BS EN 62477-1:2012+A11:2014

BSI Standards Publication

Safety requirements for power electronic converter systems and equipment

Part 1: General

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National foreword

This British Standard is the UK implementation of EN 62477-1:2012+A11:2014. It is identical to IEC 62477-1:2012. It supersedes BS EN 62477-1:2012, which will be withdrawn on 18 July 2017. It also partially supersedes BS EN 50178:1998.

The UK participation in its preparation was entrusted to Technical Committee PEL/22, Power electronics.

A list of organizations represented on this committee 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.

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Amendments/corrigenda issued since publication

Date	Text affected
30 September 2014	Implementation of CENELEC amendment A11:2014: EN supersession information updated

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 62477-1+A11

August 2014

ICS 29.200

This document partially supersedes EN 50178:1997

English version

Safety requirements for power electronic converter systems and equipment - Part 1: General
(IEC 62477-1:2012)

Exigences de sécurité applicables aux systèmes et matériels électroniques de conversion de puissance -
Partie 1: Généralités
(CEI 62477-1:2012)

Sicherheitsanforderungen an Leistungshalbleiter-Umrichtersysteme und -betriebsmittel -
Teil 1: Allgemeines
(IEC 62477-1:2012)

This European Standard was approved by CENELEC on 2012-08-28. 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.

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CENELEC

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

Management Centre: Avenue Marnix 17, B - 1000 Brussels

Ref. No. EN 62477-1:2012 E

Foreword

The text of document 22/200/FDIS, future edition 1 of IEC 62477-1, prepared by IEC/TC 22 "Power electronic systems and equipment" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62477-1:2012.

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)	2013-05-28
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2015-08-28

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Endorsement notice

The text of the International Standard IEC 62477-1:2012 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 60073:2002	NOTE	Harmonised as EN 60073:2002 (not modified).
IEC 60085	NOTE	Harmonised as EN 60085.
IEC 60216 Series	NOTE	Harmonised as EN 60216 Series (not modified).
IEC 60309-1	NOTE	Harmonised as EN 60309-1.
IEC 60664-5:2007	NOTE	Harmonised as EN 60664-5:2007 (not modified).
IEC 60695-11-5	NOTE	Harmonised as EN 60695-11-5.
IEC 60721 Series	NOTE	Harmonised as EN 60721 Series (not modified).
IEC 60947-7-1	NOTE	Harmonised as EN 60947-7-1.
IEC 60947-7-2	NOTE	Harmonised as EN 60947-7-2.
IEC 60950-1	NOTE	Harmonised as EN 60950-1.
IEC 61008 Series	NOTE	Harmonised as EN 61008 Series (partly modified).
IEC 61009 Series	NOTE	Harmonised as EN 61009 Series (partly modified).
IEC 61082-1	NOTE	Harmonised as EN 61082-1.
IEC 61140:2001	NOTE	Harmonised as EN 61140:2002 (not modified).
IEC 61508 Series	NOTE	Harmonised as EN 61508 Series (not modified).
IEC 61558-1	NOTE	Harmonised as EN 61558-1.
IEC 61558-2-16	NOTE	Harmonised as EN 61558-2-16.
IEC 61643-12	NOTE	Harmonised as CLC/TS 61643-12.
IEC 62079:2001	NOTE	Harmonised as EN 62079:2001 (not modified).
IEC 62423:2009	NOTE	Harmonised as EN 62423:2012 (modified).

Foreword to amendment A11

This document (EN 62477-1:2012/A11:2014) has been prepared by CLC/TC 22X "Power electronics".

The aim behind this Amendment is to link EN 62477-1:2012 to the Low Voltage Directive 2006/95/EC, further to a CLC/TC 22X request, approved by the Technical Board by the decision D146/C017.

In addition, a recent Technical Board decision (D147/C061), confirmed that EN 62477-1:2012 partially supersedes EN 50178:1997.

Add to the Foreword of EN 62477-1:2012:
"This document partially supersedes EN 50178:1997."

The following dates are fixed:

• latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2015-07-18
• latest date by which the national standards conflicting with this document have to be withdrawn	(dow)	2017-07-18

This standard covers the Principle Elements of the Safety Objectives for Electrical Equipment Designed for Use within Certain Voltage Limits (LVD - 2006/95/EC).

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.

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 When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60050	Series	International Electrotechnical Vocabulary (IEV)	-	-
IEC 60060-1	2010	High-voltage test techniques - Part 1: General definitions and test requirements	EN 60060-1	2010
IEC 60068-2-2	-	Environmental testing - Part 2-2: Tests - Test B: Dry heat	EN 60068-2-2	-
IEC 60068-2-6	-	Environmental testing - Part 2-6: Tests - Test Fc: Vibration (sinusoidal)	EN 60068-2-6	-
IEC 60068-2-52	-	Environmental testing - Part 2-52: Tests - Test Kb: Salt mist, cyclic (sodium chloride solution)	EN 60068-2-52	-
IEC 60068-2-68	-	Environmental testing - Part 2: Tests - Test L: Dust and sand	EN 60068-2-68	-
IEC 60068-2-78	2001	Environmental testing - Part 2-78: Tests - Test Cab: Damp heat, steady state	EN 60068-2-78	2001
IEC 60112 + corr. June + corr. October	2003 2003 2003	Method for the determination of the proof and the comparative tracking indices of solid insulating materials	EN 60112	2003
IEC 60216-4-1	-	Electrical insulating materials - Thermal endurance properties - Part 4-1: Ageing ovens - Single-chamber ovens	EN 60216-4-1	-
IEC 60364-1	-	Low-voltage electrical installations - Part 1: Fundamental principles, assessment of general characteristics, definitions	HD 60364-1	-
IEC 60364-4-41 (mod)	2005	Low-voltage electrical installations - Part 4-41: Protection for safety - Protection against electric shock	HD 60364-4-41 + corr. July	2007 2007
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 60364-5-54	2011	Low-voltage electrical installations - Part 5-54: Selection and erection of electrical equipment - Earthing arrangements and protective conductors	HD 60364-5-54	2011

Publication	Year	Title	EN/HD	Year
IEC 60417-DB		Graphical symbols for use on equipment	-	-
IEC/TS 60479-1	-	Effects of current on human beings and livestock - Part 1: General aspects	-	-
IEC 60529	1989	Degrees of protection provided by enclosures (IP Code)	EN 60529 + corr. May	1991 1993
IEC 60617-DB		Graphical symbols for diagrams	-	-
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	2003	Insulation coordination for equipment within low-voltage systems - Part 3: Use of coating, potting or moulding for protection against pollution	EN 60664-3	2003
IEC 60664-4	2005	Insulation coordination for equipment within low-voltage systems - Part 4: Consideration of high-frequency voltage stress	EN 60664-4 + corr. October	2006 2006
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 + corr. January	2000 2001	Fire hazard testing - Part 2-11: Glowing/hot-wire based test methods - Glow-wire flammability test method for end-products	EN 60695-2-11	2001
IEC 60695-2-13	-	Fire hazard testing - Part 2-13: Glowing/hot-wire based test methods - Glow-wire ignition temperature (GWIT) test method for materials	EN 60695-2-13	-
IEC 60695-10-2	-	Fire hazard testing - Part 10-2: Abnormal heat - Ball pressure test	EN 60695-10-2	-
IEC 60695-11-10	-	Fire hazard testing - Part 11-10: Test flames - 50 W horizontal and vertical flame test methods	EN 60695-11-10	-
IEC 60695-11-20	-	Fire hazard testing - Part 11-20: Test flames - 500 W flame test methods	EN 60695-11-20	-
IEC 60721-3-3	-	Classification of environmental conditions - Part 3: Classification of groups of environmental parameters and their severities - Section 3: Stationary use at weatherprotected locations	EN 60721-3-3	-
IEC 60721-3-4	-	Classification of environmental conditions - Part 3: Classification of groups of environmental parameters and their severities - Section 4: Stationary use at non-weatherprotected locations	EN 60721-3-4	-

Publication	Year	Title	EN/HD	Year
IEC 60730-1	-	Automatic electrical controls for household and similar use - Part 1: General requirements	EN 60730-1	-
IEC/TR 60755	-	General requirements for residual current operated protective devices	-	-
IEC 60949	-	Calculation of thermally permissible short-circuit currents, taking into account non-adiabatic heating effects	-	-
IEC 60990	1999	Methods of measurement of touch current and protective conductor current	EN 60990	1999
IEC 61032 + corr. January	1997 2003	Protection of persons and equipment by enclosures - Probes for verification	EN 61032	1998
IEC 61180-1	1992	High-voltage test techniques for low-voltage equipment - Part 1: Definitions, test and procedure requirements	EN 61180-1	1994
IEC Guide 104	2010	The preparation of safety publications and the use of basic safety publications and group safety publications	-	-
IEC Guide 117	2010	Electrotechnical equipment - Temperatures of touchable hot surfaces	-	-
ISO 3746	-	Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Survey method using an enveloping measurement surface over a reflecting plane	EN ISO 3746	-
ISO 3864-1	-	Graphical symbols - Safety colours and safety signs - Part 1: Design principles for safety signs in workplaces and public areas	-	-
ISO 7000	-	Graphical symbols for use on equipment - Index and synopsis	-	-
ISO 7010	-	Graphical symbols - Safety colours and safety signs - Registered safety signs	EN ISO 7010	-
ISO 9614-1	-	Acoustics - Determination of sound power levels of noise sources using sound intensity - Part 1: Measurement at discrete points	EN ISO 9614-1	-
ISO 9772	-	Cellular plastics - Determination of horizontal burning characteristics of small specimens subjected to a small flame	-	-
ANSI/ASTM E84-11b	-	Standard test method for surface burning characteristics of building materials	-	-
ASTM E162-11a	-	Standard test method for surface flammability of materials using a radiant heat energy source	-	-

CONTENTS

INTRODUCTION

This International Standard relates to products that include power electronic converters, with a rated system voltage not exceeding 1 000 V a.c. or 1 500 V d.c. It specifies requirements to reduce risks of fire, electric shock, thermal, energy and mechanical hazards, except functional safety as defined in IEC 61508. The objectives of this document are to establish a common terminology and basis for the safety requirements of products that contain power electronic converters across several IEC technical committees.

