floating conductive part

A creepage distance may be split into several parts, made with insulation material having the same CTI, and including or separated by floating conductors as long as the sum of the distances across each individual part is equal to 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 (see also Example 11) of IEC 60664-1:2007.

C.5 Measurement of creepage distances and clearances

In determining creepage distances according to IEC 60664-1, the dimension X, specified in the following examples, has a minimum value of 1,0 mm for pollution degree 2.

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

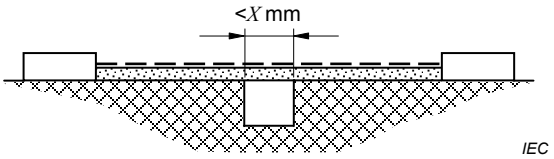
The methods of measuring creepage distances and clearances are indicated in the following Examples 1 to 11. These cases do not differentiate between gaps and grooves or between types of insulation.

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 the 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.

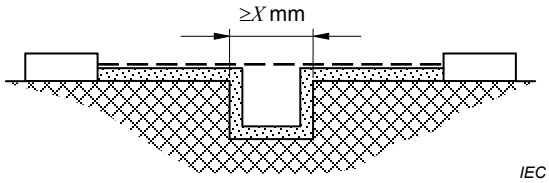
– Example 1



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.

1 clearance 2 creepage distance

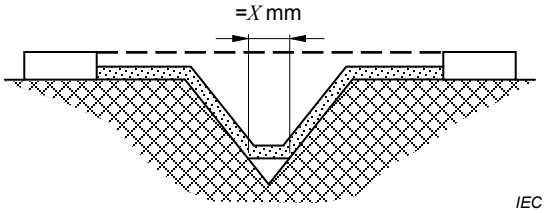
– Example 2



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.

1 clearance 2 creepage distance

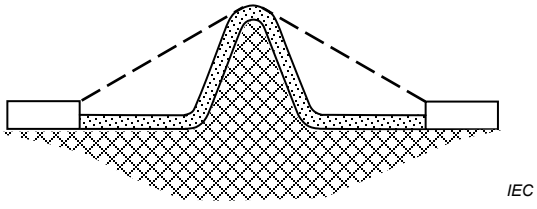
– Example 3



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.

1 clearance 2 creepage distance

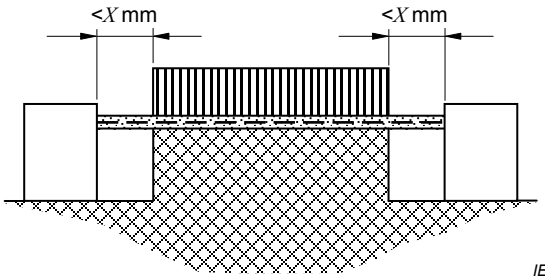
– Example 4



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.

1 clearance 2 creepage distance

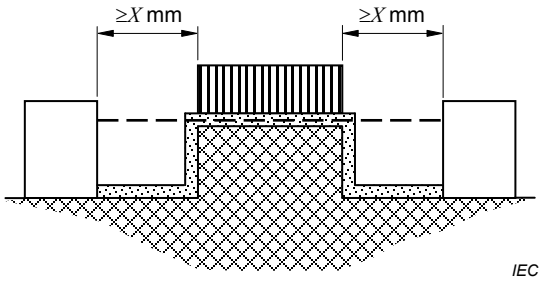
– Example 5



Condition: Path under consideration includes an uncemented joint with groove less than X mm wide on each side.
Rule: Creepage and clearance path is the 'line of sight' distance shown.

1 clearance 2 creepage distance

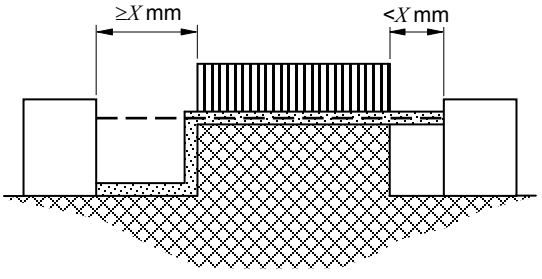
– Example 6



Condition: Path under consideration includes an uncemented joint with grooves equal to or more than X mm wide on each side.
Rule: Clearance is the 'line of sight' distance. Creepage path follows the contour of the grooves.