This standard has been developed with the intention:

- to be used as a reference document for product committees inside TC 22 in the development of product standards for power electronic converter systems and equipment;
- to replace IEC 62103 as a product family standard providing minimum requirements for safety aspects of power electronic converter systems and equipment in apparatus for which no product standard exists; and

NOTE The scope of IEC 62103 contains reliability aspects, which are not covered by this standard.

- to be used as a reference document for product committees outside TC 22 in the development of product standards of power electronic converter systems and equipment intended renewable energy sources. TC 82, TC 88, TC 105 and TC 114, in particular, have been identified as relevant technical committees at the time of publication.

Technical committees using this document should carefully consider the relevance of each paragraph in this document for the product under consideration and reference, add, replace or modify requirement as relevant. Product specific topics not covered by this document are in the responsibility of the technical committees using this document as reference document.

This group safety standard will not take precedence on any product specific standard according to IEC Guide 104. IEC Guide 104 provides information about the responsibility of product committees to use group safety standards for the development of their own product standards.

SAFETY REQUIREMENTS FOR POWER ELECTRONIC CONVERTER SYSTEMS AND EQUIPMENT –

Part 1: General

1 Scope

This part of IEC 62477 applies to Power Electronic Converter Systems (PECS) and equipment, their components for *electronic power conversion* and electronic power switching, including the means for their control, protection, monitoring and measurement, such as with the main purpose of converting electric power, with rated system voltages not exceeding 1 000 V a.c. or 1 500 V d.c.

This document may also be used as a reference standard for product committees producing product standards for:

- adjustable speed electric power drive systems (PDS);
- standalone uninterruptible power systems (UPS);
- low voltage stabilized d.c. power supplies.

For PECS for which no product standard exists, this standard provides minimum requirements for safety aspects.

This part of IEC 62477 has the status of a group safety publication in accordance with IEC Guide 104 for power electronic converter systems and equipment for solar, wind, tidal, wave, fuel cell or similar energy sources.

According to IEC Guide 104, one of the responsibilities of technical committees is, wherever applicable, to make use of basic safety publications and/or group safety publications in the preparation of their product standards.

This International Standard:

- establishes a common terminology for safety aspects relating to PECS and equipment;
- establishes minimum requirements for the coordination of safety aspects of interrelated parts within a PECS;
- establishes a common basis for minimum safety requirements for the PEC portion of products that contain PEC;
- specifies requirements to reduce risks of fire, electric shock, thermal, energy and mechanical hazards, during use and operation and, where specifically stated, during service and maintenance;
- specifies minimum requirements to reduce risks with respect to pluggable and permanently connected equipment, whether it consists of a system of interconnected units or independent units, subject to installing, operating and maintaining the equipment in the manner prescribed by the manufacturer.

This International Standard does not cover:

- telecommunications apparatus other than power supplies to such apparatus;
- functional safety aspects as covered by e.g. IEC 61508;
- electrical equipment and systems for railways applications and electric vehicles.

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 60050 (all parts), *International Electrotechnical Vocabulary* (available at <http://www.electropedia.org>)

IEC 60060-1:2010, *High-voltage test techniques – Part 1: General definitions and test requirements*

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

IEC 60068-2-6, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-52, *Environmental testing – Part 2-52: Tests – Test Kb: Salt mist, cyclic (sodium chloride solution)*

IEC 60068-2-68, *Environmental testing – Part 2-68: Tests – Test L: Dust and sand*

IEC 60068-2-78:2001, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

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

IEC 60216-4-1, *Electrical insulating materials – Thermal endurance properties – Part 4-1: Ageing ovens – Single-chamber ovens*

IEC 60364-1, *Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions*

IEC 60364-4-41:2005, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

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

IEC 60364-5-54:2011, *Low voltage electrical installations – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective conductors*

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

IEC/TS 60479-1, *Effects of current on human beings and livestock – Part 1: General aspects*

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

IEC 60617, *Graphical symbols for diagrams* (available from <http://std.iec.ch/iec60617>)

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

IEC 60664-3:2003, *Insulation coordination for equipment within low-voltage systems – Part 3: Use of coating, potting or moulding for protection against pollution*

IEC 60664-4:2005, *Insulation coordination for equipment within low-voltage systems – Part 4: Consideration of high-frequency voltage stress*

IEC 60695-2-11:2000, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end-products*

IEC 60695-10-2, *Fire hazard testing – Part 10-2: Abnormal heat - Ball pressure test*

IEC 60695-11-10, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

IEC 60721-3-3, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 3: Stationary use at weatherprotected locations*

IEC 60721-3-4, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 4: Stationary use at non-weatherprotected locations*

IEC 60730-1, *Automatic electrical controls for household and similar use – Part 1: General requirements*

IEC/TR 60755, *General requirements for residual current operated protective devices*

IEC 60949, *Calculation of thermally permissible short-circuit currents, taking into account non-adiabatic heating effects*

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

IEC 60695-2-13, *Fire hazard testing – Part 2-13: Glowing/hot-wire based test methods – Glow-wire ignition temperature (GWIT) test method for materials*

IEC 60695-11-10, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

IEC 60695-11-20, *Fire hazard testing – Part 11-20: Test flames – 500 W flame test methods*

IEC 60990:1999, *Methods of measurement of touch current and protective conductor current*

IEC 61032:1997, *Protection of persons and equipment by enclosures – Probes for verification*

IEC 61180-1:1992, *High-voltage test techniques for low-voltage equipment – Part 1: Definitions, test and procedure requirements*

IEC Guide 104:2010, *The preparation of safety publications and the use of basic safety publications and group safety publications*

IEC Guide 117:2010, *Electrotechnical equipment – Temperatures of touchable hot surfaces*

ISO 3864-1, *Graphical symbols – Safety colours and safety signs – Part 1: Design principles for safety signs in workplaces and public areas*

ISO 3746, *Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Survey method using an enveloping measurement surface over a reflecting plane*

ISO 7000, *Graphical symbols for use on equipment – Index and synopsis* (available from <http://www.graphical-symbols.info/equipment>)

ISO 7010, *Graphical symbols – Safety colours and safety signs – Registered safety signs*

ISO 9614-1, *Acoustics – Determination of sound power levels of noise sources using sound intensity – Part 1: Measurement at discrete points*

ISO 9772, *Cellular plastics – Determination of horizontal burning characteristics of small specimens subjected to a small flame*

ANSI/ASTM E84 – 11b, *Standard test method for surface burning characteristics of building materials*

ASTM E162 – 11a, *Standard test method for surface flammability of materials using a radiant heat energy source*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-111:1996, IEC 60050-151:2001, IEC 60050-161:1990, IEC 60050-191:1990, IEC 60050-441:1984, IEC 60050-442:1998, IEC 60050-551:1998, IEC 60050-601:1985 and IEC 60664-1:2007, and the following apply.

Table 1 provides an alphabetical cross-reference listing of terms.

Table 1 – Alphabetical list of terms

Term	Term number	Term	Term number	Term	Term number
adjacent circuit	3.1	low voltage	3.23	protective separation	3.44
basic insulation	3.2	mains supply	3.24	PEC	3.45
basic protection	3.3	muscular reaction (inability to let go)	3.25	PECS	3.46
commissioning test	3.4	non-mains supply	3.26	reinforced insulation	3.47
decisive voltage class (*DVC*)	3.5	open type	3.27	restricted access area	3.48
double insulation	3.6	output short circuit current	3.28	routine test	3.49
DVC As	3.7	PELV (systems)	3.29	sample test	3.50
DVC Ax	3.8	permanently connected (equipment)	3.30	SELV (systems)	3.51
electrical breakdown	3.9	pluggable equipment type A	3.31	short circuit backup protection	3.52
(electrical) insulation	3.10	pluggable equipment type B	3.32	simple separation	3.53
(electronic) (power) conversion	3.11	port	3.33	single fault condition	3.54
enclosure	3.12	power semiconductor device	3.34	startle reaction	3.55
enhanced protection	3.13	prospective short circuit current	3.35	supplementary insulation	3.56
expected lifetime	3.14	protective equipotential bonding	3.36	surge protective device (SPD)	3.57
Extra Low Voltage (ELV)	3.15	protective class I	3.37	system	3.58
fault protection	3.16	protective class II	3.38	system voltage	3.59
field wiring terminal	3.17	protective class III	3.39	temporary overvoltage	3.60
fire enclosure	3.18	protective earthing (PE)	3.40	touch current	3.61
functional insulation	3.19	PE conductor	3.41	type test	3.62
hazardous live part	3.20	protective impedance	3.42	ventricular fibrillation	3.63
installation	3.21	(electrically) protective screening	3.43	working voltage	3.64
live part	3.22			zone of equipotential bonding	3.65

3.1
adjacent circuit
circuit next to the circuit under consideration having a requirement for functional, simple or protective *insulation*

3.2
basic insulation
insulation applied to *hazardous live parts* to provide *basic protection* against electric shock

[SOURCE: IEC 60050-195:1998, 195-06-06, modified]

3.3
basic protection
protection against electric shock under fault-free conditions

[SOURCE: IEC 60050-195:1998, 195-06-01]

3.4
commissioning test
test on a device or equipment performed on site, to prove the correctness of installation and operation

[SOURCE: IEC 60050-411:1996, 411-53-06, modified]

3.5
decisive voltage class
DVC
classification of voltage range used to determine the protective measures against electric shock and the requirements of *insulation* between circuits

3.6
double insulation
insulation comprising both *basic insulation* and *supplementary insulation*

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

3.7
DVC As
maximum safe voltage values to be touchable, coming from *DVC Ax*

3.8
DVC Ax
DVC Ax is the general *DVC* value used for *DVC A*, *DVC A1*, *DVC A2* or *DVC A3*

3.9
electrical breakdown
failure of *insulation* under electric stress when the discharge completely bridges the *insulation*, thus reducing the voltage between the electrodes almost to zero

[SOURCE: IEC 60664-1:2007, 3.20]

3.10
(electrical) insulation
electrical separation between circuits or conductive parts provided by clearance or creepage distance or solid *insulation* or combinations of them

3.11
(electronic) (power) conversion
change of one or more of the characteristics of an electric power *system* essentially without appreciable loss of power by means of *power semiconductor devices*

Note 1 to entry: Characteristics are, for example, voltage, number of phases and frequency, including zero frequency.

[SOURCE: IEC 60050-551:1998, 551-11-02, modified]

3.12
enclosure
housing affording the type and degree of protection suitable for the intended application

Note 1 to entry: This standard provides requirement for the *enclosure* according to IEC 60529 as well as additional requirement for mechanical and environmental impact. The purpose of the additional requirement is to ensure the *enclosures* ability to provide *basic protection* under the environmental conditions specified by the manufacturer.

[SOURCE: IEC 60050-195:1998, 195-02-35]

3.13
enhanced protection
protective provision having a reliability of protection not less than that provided by two independent protective provisions

3.14
expected lifetime
design duration for which the performance characteristics are valid at rated conditions of operation

3.15
extra-low voltage
ELV
voltage not exceeding the relevant voltage limit of band I specified in IEC 60449

Note 1 to entry: In IEC 60449, band I is defined as not exceeding 50 V a.c. r.m.s. and 120 V d.c. Other product committees may have defined *ELV* with different voltage levels.

Note 2 to entry: In this standard, protection against electric shock is dependent on the *decisive voltage classification*.

[SOURCE: IEC 60050-826:2004, 826-12-30, modified]

3.16
fault protection
protection against electric shock under single-fault conditions

Note 1 to entry: For low-voltage *installations*, *systems* and equipment, *fault protection* generally corresponds to protection against indirect contact as used in IEC 60364-4-41, mainly with regard to failure of *basic insulation*.

[SOURCE: IEC 60050-195:1998, Amendment 1:1998, 195-06-02]

3.17
field wiring terminal
terminal provided for connection of external conductors to the *PECS*

3.18
fire enclosure
part of the equipment intended to minimize the spread of fire or flames from within

3.19
functional insulation
insulation between conductive parts within a circuit that is necessary for the proper functioning of the circuit, but which does not provide protection against electric shock

Note 1 to entry: *Functional insulation* may, however, reduce the likelihood of ignition and fire.

3.20
hazardous-live-part
live part which, under certain conditions, can give a harmful electric shock

[SOURCE: IEC 60050-195:1998, 195-06-05]

3.21
installation
equipment or equipments including at least the PECS

Note 1 to entry: The word installation is also used in this standard to denote the process of installing a *PECS*. In these cases, the word does not appear in italics.

3.22
live part
conductor or conductive part intended to be energized in normal operation, including a neutral conductor, but by convention not a *protective earth conductor* or *protective earth* neutral

Note 1 to entry: This concept does not necessarily imply a risk of electric shock.

[SOURCE: IEC 60050-195:1998, 195-02-19, modified]

3.23
low voltage
LV
set of voltage levels used for the distribution of electricity and whose upper limit is generally accepted to be 1 000 V a.c. or 1 500 V d.c.

[SOURCE: IEC 60050-601:1985, 601-01-26, modified]

3.24
mains supply
low voltage a.c. power distribution *system* for supplying power to a.c. equipment

3.25
muscular reaction (inability to let go)
physiological reaction due to a minimum derived value of touch voltage for a population for which a current flowing through the body is just enough to cause involuntary contraction of a muscle, such as inability to let go from an electrode, but not including *startle reaction*

[SOURCE: IEC/TR 60479-5:2007, 3.3.2, modified]

3.26
non-mains supply
electrical circuit that is not energized directly from the *mains supply*, but is, for example, isolated by a transformer or supplied by a battery, generator, or similar sources not directly connected to the a.c. power distribution *system*

3.27
open type
product intended for incorporation within *enclosure* or assembly that will provide protection against hazards

3.28
output short circuit current
available current r.m.s or d.c. that flows at the output of the *PECS* when a short circuit is applied by a conductor of negligible impedance

3.29
PELV (system)
electric system in which the voltage cannot exceed the value of *extra low voltage*:

– under normal conditions; and
– under *single fault conditions*, except earth faults in other electric circuits

Note 1 to entry: PELV is the abbreviation for protective *extra low voltage*.

[SOURCE: IEC 60050-826:2004, 826-12-32]

3.30
permanently connected (equipment)
equipment that is intended for connection to the building *installation* wiring using screw terminals or other reliable means

3.31
pluggable equipment type A
equipment that is intended for connection to the *mains supply* via a non-industrial plug and socket-outlet or a non-industrial appliance coupler, or both

3.32
pluggable equipment type B
equipment that is intended for connection to the *mains supply* via an industrial plug and socket-outlet or an appliance coupler, or both, complying with IEC 60309 or with a comparable national standard

3.33
port
access to a device or network where electromagnetic energy or signals may be supplied or received or where the device or network variables may be observed or measured

[SOURCE: IEC 60050-131:2002, 131-12-60]

3.34
power semiconductor device
semiconductor device used for *electronic power conversion*

3.35
prospective short circuit current
available current that flows when a short circuit is applied by a conductor of negligible impedance

3.36
protective-equipotential-bonding
equipotential bonding for purposes of safety (e.g. protection against electric shock)

[SOURCE: IEC 60050-195:1998, 195-01-15, modified]

3.37
protective class I
equipment in which protection against electric shock does not rely on *basic insulation* only, but which includes an additional safety precaution in such a way that means are provided for the connection of accessible conductive parts to the *protective (earthing) conductor* in the fixed wiring of the *installation*, so that accessible conductive parts cannot become live in the event of a failure of the *basic insulation*

3.38
protective class II
equipment in which protection against electric shock does not rely on *basic insulation* only, but in which additional safety precautions such as *supplementary insulation* or *reinforced insulation* are provided, there being no provision for *protective earthing* or reliance upon *installation* conditions

3.39
protective class III
equipment in which protection against electric shock relies on supply at *DVC Ax* (or *B* under certain conditions) and in which voltages higher than those of *DVC Ax* (*B*) are not generated and there is no provision for *protective earthing*

Note 1 to entry: Other standards define *protective class III* as supplied by *ELV*.

3.40
protective earthing
PE
earthing of a point in a *system*, or equipment, for protection against electric shock in case of a fault

3.41
PE conductor
conductor in the building *installation* wiring, or in the power supply cord, connecting a main *protective earthing* terminal in the equipment to an earth point in the building *installation* for safety purposes

3.42
protective impedance
impedance connected between *hazardous live parts* and accessible conductive parts, of such value that the current, in normal use and under likely fault conditions, is limited to a safe value, and which is so constructed that its ability is maintained throughout the life of the equipment

[SOURCE: IEC 60050-442:1998, 442-04-24, modified]

3.43
(electrically) protective screening
separation of circuits from hazardous live-parts by means of an interposed conductive screen, connected to the means of connection for a *PE conductor,* either directly or via *protective equipotential bonding*

3.44
(electrically) protective separation
separation of one electric circuit from another by means of:

- *double insulation* or
- *basic insulation* and electrically *protective screening* or
- *reinforced insulation*

[SOURCE: IEC 60050-195:1998, Amendment 1:1998, 195-06-19]

3.45
power electronic converter
PEC
device or part thereof for the purpose of *electronic power conversion*, including signalling, measurement, control circuitries and other parts, if essential for the *power* conversion function

3.46
power electronic converter *system*
PECS
one or more *power electronic converters* intended to work together with other equipment

3.47
reinforced insulation
insulation of *hazardous-live-parts* which provides a degree of protection against electric shock equivalent to *double insulation*

[SOURCE: IEC 60664-1:2007, 3.17.5]

3.48
restricted access area
area accessible only to electrically skilled persons and electrically instructed persons with the proper authorization

Note 1 to entry: An electrically skilled person is a person with relevant education and experience to enable him or her to perceive risks and to avoid hazards which electricity can create

Note 2 to entry: An electrically instructed person is a person adequately advised or supervised by electrically skilled persons to enable him or her to perceive risks and to avoid hazards which electricity can create

[SOURCE: IEC 60050-195:1998, 195-04-04, modified]

3.49
routine test
test to which each individual device is subjected during or after manufacture to ascertain whether it complies with certain criteria

[SOURCE: IEC 60050-411:1996, 411-53-02, modified]

3.50
sample test
test on a number of devices taken at random from a batch

3.51
SELV (system)
electric system in which the voltage cannot exceed the value of *extra-low voltage*:

– under normal conditions; and
– under *single fault conditions*, including earth faults in other electric circuits

NOTE SELV is the abbreviation for safety *extra low voltage*.

[SOURCE: IEC 60050-826:2004, 826-12-31, modified]

3.52
short circuit backup protection
protection that is intended to operate when other protective measures within a *system* or equipment fail to clear a fault

3.53
simple separation
separation between electric circuits or between an electric circuit and local earth by means of *basic insulation*

[SOURCE: IEC 60050-826:2004, 826-12-28]

3.54
single fault condition
condition in which one failure is present which could cause a hazard covered by this standard

Note 1 to entry: If a *single fault condition* results in other subsequent failures, the set of failures is considered as one *single fault condition*.

Note 2 to entry: Examples of hazards include, but are not limited to electric shock, fire, energy, mechanical, sonic pressure etc.

3.55
startle reaction
physiological reaction due to a minimum derived value of touch voltage for a population for which a current flowing through the body is just enough to cause involuntary muscular contraction to the person through which it is flowing

[SOURCE: IEC/TR 60479-5:2007, 3.3.1, modified]

3.56
supplementary insulation
independent *insulation* applied in addition to *basic insulation* for *fault protection*

Note 1 to entry: *Basic* and *supplementary insulation* are separate, each designed for *simple separation* against electric shock.

[SOURCE: IEC 60664-1: 2007, 3.17.3, modified]

3.57
surge protective device
SPD
device that contains at least one non-linear component that is intended to limit surge voltages and divert surge currents

Note 1 to entry: An SPD is a complete assembly, having appropriate connecting means.

[SOURCE: IEC 61643-11:2011, 3.1.1]

3.58
system
set of interrelated and/or interconnected independent elements

Note 1 to entry: A *system* is generally defined with the view of achieving a given objective, for example by performing a definite function.

3.59
system voltage
voltage used to determine *insulation* requirements

Note 1 to entry: See 4.4.7.1.6 for further consideration of *system voltage*.