1 clearance 2 creepage distance

– Example 7

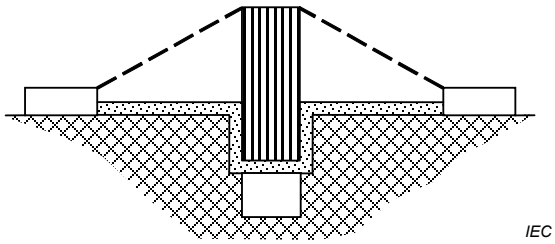


Condition: Path under consideration includes an uncemented joint with a groove on one side less than X mm wide and the groove on the other side equal to or more than X mm wide.

Rule: Clearance and creepage paths are as shown.

1 clearance 2 creepage distance

– Example 8

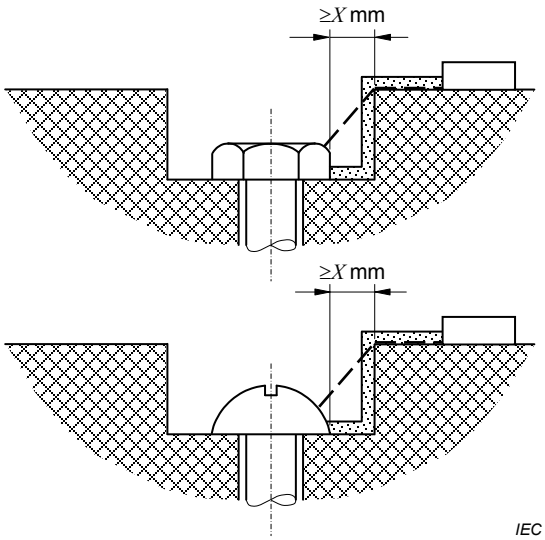


–

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.

1 clearance 2 creepage distance

– Example 9

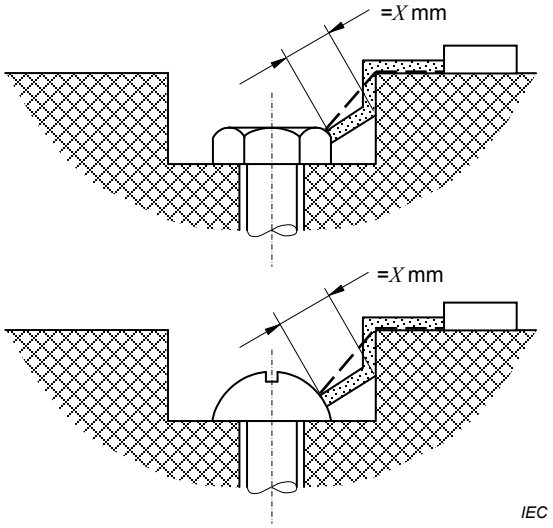


–

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

1 clearance 2 creepage distance

– Example 10

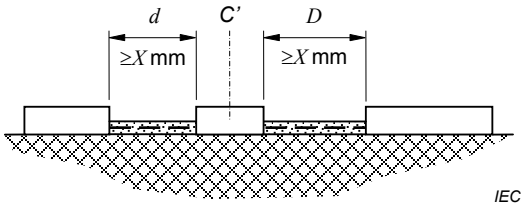


–

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.

1 clearance 2 creepage distance

– Example 11



–

Clearance is the distance $d + D$
Creepage distance is also $d + D$
C' Floating part

1 clearance 2 creepage distance

Annex D
(informative)

Switched-protective conductor application

D.1 Explanation of switched-protective conductor (SPE) function and application

IC-CPDs for special use are covered by this standard. IC-CPDs classified according to 3.3.3.11, 3.3.3.12 and 3.3.3.13 have a switched protective earth (SPE) and offer additional protection against certain hazardous situations.

PRCDs for household and similar use are covered by IEC 61540.

For mode 2 power supply of EVs according to IEC 61851-1 an IC-CPD offers supplementary protection where the correct wiring of the supply or the existence of an operating RCD with a rated operating residual current not exceeding 0,03 A upstream has not been verified.