3.60
temporary overvoltage
overvoltage at power frequency of relatively long duration

[SOURCE: IEC 60664-1:2007, 3.7.1]

3.61
touch current
electric current passing through a human body or through an animal body when it touches one or more accessible parts of an electrical *installation* or electrical equipment

[SOURCE: IEC 60050-826:2004, 826-11-12]

3.62
type test
test of one or more devices made to a certain design to show that the design meets certain specifications

[SOURCE: IEC 60050-811:1991, 811-10-04]

3.63
ventricular fibrillation
cardiac fibrillation, limited to the ventricles, leading to ineffective circulation and then to heart failure

Note 1 to entry: Ventricular fibrillation stops blood circulation.

[SOURCE: IEC 60050-891:1998, 891-01-16]

3.64
working voltage
voltage, at rated supply conditions (without tolerances) and worst case operating conditions, that occurs by design in a circuit or across *insulation*

Note 1 to entry: The *working voltage* can be d.c. or a.c. Both the r.m.s. and recurring peak values are used.

3.65
zone of equipotential bonding
zone where all simultaneously accessible conductive parts are electrically connected to prevent hazardous voltages appearing between them

Note 1 to entry: For equipotential bonding, it is not necessary for the parts to be earthed.

4 Protection against hazards

4.1 General

Clause 4 defines the minimum requirements for the design and construction of a *PECS*, to ensure its safety during installation, normal operating conditions and maintenance for the *expected lifetime* of the *PECS*. Consideration is also given to minimising hazards resulting from reasonably foreseeable misuse.

Manufacturers and product committees using this standard as a reference document shall clearly specify what is contained in the *PECS*, covered by and evaluated according to this standard. This shall as a minimum cover the *PEC* including the load interface and supply interface.

Protection against hazards shall be maintained under normal and *single fault conditions,* as specified in this standard.

Components compliant with a relevant IEC product standard which provides similar safety requirements as the requirement of this standard do not require separate evaluation. Components or assemblies of components, for which no relevant product standard exists, shall be tested according to the requirements of this standard.

Product committees using this standard as reference should make use of 7.3 from IEC Guide 104:2010.

Where the *PECS* is intended to be used together with specific auxiliary equipment, the safety evaluation and test shall include this auxiliary equipment unless it can be shown that it does not affect the safety of either equipment.

4.2 Fault and abnormal conditions

The *PECS* shall be designed to avoid operating modes or sequences that can cause a fault condition or component failure leading to a hazard, unless other measures to prevent the hazard are provided by the *installation* and are described in the installation information provided with the *PECS*. The requirements in this clause also apply to abnormal operating conditions as applicable.

Circuit analysis or testing shall be performed to determine whether or not failure of a particular component (including *insulation system*s) would result in hazard.

This analysis shall include situations where a failure of the component or the *insulation* (*functional, basic and supplementary)* would result in:

- an impact on the decisive voltage determination according to 4.4.2;
- a risk of electric shock due to:
  - degradation of the *basic protection* according to 4.4.3, or
  - degradation of the *fault protection* according to 4.4.4;
- a risk of energy hazard according to 4.5;
- a risk of degradation due to emission of flame, burning particles or molten metal of the fire according to 4.6;
- a risk of thermal hazard due to high temperature according to 4.6;
- a risk of mechanical hazard according to 4.7.

NOTE This standard does not provide any requirement to protect against chemical hazard. Product committees or manufacturers might consider this when it applies to their products.

The analysis or testing shall include the effect of short circuit and open-circuit conditions of the component. Testing is necessary unless analysis can conclusively show that no hazard will result from failure of the component. Compliance shall be checked by test of 5.2.4.6.

The evaluation of components shall be based on the expected stress occurring in the *expected lifetime* of the *PECS* including, but not limited to:

- specified climatic and mechanical conditions according to 4.9 (temperature, humidity, vibration, etc.);
- electrical characteristics according to 4.4.7 (expected impulse voltage, *working voltage*, *temporary overvoltage*, etc.);
- micro environment according to 4.4.7 (pollution degree, humidity, etc.).

Components evaluated for their reliability according to relevant product standards are considered to meet these requirements and do not need any further investigation, if tested under conditions that fulfill the conditions for which the *PECS* is designed.

Clearance and creepage distances on printed wiring boards (PWBs) including components mounted on PWBs, for *functional, basic, supplementary* and *reinforced insulation,* designed according to 4.4.7.4 and 4.4.7.5, are considered to meet these requirements and do not need any further investigation.

Functional insulation on PWB and between legs of components assembled on PWBs not fulfilling the requirements for clearance and creepage distance in 4.4.7.4 and 4.4.7.5 shall meet the requirement of 4.4.7.7.

Consideration shall be given to potential safety hazards associated with major component parts of the *PECS*, such as flammability of transformer and capacitor fluids.

4.3 Short circuit and overload protection

4.3.1 General

The *PECS* shall not present a hazard, under short circuit or overload conditions at any *port*, including phase to phase, phase to earth and phase to neutral. Adequate information shall be provided in the documentation to allow proper selection of external wiring and protective devices (see 6.3.7.6 and 6.3.7.7).

Protective *systems* or devices shall be provided or specified in sufficient quantity and location so as to detect and to interrupt or limit the current flowing in any possible fault current path between conductors or from conductors to earth.

NOTE 1 In this standard, the term overcurrent covers both short circuit and overload.

NOTE 2 Local *installation* codes will still usually require provision of such protection for the purposes of protecting the input wiring in the *installation.*

Protection against overcurrents shall be provided for all input circuits, and for output circuits that do not comply with the requirements for limited power sources in 4.6.5.

If the *PECS* complies with all normal, abnormal and fault test conditions in this standard without such protection provided, provision or specification of overcurrent protection for input circuits is not necessary for the protection of the *PECS*.

No protection is required against overcurrent to earth in equipment that either

- has no connection to earth; or
- has *double insulation* or *reinforced insulation* between *live parts* and all parts connected to earth.

NOTE 3 Under a *single fault condition* in an IT system no short circuit current or a limited short circuit current will flow. The interruption of the short circuit current in an IT system (see 4.4.7.1.4) is done when a second fault occurs. Typically only detection is done after the first fault in an IT *system.*

NOTE 4 Where *double insulation* or *reinforced insulation* is provided, a short circuit to earth would be considered to be two faults.

For *pluggable equipment type A*, the protective device is provided in the *installation* and shall not require any specific characteristics other than that required in IEC 60364 or other local *installation* codes.

For *pluggable equipment type B* or fixed installed equipment, this protection may be provided by devices external to the equipment, in which case the installation instructions shall state the need for the protection to be provided in the *installation* and shall include the specifications for the required short circuit and/or overload protection (see 6.3.7).

NOTE 5 IEC 60364 provides requirements for short circuit and overload protection of the input wiring in the *installation.*The above requirement ensures that the user is informed about any special characteristics of the protective devices for the protection of the *PECS*, in addition to the requirements in IEC 60364 or other local *installation* codes.

If a protective device interrupts the neutral conductor, it shall also simultaneously interrupt all other supply conductors of the same circuit. It is permissible for the protective device to interrupt the neutral conductor after the other supply conductors of the same circuit.

Compliance shall be checked by inspection and where necessary, by simulation of *single fault conditions* (see 4.2) and by the tests of 5.2.4.4 and 5.2.4.5.

4.3.2 Specification of input short-circuit withstand strength and output short circuit current ability

4.3.2.1 General

The interrupting capability of the overcurrent protective device shall be equal or greater than the *prospective short circuit current* of the *mains supply*.

For *pluggable equipment type A*, either the *PECS* shall be designed so that the building *installation* provides *short circuit backup protection*, or additional *short circuit backup protection* shall be provided as part of the equipment.

For *permanently connected equipment* or *pluggable equipment type B*, it is permitted for *short circuit backup protection* to be in the building *installation*.

4.3.2.2 Input *ports* short-circuit withstand strength

The input *prospective short circuit current* ratings apply to *ports* intended to be connected to battery circuits, external *mains supply*, *non-mains* a.c. or d.c. sources, and to other *ports* for which overcurrent protection is necessary.

For co-ordination and selection of internal or external protective devices, the *PECS* manufacturer shall specify:

- a maximum allowable *prospective short circuit current* for each input *port* of the *PECS*; and
- a minimum required *prospective short circuit current* in order to ensure proper operation of the protective device

NOTE 1 This requirement is especially applicable to fuses, which are not specified to be operated below a certain fault current value.

NOTE 2 The maximum allowable and minimum required *prospective short circuit current* are used to ensure a proper coordination between the *prospective short circuit current and a suitable protective device* at the location of the electrical *installation*.

If external protective devices are specified or provided the characteristics of those shall be specified by the manufacturer.

See 6.2 for marking.

4.3.2.3 Output short circuit current ability

The *output short circuit current* ratings appliy to a.c. and d.c. power output *ports* and to other *ports* for which overcurrent protection is necessary.

For all output *ports*, short circuit evaluation to determine the minimum and maximum *output short circuit current* shall be performed according to 5.2.4.4 and the *output short circuit current* available from the *PECS* shall be specified as in 5.2.4.4 and 6.2.

Internal electronic output short circuit protection is considered acceptable as an output short circuit protection device of the *PECS*, when compliance is shown by test in 5.2.4.4.

4.3.2.4 Combined input and output *ports*

For *ports* which are both input and output *ports* the applicable requirements of both 4.3.2.1 and 4.3.2.3 apply.

4.3.3 Short-circuit coordination (backup protection)

Protective devices provided or specified shall have adequate breaking capability to interrupt the maximum *prospective short circuit current* specified for the *port* to which they are connected.

If internal protection of the *PECS* is not rated for the *prospective short circuit current,* the installation instructions shall specify an upstream protective device, rated for this *prospective short circuit current* of that *port*, which shall be used to provide backup protection. Analysis shall ensure the protection coordination between the external and internal protective device.

NOTE IEC 60364 provides requirements for upstream protective devices of the backup protection in the *installation.* The above requirement ensures that the user is informed about any special characteristics of the upstream protective devices for the backup protection of the *PECS*, in addition to the requirements in IEC 60364 or other local *installation* codes.

Compliance shall be checked by inspection and by the tests of 5.2.4.4 and 5.2.4.5 .

4.3.4 Protection by several devices

Where protective devices that require manual replacement or resetting are used in more than one pole of a supply to a given load, those devices shall be located together. It is permitted to combine two or more protective devices in one component.

Compliance shall be checked by inspection.

4.4 Protection against electric shock

4.4.1 General

Protection against electric shock depends on the *decisive voltage class* from 4.4.2 and *insulation* requirements from 4.4.2.3, and is to be provided by at least one of the following measures:

- *basic protection* from 4.4.3 and *fault protection* from 4.4.4;
- *enhanced protection* from 4.4.5

Protection under normal conditions is provided by *basic protection*, and protection under *single fault conditions* is provided by *fault protection*.

Enhanced protection provides protection under both conditions.

Additional protection can be provided by residual current-operated protective devices (RCD). For further information, see 4.4.8.

NOTE In this standard, 4.4.1 to 4.4.6 have been harmonized with the concepts of the horizontal standard IEC 61140 for protection against electrical shock. *Basic protection*, *fault protection*, *enhanced protection* and the combination of those measures has been implemented.

4.4.2 *Decisive voltage class*

4.4.2.1 General

The probability of electric shock increases with voltage level, surface area of the accessible conductive part or circuit in contact with the skin and the humidity condition of skin. To reduce the likelihood of electric shock, it is important to determine the safe *decisive voltage class* (*DVC As*).

For the selection of the relevant *decisive voltage class Ax* for accessible circuits the following apply:

- the reaction of the body (see A.5);
- the area of the accessible part of the equipment in relation to the area of the part of the body that may contact the accessible part, from Table 3;
- the humidity condition of the body skin from Table 4.

The values in Table 5 are based on a current path from the contact area of the body to feet with the person in standing position.

No protection is required if:

- under normal operation, the limits derived from Table 5, and
- under *single fault condition* the limits of touch voltage limits from Figures 1 to Figure 3,

are not exceeded.

DVC Ax, as chosen in Table 5 becomes the highest voltage value permitted to be touched for the *PECS* under consideration and is so-called *DVC As* for use in this standard. Other *DVC Ax* values higher than *DVC As* shall then be treated as *DVC B*.

In this standard, values of *DVC B* and *DVC C* are not allowed to be touchable, except under dry condition with finger tip for *DVC B* as shown in Table 2.

NOTE Within the *PECS*, this standard allows more than one *DVC As* circuit with different levels of *DVC As*.

4.4.2.2 Determination of *decisive voltage class*

4.4.2.2.1 General

For protection against the *ventricular fibrillation* body reaction, *DVC* can be selected from Table 2. For less severe reactions of the body, more information is given in A.5.

If it is impossible to protect against the body reaction relevant to the *DVC As,* a *basic protection* against accessibility to *hazardous live parts* according to 4.4.3 is required.

The *DVC* voltage limits for the steady-state values under normal operation from Table 2 are given in Table 5. The short term non-recurring touch voltage limits are given in Figure 1 to Figure 3.

Table 2 – Selection of *DVC* for touch voltage to protect against *ventricular fibrillation*

Body skin humidity conditions	Body contact area		
	Part of the body	Hand	Finger tip
Dry	*DVC A2*	*DVC A*	*DVC B*
Water wet	*DVC A1*	*DVC A2*	*DVC A*
Saltwater wet	*Basic protection* against accessibility is required	*DVC A1*	*DVC A2*

4.4.2.2.2 Selection tables for contact area and skin humidity condition

In order to protect against *ventricular fibrillation*, the appropriate conditions from Table 3 and Table 4 shall be selected.

If this standard is used for a product for which no product standard exists, select “Hand” for the contact area and “Dry” for the skin humidity condition. When a product for which no product standard exists is identified for use where the skin and humidity condition and/or the body contact area are other than "Hand" or "Dry", then those conditions shall be selected from Table 3 and Table 4.

Table 3 – Selection of body contact area

Contact area of accessible parts		
Finger tip cm^2	**Hand** cm^2	**Part of the body** cm^2
accessible parts < 1	1 < accessible parts < 80	80 < accessible parts < 500
NOTE In order to match several basic standards, dealing with Small, Medium and Large contact areas, this standard is using Finger tip instead of Small, Hand instead of Medium and Part of the body instead of Large.		

Table 4 – Selection of humidity condition of the skin

Humidity condition of the skin		
Dry	**Water wet**	**Saltwater wet**
normal indoor condition	immersed for more than 1 min in normal water (average value ρ = 35 Ωcm, pH = 7,7 to 9)	immersed for more than 1 min in a solution of 3 % NaCl in water (average value ρ = 0,25 Ωcm, pH = 7,5 to 8,5)
NOTE 1 For selection of skin humidity condition Table 18 provides the relevant skin condition related to the service environment condition. NOTE 2 Information and values are taken from IEC 60479-1		

4.4.2.2.3 Limits of the *working voltage* for the *DVC*

Limits for the *working voltage* regarding the *DVC* for normal operation are given in Table 5.

Table 5 – Steady state voltage limits for the *decisive voltage classes*

DVC	**Limits of *working voltage*** V		
	AC voltage (r.m.s.) U_{ACL}	**AC voltage (peak)** U_{ACPL}	**DC voltage (mean)** U_{DCL}
A1	8	11,3	22
A2	12	17	28
A3	20	28,3	48
A	30 [a]	42,4	60
B	50	71	120
C	>50	>71	>120
NOTE In some standards *SELV* and *PELV* have similar limits to *DVC B*.			
[a] In this standard the *DVC A* limits are considered for one circuit only. When more than one *DVC A* circuit of the *PECS* is accessible and evaluation from 4.2 shows that the voltage of the two circuit can add together under *single fault condition*, the limit is 25V for a.c. voltage r.m.s.			

A.6 shows three examples of different waveforms of *working voltage* and provides methods to evaluate the voltage under consideration to match with the *DVC* levels.

The short term non-recurring touch voltages limits during a single fault are given in Figure 1, Figure 2 and Figure 3.

Within 10 000 ms, the voltage has to decrease to the steady state value given in Table 5.

Table 5, or the fault is to be interrupted by a protective device. Under fault conditions where a protective device is used the characteristics of such device shall ensure that the time-voltage limits given in Figure 1 to Figure 3 are not exceeded. If an external protective device is used, information on characteristics of such device shall be specified by the *PECS* manufacturer in the installation manual according to 6.3.7.7.

NOTE 1 Figure 1 to Figure 3 only provide d.c. values for touch voltage because most frequent touchable voltage are d.c. values. If the manufacturer needs values for a.c. voltage, see A.5.5.

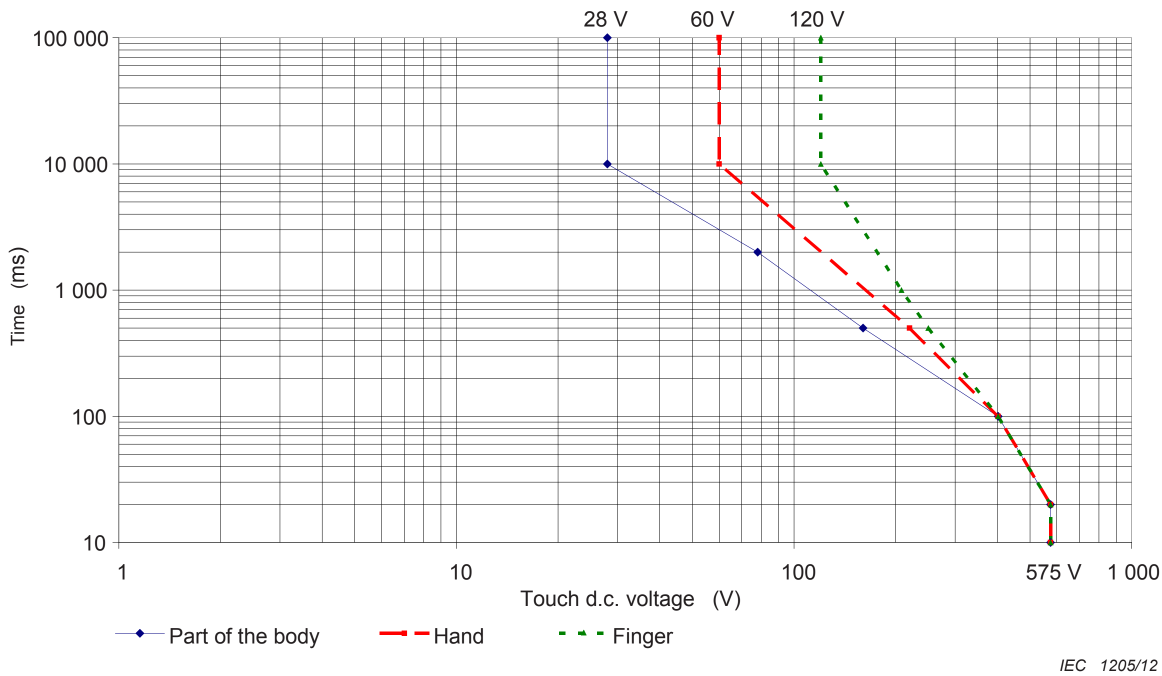


Figure 1 – Touch time - d.c. peak voltage zones of *ventricular fibrillation* in dry skin condition