The SPE ensures that if the protective conductor is live the SPE unit cannot be closed at all or disconnects in case of a residual current. If the protective conductor is not switched then a live protective conductor could remain connected to the exposed metal of class I equipment. A person contacting a live protective conductor will remain connected.

The protective conductor circuit of an IC-CPD should be of high integrity. Tests of the protective conductor circuit for temperature rise and short-circuit withstand are included to ensure this high integrity.

IEC 60364 requires that the installation protective conductor cannot be switched. This ensures that class 1 equipment is always connected to the protective conductor and hence earthed when in use. The opening of the protective conductor to class I equipment supplied by a plug occurs every time the plug is removed. The IC-CPD also has the protective conductor circuit open before plugging in. The line and neutral contacts are linked to the protective conductor contact and cannot close unless the protective conductor contact also closes. When plugging in to the supply, if the supply conditions allow the IC-CPD to close, then the protective conductor, line and neutral contacts all close substantially together. The integrity of the protective conductor to class I equipment, when supplied from an IC-CPD, is the same as when supplied from a PRCD of the IEC 61540 type, or from a normal plug. Therefore class I equipment supplied by the IC-CPD has the protective conductor connected and hence earthed when in use.

Table 14 and Table 15 give the tests required for the SPE units. These include tests for a hazardous live protective conductor (with variations of L and N supply), and open circuit N and an open circuit protective conductor.

In some countries a reversal of the supply polarity of L and N is regarded as hazardous if the L is not switched correctly. An open circuit earth is regarded as a loss of fundamental protection for class I equipment. A loss of the neutral supply may also be considered a hazard and is covered by the IC-CPD functional tests.

A hazardous live protective conductor is defined in 3.3.3.18 of this standard. This can be caused by incorrect supply if miswiring of the socket outlet occurs.

Examples of some common hazardous situations are included in the Figure D.1 and Figure D.2.

The outcome of the tests ensures that the IC-CPD provides additional protection against miswiring faults and that the residual current function is not impaired for a residual current flow from any conductor that is live.

The IC-CPD may detect a live protective conductor but in some cases (such as NLL) closure may occur. In such a rare case, it is imperative that the IC-CPD still operates on a residual current. A consequence is that the protective conductor may pass through the toroid. The outcome is also that when a current from an external source flows only in the protective conductor then the SPE unit may operate. This is regarded as an acceptable result. Acceptance of the protective conductor through the sensing toroid solved many of the difficulties in recognizing certain faults and provides the IC-CPD the ability to recognize unsafe residual currents on all live conductors.

Consideration has been given in evaluating the risk of a current from external source flowing alone in the protective conductor circuit. For applications covered by this standard it is seen to be unlikely and a smaller risk.

D.2 Examples of incorrect supply wiring

Provided above each diagram in abbreviated form are the conclusions after analysing the effect of the miswired configurations.

According to the following legend (obvious indicators such as open N and open protective conductor are omitted):

a) $< U_e$: = reduced IC-CPD supply voltage.

b) For LLSE subject to a supply configuration typically 0,5 for single phase, 0,577 for two-phase: U_e (0,5 or 0,577).