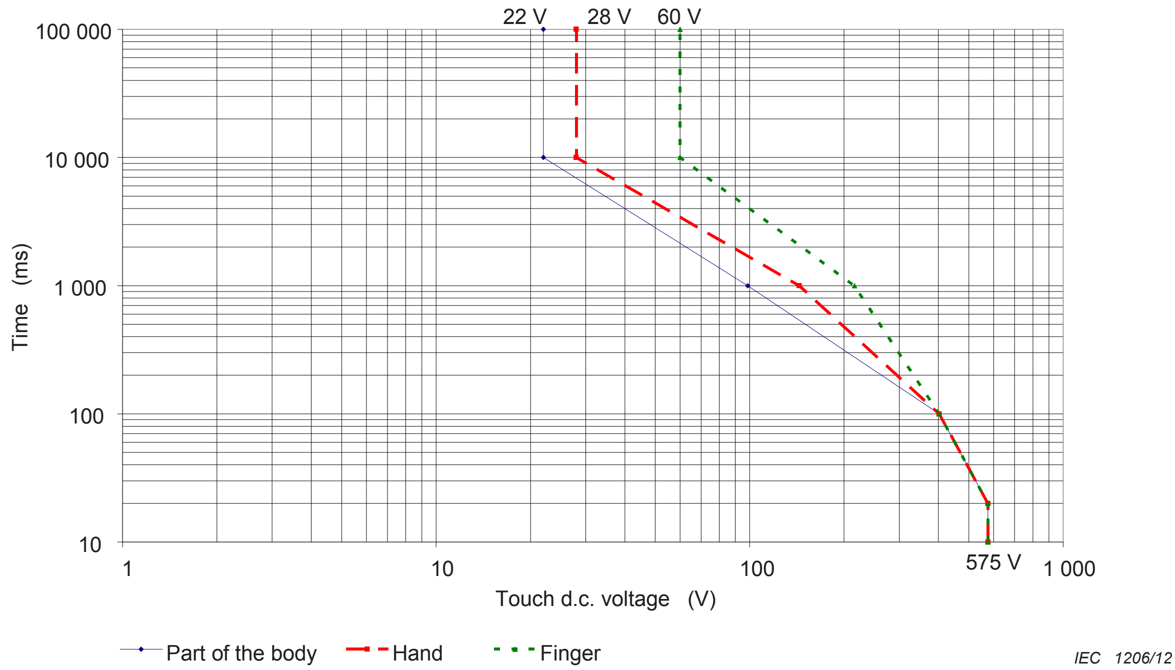


Figure 2 – Touch time - d.c. peak voltage zones of *ventricular fibrillation* in water-wet skin condition

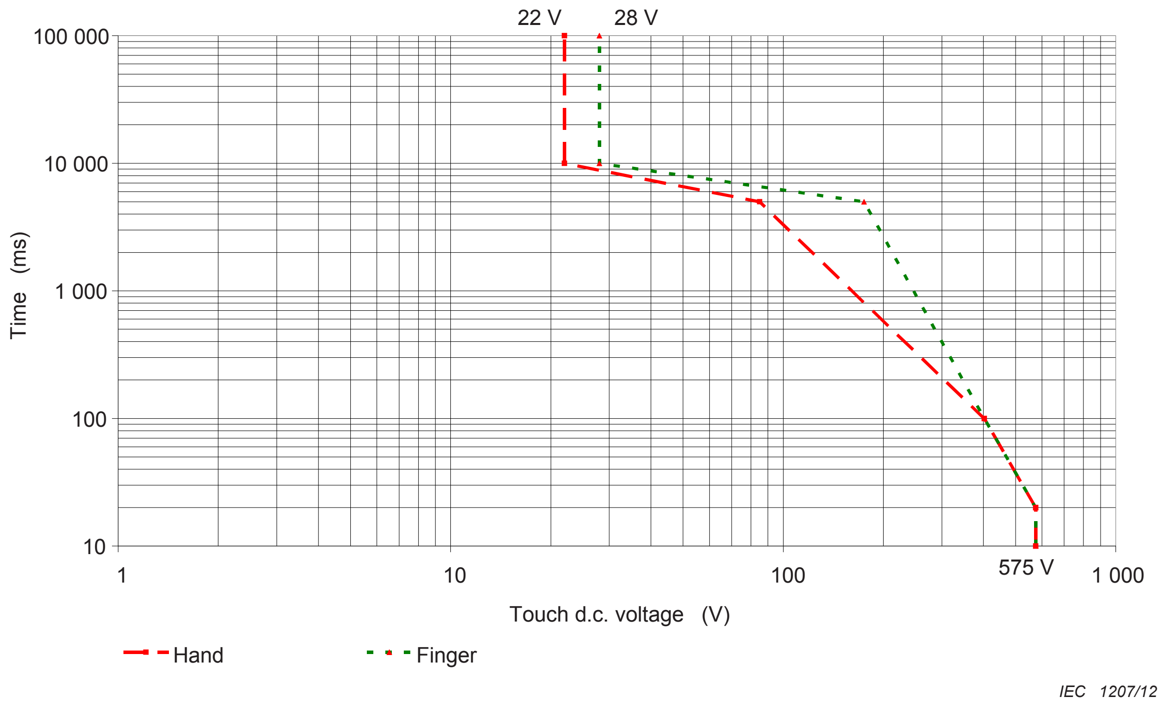


Figure 3 – Touch time - d.c. peak voltage zones of *ventricular fibrillation* in saltwater-wet skin condition

For part of the body, no information for time-voltage zone is given. *Basic protection* against accessibility is required.

For testing, see 5.2.4.

If the test results in a failure, additional measure is required for protection against electric shock according to 4.4.3.

4.4.2.3 Requirements for protection against electric shock

Table 6 shows possible solutions for compliance with 4.4 for the application of *simple* or *protective separation*, dependent on the *DVC* of the circuit under consideration and of *adjacent circuits*.

The requirements of this standard for protection against electric shock may be fulfilled by other means than shown in Table 6, in which case failure analysis and testing shall show that the requirements of 4.1 and 4.4 are met.

Table 6 – Protection requirements for circuit under consideration

DVC **of circuit under consideration**	**Protection against accessibility**	**Protection to accessible conductive parts connected to PE**	**Protection to accessible conductive parts that are not connected to PE**[g]	**Protection to *adjacent circuit* of DVC:**		
				As[a]	***B*** **or** ***Ax* > *As***	***C***
As[a]	No	1[b]	1	1[c] or 2[d]	2	*enhanced protection*
B **or** ***Ax* > *As***	*basic protection*[e]	*basic protection*[e]	*basic protection*		1[c] or 2[d]	*enhanced protection*
C	*enhanced protection*	*basic protection*	*enhanced protection*			1 or 2[f]

NOTE 1

1 Protection is not necessary for safety, but may be required for functional reasons according to 4.4.7.3.

2 *Basic protection* for circuit of higher voltage.

1 or 2 Depending on separation with other circuits.

NOTE 2 *Ax* > *As* Voltage less than *DVC B* but higher than *DVC As,* that does not meet 4.4.2.2.

[a] A, A1, A2 or A3, which ever is appropriate according to 4.4.2.2.

[b] If the considered circuit is designated as a *SELV* circuit, *basic protection* is required from earth and from *PELV* circuits.

[c] Both circuits under consideration have the same *DVC As* level.

[d] Both circuits under consideration have different *DVC As* level.

[e] Except for Finger tip. See Table 2.

[f] *Basic protection* is required between galvanically isolated circuits (e.g. *mains supply*, UPS output, PV or generator output, auxiliaries).

[g] Also applies to conductive parts connected to functional earth.

To ensure the integrity of the *insulation* of the *PECS*, the manufacturer of a *PECS* shall state the maximum voltage allowed to be connected to each *port*. See 6.3.7.1 for marking.

4.4.3 Provision for *basic protection*

4.4.3.1 General

Basic protection is employed to prevent persons from touching *hazardous live parts*. It shall be provided by one or more of the measures given in:

- Protection by means of *basic insulation* of live parts in 4.4.3.2;
- Protection by means of *enclosures* or barriers in 4.4.3.3;
- Protection by means of limitation of touch current and charge in 4.4.3.4;
- Protection by means of limited voltages in 4.4.3.5.

NOTE Further measures to fulfill the requirement for *basic protection* are given in IEC 61140. Product committees using this document as reference document might consider those measures.

4.4.3.2 Protection by means of *basic insulation* of *live parts*

Live parts shall be completely surrounded with *insulation* if their *working voltage* is greater than *DVC As* or if they do not have *protective separation* from *adjacent circuits* of *DVC C*.

Basic insulation may be provided by solid *insulation* or air clearance.

The *insulation* shall be rated according to the impulse voltage, *temporary overvoltage* or *working voltage* (see 4.4.7.2.1), whichever gives the most severe requirement. It shall not be possible to remove the *insulation* without the use of a tool or key.

An accessible conductive part is considered to be conductive if its surface is bare or is covered by an insulating layer that does not comply with the requirements of at least *basic insulation*.

Any accessible conductive part is considered to be a *hazardous live part* if not separated from the *live parts* by at least as specified in Table 6.

The *basic insulation* shall be designed and tested to withstand the impulse voltages and *temporary overvoltages* for the circuits to which they are connected. See 5.2.3.2 and 5.2.3.4 for tests.

A.7 provides examples of the use of elements of protective measures.

4.4.3.3 Protection by means of *enclosures* or barriers

Live parts with voltage higher than *DVC As* shall be:

- arranged in *enclosures* or located behind *enclosures* or barriers, which meet at least the requirements of the Protective Type IPXXB according to Clause 7 of IEC 60529:1989;
- located at the top surfaces of *enclosures* or barriers which are accessible when the equipment is energized shall meet at least the requirements of the protective type IP3X with regard to vertical access only.

For moveable equipment with no defined top and bottom this requirement of protective Type IP3X applies to all sides.

If the *PECS* is installed in a *restricted access area*, IPXXB instead of IP3X applies.

Product committees using this document as reference document might consider less requirement for equipment having openings in the top of an *enclosure* with a height exceeding 1,8 m.

Compliance is shown by test of 5.2.2.2.

It shall only be possible to open *enclosures* or remove barriers:

- with the use of a tool or key; or
- after de-energization of these *live parts*.

Where the *enclosure* is required to be opened and the *PECS* energized during installation or maintenance:

a) accessible *live parts* of voltage higher than *DVC As* shall be protected by at least IPXXA;

b) *live parts* of voltage higher than *DVC As* that are likely to be touched when making adjustments shall be protected by at least IPXXB;

c) it shall be ensured that persons are aware that *live parts* with voltage higher than *DVC As* are accessible.

Open type sub-assemblies and equipment do not require protective measures for *basic protection*. The information provided with the *PECS* shall indicate that protection shall be provided in the end application.

For marking requirements, see 6.3.7.1.

Products containing circuits of *DVC A, B* or *C*, intended for installation in *restricted access areas* as defined in 3.48, need not have protective measures for *basic protection*.

4.4.3.4 Protection by means of limitation of *touch current* and charge

The limitation of *touch current* and discharge energy shall not exceed:

- a value of 3,5 mA a.c. or 10 mA d.c. for the limitation of *touch current*; and
- a value of 50 μC for the limitation of discharge energy.