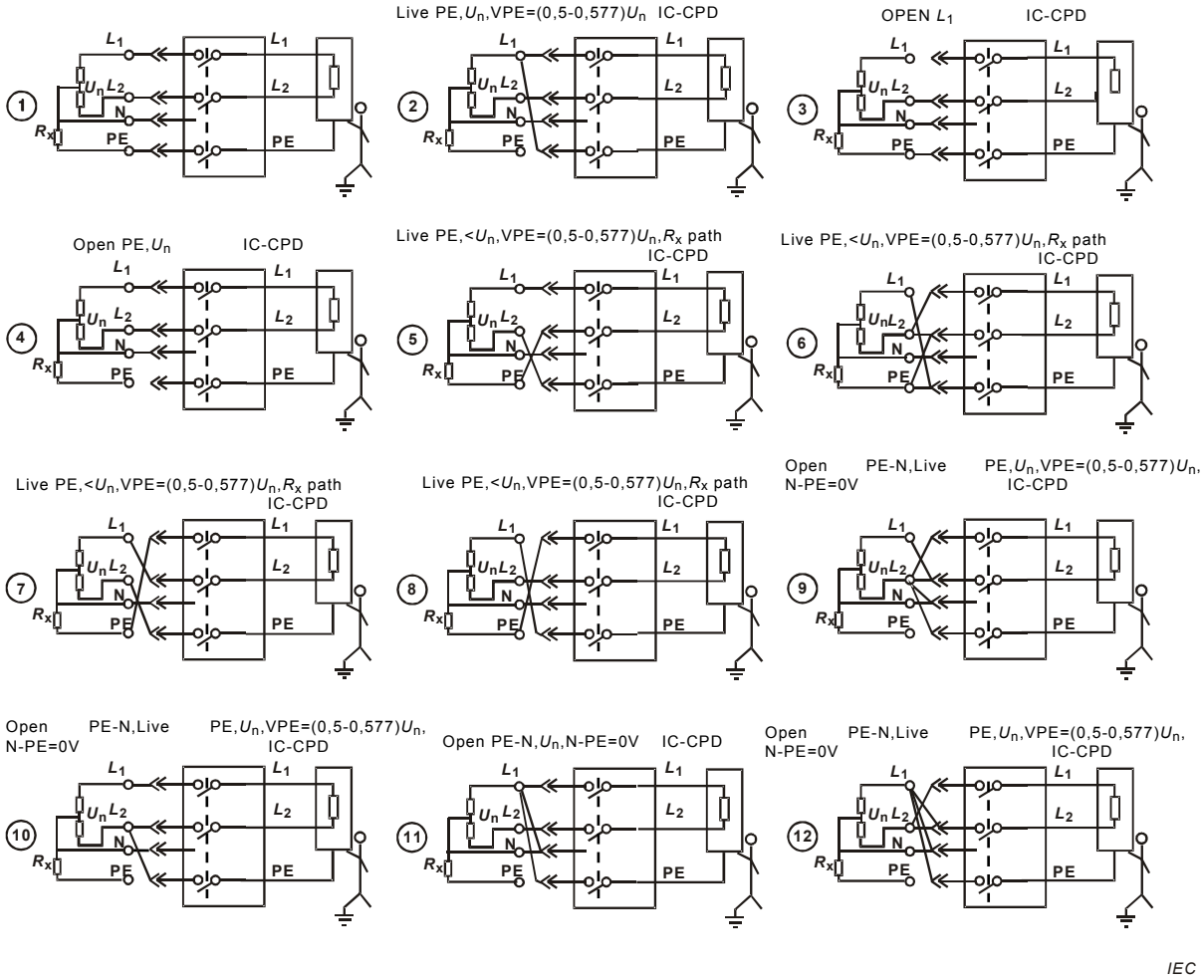
c) For LNSE subject to the R_x path: ratio between the load impedance (R_L) and the earth loop return impedance (R_x): U_e ($R_L/(R_L + R_x)$.

NOTE For example, considering the value of R_x = 200 Ω for the reversal of the neutral and the protective conductor, with a load current of 15 A, almost all the supply voltage to the IC-CPD would be lost. The test of 9.14 covers this situation.

R_x path: (for TT systems) = earth loop impedance (R_x) in series with load impedance.