See A.3 and A.4 for examples of these measures.

NOTE 1 The value of the *touch current* is independent of the *DVC Ax*.

NOTE 2 Product committees using this document as reference document may consider the *touch current* level of 0,5 mA a.c. / 2 mA d.c. as threshold of perception as recommended by IEC 61140.

4.4.3.5 Protection by means of limited voltages

The voltage between simultaneously accessible parts shall not be greater than *DVC As* as determined in 4.4.2.2.

See A.2, A.3 and A.4 for examples of these measures.

4.4.4 Provision for *fault protection*

4.4.4.1 General

Fault protection is required to prevent shock currents which can result from contact with accessible conductive parts during and after an *insulation* failure.

Fault protection shall be provided by one or more of the following measures:

- *Protective equipotential bonding* in 4.4.4.2 in combinations with the *PE conductor* in 4.4.4.3;
- Automatic disconnection of supply in 4.4.4.4;
- *Supplementary insulation* in 4.4.4.5;
- Simple separation between circuits in 4.4.4.6;
- Electrically *protective screening* in 4.4.4.7.

Fault protection shall be independent and additional to those for *basic protection*.

NOTE Further measures to fulfill the requirement for *fault protection* are given in IEC 61140. Product committees using this document as reference document might consider those measures.

4.4.4.2 *Protective equipotential bonding*

4.4.4.2.1 General

Protective equipotential bonding shall be provided between accessible conductive parts of the equipment and the means of connection for the *PE conductor*, except:

a) accessible conductive parts that are protected by one of the measures in 4.4.6.4; or

b) when accessible conductive parts are separated from *live parts* using *double* or *reinforced insulation*.

Electrical contact to the means of connection of the *PE conductor* shall be achieved by one or more of the following means:

- through direct metallic contact;
- through other accessible conductive parts or other metallic components which are not removed when the *PECS* is used as intended;
- through a dedicated *protective equipotential bonding* conductor.

When painted surfaces (in particular powder painted surfaces) are joined together, masking of paint, paint piercing methods or a separate connection shall be made to ensure reliable contact.

Where electrical equipment is mounted on lids, doors, or cover plates, continuity of the *protective equipotential bonding* circuit shall be ensured by a dedicated conductor or equivalent means complying with the requirements for *protective equipotential bonding*. If fasteners, hinges or sliding contacts do not provide and guarantee low enough impedance, sufficient parallel bonding is required.

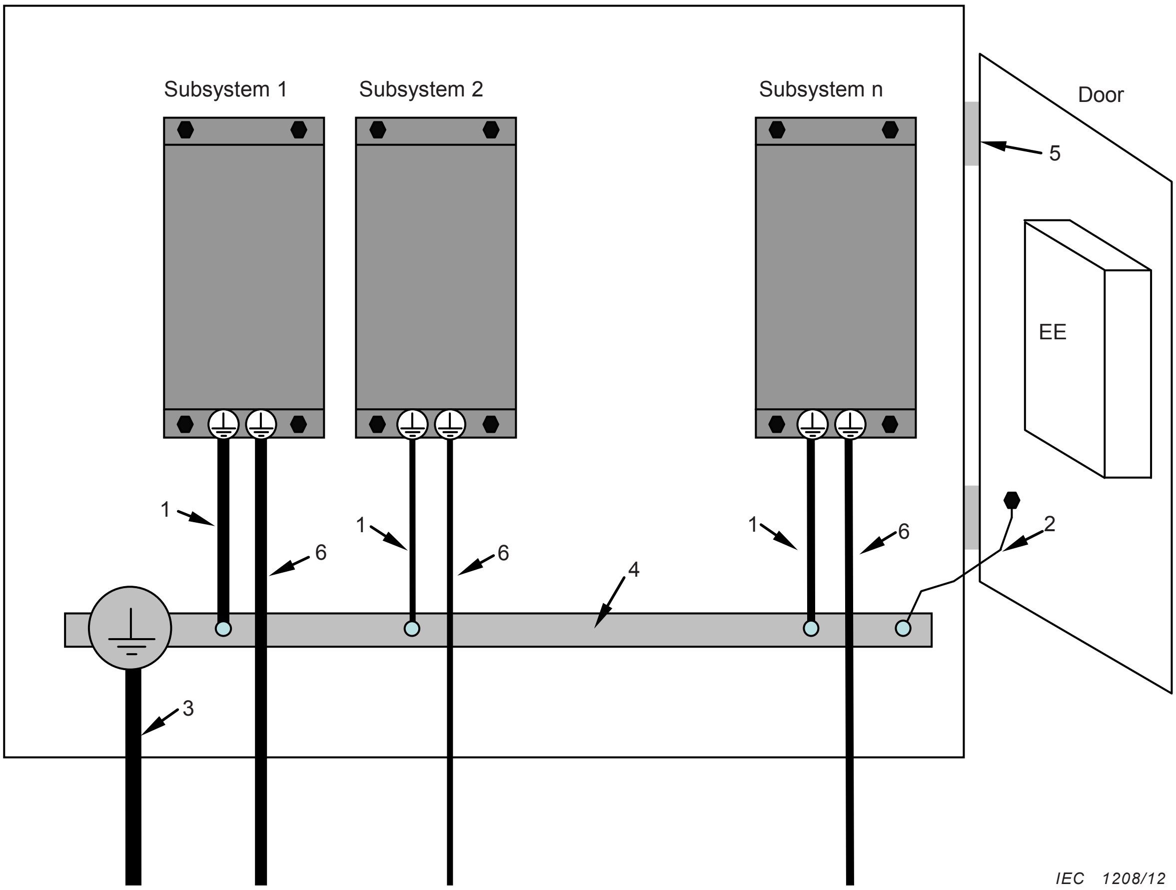
Electrical connections of *protective equipotential bonding* circuit shall be designed so that contact pressure is not transmitted through insulating material, unless there is sufficient resilience in the metallic parts to compensate for any possible shrinkage or distortion of the insulating material.

Unless specified by the manufacturer and in compliance with 4.4.4.2.2 metal ducts of flexible or rigid construction and metallic cable sheaths shall not be used as *protective equipotential bonding* means. Nevertheless, such metal ducts and the metal sheathing of all connecting cables (for example cable armouring, lead sheath) shall be connected to the *protective equipotential bonding* circuit.

The *protective equipotential bonding* circuit shall not incorporate a component such as switch or overcurrent protective devices which may open the circuit.

The electrical connection points of the *protective equipotential bonding* shall be corrosion-resistant.

Figure 4 shows an example of a *PECS* assembly and its associated *protective equipotential bonding*.



Key

1 *protective equipotential bonding* of sub*system*s or *PECS PE conductor* (dimensioned according to *PECS* requirements)

2 *protective equipotential bonding*

3 *PE conductor* (dimensioned according to *PECS* requirements) to *installation* earthing point

4 *earth* bar

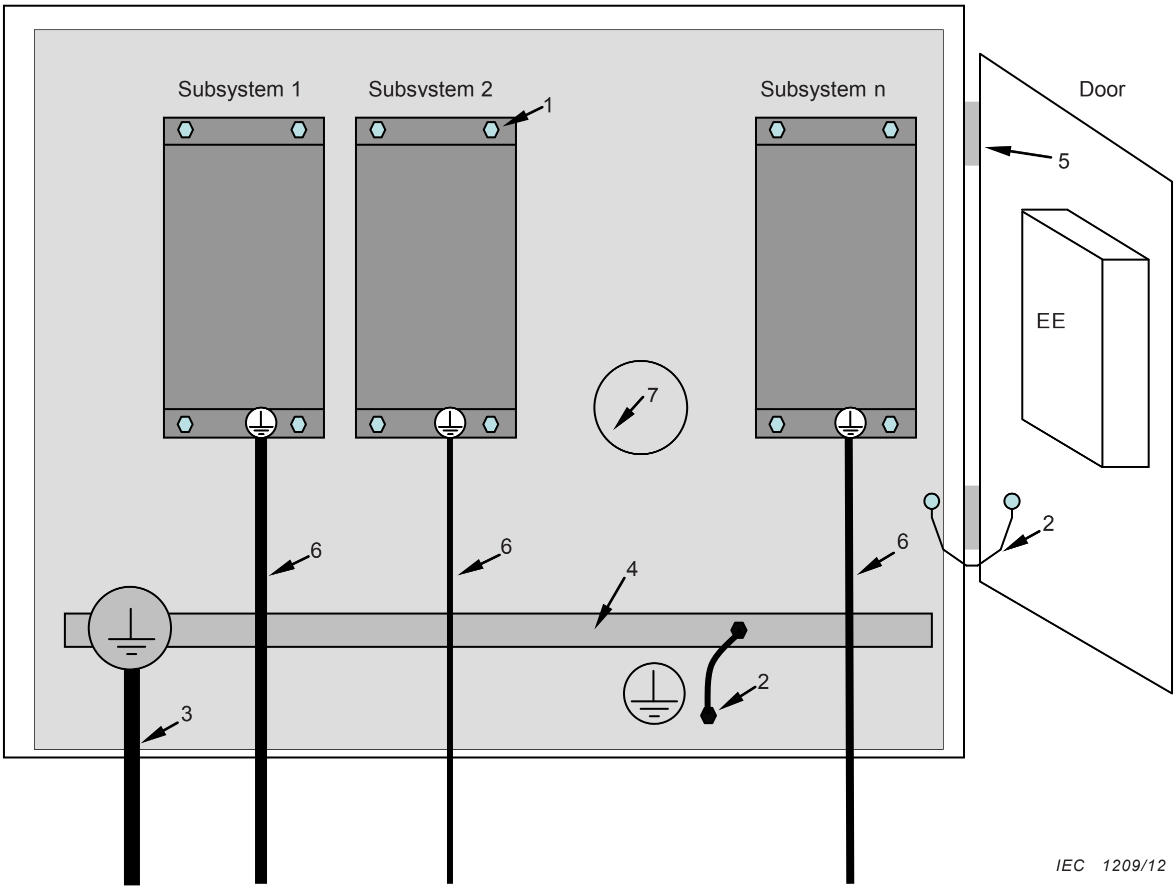
5 hinge

6 PE conductor to the load

EE other electrical equipment (bonded as relevant for that equipment)

Figure 4 – Example of a *PECS* assembly and its associated *protective equipotential bonding*

Figure 5 shows an example of a *PECS* assembly and its associated *protective equipotential bonding* through direct metallic contact.