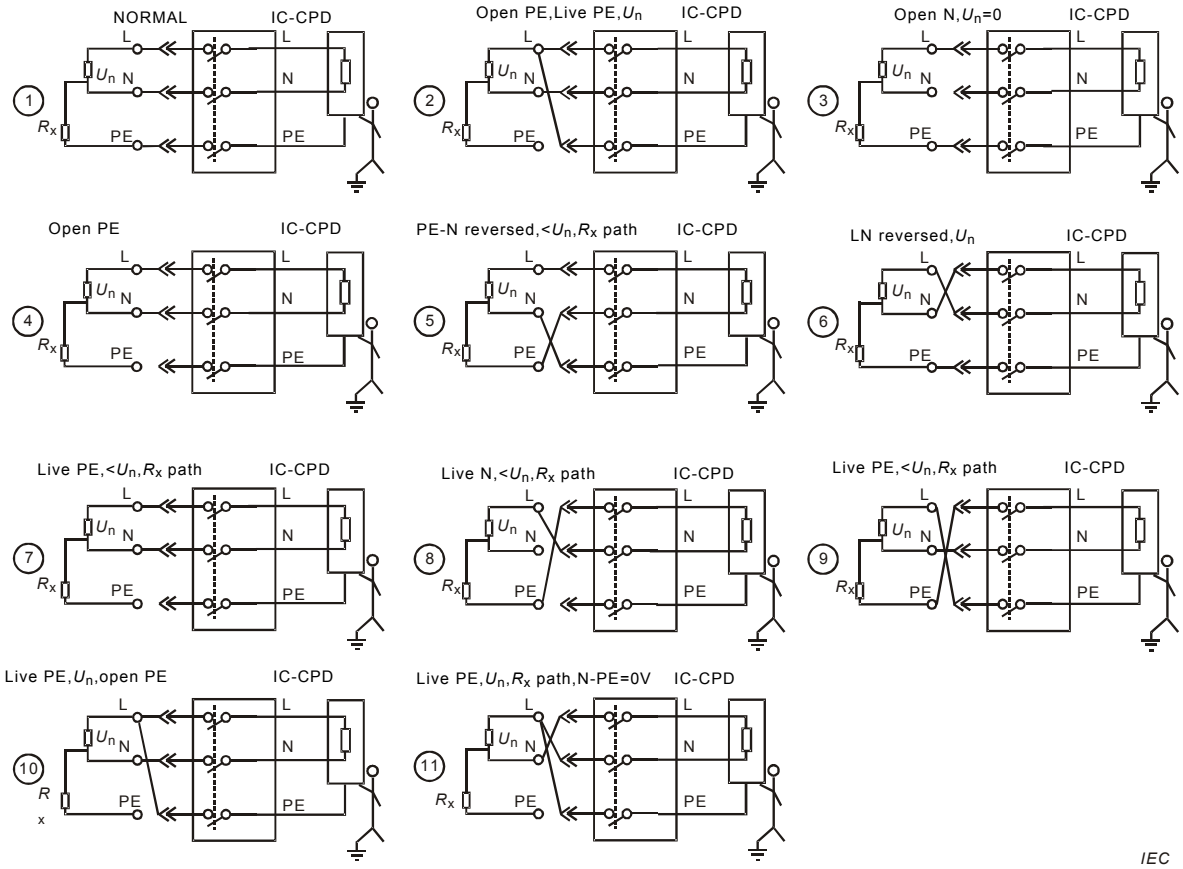
N − PE = 0 V: = neutral (N) and protective conductor (PE) connected together.

Live protective conductor: the protective conductor is connected to a live supply conductor.



NOTE R_x (200 Ω max.) is illustrated for TT systems.

Figure D.1 – Examples of incorrect supply wirings for LLSE types



NOTE R_X (200 Ω max.) is illustrated for TT systems.

Figure D.2 – Examples of incorrect supply wirings for LNSE types

Annex E
(informative)

Example of IC-CPD for mode 2 charging

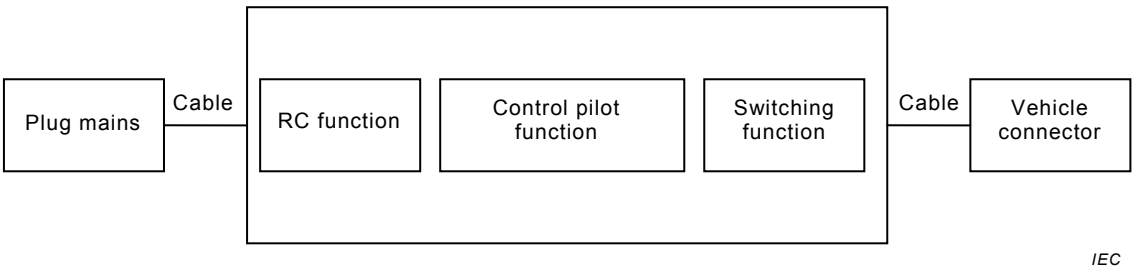


Figure E.1 – Example for IC-CPD showing the different parts and functions

Annex F
(informative)

Types of IC-CPD according to construction and assembly

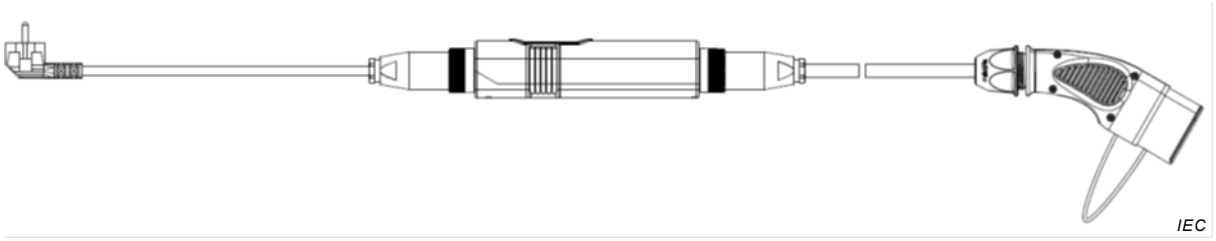


Figure F.1 – Example of IC-CPD including function box, cables, plug and connector according to 4.2.2

Figure F.2 – Example of plug integrated function box according to 4.2.3

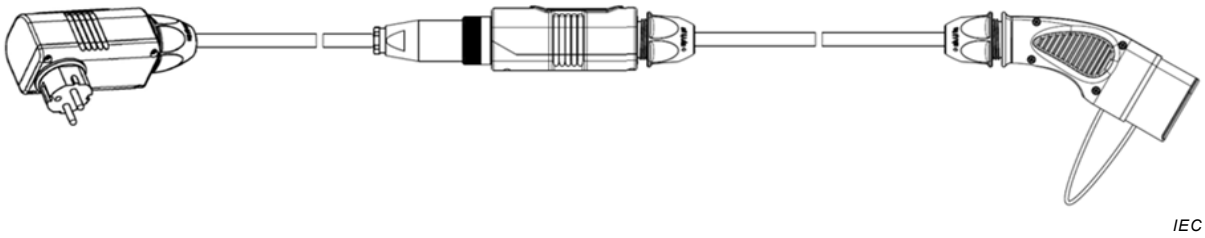


Figure F.3 – Example of modular IC-CPD according to 4.2.4a)

Figure F.4 – Example of modular IC-CPD according to 4.2.4b)

Annex G
(informative)

Methods for determination of short-circuit power factor

G.1 Overview

There is no uniform method by which the short-circuit power factor can be determined with precision. Two examples of acceptable methods are given in Annex G.

G.2 Method I – Determination from d.c. components

The angle φ may be determined from the curve of the d.c. component of the asymmetrical current wave between the instant of the short-circuit and the instant of contact separation.

The formula for the d.c. component is

$$I_d = I_{do} \times e^{-Rt/L}$$

where

I_d is the value of d.c. components at the instant t;

I_{do} is the value of the d.c. component at the instant taken as time origin;

L/R is the time-constant of the circuit, in (s);

t is the time, in seconds, taken from the initial instant;

e is the base of the Neperian logarithms.

The time-constant L/R can be ascertained from the above formula as follows:

a) measure the value of I_{do} at the instant of short-circuit and the value of I_d at another instant t before the contact separation;

b) determine the value of $e^{-Rt/L}$ by dividing I_d by I_{do};

c) from a table of values of e^{-x} determine the value of –x corresponding to the ratio of I_d / I_{do};

d) the value x represents Rt/L from which L/R is obtained.

Determine the angle from:

$$\varphi = \text{art tan } \omega \text{ L/R}$$

where ω is 2 π times the actual frequency.

This method should not be used when the currents are measured by current transformers.

G.3 Method II – Determination with pilot generator

When a pilot generator is used on the same shaft as the test generator, the voltage of the pilot generator on the oscillogram may be compared in phase first with the voltage of the test generator and then with the current of the test generator.

The difference between the phase angles between the pilot generator voltage and the main generator voltage on the one hand, and the pilot generator voltage and test generator current

on the other hand, gives the phase angle between the voltage and current of the test generator from which the power factor can be determined.

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BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

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