Key

1 *protective equipotential bonding* of sub*system*s through direct metallic contact (paint removed)

2 *protective equipotential bonding*

3 *PE conductor* (dimensioned according to *PECS* requirements) to *installation* earthing point

4 *earth* bar

5 hinge

6 *PE conductor* to the load

7 metal subplate

EE other electrical equipment (bonded as relevant for that equipment)

Figure 5 – Example of a *PECS* assembly and its associated *protective equipotential bonding*

4.4.4.2.2 Rating of *protective equipotential bonding*

Protective equipotential bonding shall either be:

a) sized in accordance with the requirements for the *PE conductor* in 4.4.4.3 and the means of connection for the *PE conductor* in 4.4.4.3.2 to ensure no voltage drop exceeding the values from 4.4.2.2.3 during a fault; or

b) sized

- to withstand the highest stresses that can occur to the *PECS* item(s) concerned when they are subjected to a fault connecting to accessible conductive parts; and
- to remain effective for as long as a fault to the accessible conductive parts persists or until an upstream protective device removes power from the part; and

- to ensure no voltage drop exceeding the values from 4.4.2.2.3 during normal operation and during a fault.

Compliance shall be checked with the *type test*s in 5.2.3.11.

4.4.4.3 *PE conductor*

4.4.4.3.1 General

A *PE conductor* shall be connected at all times when power is supplied to the *PECS*, unless the *PECS* complies with the requirements of *protective class II* (see 4.4.6.3) or *protective class III*. Unless local wiring regulations state otherwise, the *PE conductor* cross-sectional area shall be determined from Table 7 or by calculation according to 543.1 of IEC 60364-5-54:2011.

If the *PE conductor* is routed through a plug and socket, or similar means of disconnection, it shall not be possible to disconnect it unless power is simultaneously removed from the part to be protected.

Table 7 – *PE conductor* cross-section[a]

Cross-sectional area of phase conductors of the *PECS* S mm^2	Minimum cross-sectional area of the corresponding *PE conductor* S_p mm^2
$S \leq 16$	S
$16 < S \leq 35$	16
$35 < S$	$S/2$

[a] These values are valid only if the *PE conductor* is made of the same material as the phase conductors.In case of different materials the cross-sectional area of the *PE conductor* shall be determined in a manner which produces a conductance equivalent to that which results from the application of this table.

The cross-sectional area of every *PE conductor* that does not form part of the supply cable or cable *enclosure* shall, in any case, be not less than:

- 2,5 mm^2 if mechanical protection is provided; or
- 4 mm^2 if mechanical protection is not provided.

Provisions within cord-connected equipment shall be made so that the *PE conductor* in the cord shall, in the case of failure of the strain-relief mechanism, be the last conductor to be interrupted.

For special *system* topologies, the *PECS* designer shall verify the *PE conductor* cross-section required.

4.4.4.3.2 Means of connection for the *PE conductor*

PECS shall have a means of connection for the *PE conductor*, located near the terminals for the respective live conductors. The means of connection shall be corrosion-resistant and shall be suitable for the connection of conductors according to Table 7 and of cables in accordance with the wiring rules applicable at the *installation*. The means of connection for the *PE conductor* shall not be used as a part of the mechanical assembly of the equipment or for other connections. Connection and bonding points shall be designed so that their current-carrying capacity is not impaired by mechanical, chemical, or electrochemical influences.

Where enclosures and/or conductors of aluminium or aluminium alloys are used, particular attention should be given to the problems of electrolytic corrosion.

Compliance shall be checked by inspection.

Annex K provides further information about electrochemical corrosion.

See 6.3.7.3.2 for marking requirements.

The marking shall not be placed on or fixed by screws, washers or other parts which might be removed when conductors are being connected.

4.4.4.3.3 *Touch current* in case of failure of *PE conductor*

The requirements of this subclause shall be satisfied to prevent accessible conductive parts to become dangerous in case of damage to or disconnection of the *PE conductor*.

For *pluggable type A* equipment, the *touch current* shall not exceed the limits specified in 4.4.3.4

For all other *PECS*, one or more of the following measures shall be applied, unless the *touch current* can be shown to be less than the limits specified in 4.4.3.4:

a) Use of a fixed connection and
   - a cross-section of the *PE conductor* of at least 10 mm^2 Cu or 16 mm^2 Al; or
   - automatic disconnection of the supply in case of discontinuity of the *PE conductor*; or
   - provision of an additional terminal for a second *PE conductor* of the same cross-sectional area as the original *PE conductor*;

or

b) Use of a *pluggable type B* connection with a minimum *PE conductor* cross-section of 2,5 mm^2 as part of a multi-conductor power cable. Adequate strain relief shall be provided.

For marking requirements, see 6.3.7.4.

Compliance is checked by inspection and by test of 5.2.3.7.

For equipment which may be energized from multiple sources of supply, the *touch current* limits above apply in all possible intended *installation* configurations and combinations of sources that may be energized at the same time, unless one of the measures in a) or b) above is used.

When it is intended and allowed to interconnect two or more *PECS* using one common *PE conductor*, the above *touch current* requirements apply to the maximum number of *PECS* to be interconnected, unless one of the measures in a) or b) above is used. The maximum number of interconnected *PECS* is used in the testing and has to be stated in the installation manual.

4.4.4.4 Automatic disconnection of supply

For automatic disconnection of supply:

- a *protective equipotential bonding system* shall be provided; and
- a protective device operated by the fault current shall disconnect one or more of the line conductors supplying the equipment, *system* or *installation*, in case of a failure of *basic insulation*.

The protective device shall interrupt the fault current within a time as specified in Figure 1, Figure 2 or Figure 3 in 4.4.2.2.3.

4.4.4.5 Supplementary *insulation*

Supplementary insulation is an independent *insulation* applied in addition to *basic insulation* for *fault protection* and shall be dimensioned to withstand the same stresses as specified for *basic insulation*.

4.4.4.6 *Simple separation* between circuits

Simple separation between a circuit and other circuits or earth shall be achieved by *basic insulation* throughout, rated for the highest voltage present.

If any component is connected between the separated circuits, that component shall withstand the electric stresses specified for the insulation which it bridges.

If any component is connected between a circuit and a circuit connected to earth, its impedance shall limit the current flow through the component to the steady-state *touch current* values indicated in 4.4.3.4.

4.4.4.7 *Electrically protective screening*

Electrically protective screening interposed between *hazardous live parts* of a *PECS*, shall consist of a conductive screen connected to the *protective equipotential bonding* of the *PECS* whereby the screen is separated from *live parts* by at least *simple separation*.

The protective screen and the connection to the *protective equipotential bonding system* of the *PECS* and that interconnection shall comply with the requirements of 4.4.4.2.

4.4.5 *Enhanced protection*

4.4.5.1 General

Enhanced protection shall provide both *basic* and *fault protection* and can be achived by means of:

- Reinforced insulation in 4.4.5.2;
- Protective separation between circuits in 4.4.5.3;
- Protection by means of in 4.4.5.4.

NOTE Further measures to fulfil the requirement for *enhanced protection* are given in IEC 61140. Product committees using this document as reference document might consider those measures.

4.4.5.2 *Reinforced insulation*

Reinforced insulation shall be so designed as to be able to withstand electric, thermal, mechanical and environmental stresses with the same reliability of protection as provided by *double insulation* (*basic insulation* and *supplementary insulation*, see 4.4.3.2 and 4.4.4.5).

4.4.5.3 *Protective separation* between circuits

Protective separation between a circuit and other circuits shall be achieved by one of the following means:

- *double insulation* (*basic insulation* and *supplementary insulation* in 4.4.3.2 and 4.4.4.5);
- *reinforced insulation* in 4.4.5.2;
- *electrically protective screening* in 4.4.4.7;
- a combination of these provisions.

If conductors of the separated circuit are contained together with conductors of other circuits in a multi-conductor cable or in another grouping of conductors, they shall be insulated, individually or collectively, for the highest voltage present, so that *double insulation* is achieved.

If any component is connected between the separated circuits, that component shall comply with the requirements for *protective impedance* devices (see 4.4.5.4)

4.4.5.4 Protection by means of *protective impedance*

Protective impedance shall be arranged so that under both normal and *single fault conditions* the current and discharge energy available shall be limited according to 4.4.3.4.

The *protective impedances* shall be designed and tested to withstand the impulse voltages and *temporary overvoltages* for the circuits to which they are connected. See 5.2.3.2 and 5.2.3.4 for tests.

Compliance with the requirement for the limitation of *touch current* is checked by test of 5.2.3.6.

Compliance with the requirement for the discharge energy shall be checked by performing calculations and/or measurements to determine the voltage and capacitance.

NOTE A *protective impedance* designed according to this subclause is not considered to be a galvanic connection.

4.4.6 Protective measures

4.4.6.1 General

That part of a *PECS* which meets the requirements of 4.4.6.2 is defined as *protective class I*.

That part of a *PECS* which meets the requirements of 4.4.6.3 is defined as *protective class II*.

That part of a *PECS* which meets the requirements of 4.4.6.4 is defined as *protective class III*.

Compliance shall be checked by satisfying the requirements for *protective class I*, *class II* or *class III*.

A.7 provides Examples of the use of elements of protective measures.

Equipment of protective *class I, II and III* shall be marked according to 6.3.7.3.

4.4.6.2 Protective measures for *protective class I* equipment

Protective class I equipment shall meet the requirements for:

- *basic protection* in 4.4.3; and
- *fault protection* in 4.4.4.2 and 4.4.4.3 with respect to equipotential bonding and *PE conductor.*

4.4.6.3 Protective measures for *protective class II* equipment

Protective class II equipment shall meet the requirements for *enhanced protection* according to 4.4.5 and the *enclosure* shall meet the requirement for *basic protection* in 4.4.3 with respect to accessibility to *hazardous live parts*.

Protective class II equipment shall not have means of connection for the *PE conductor*. This does not apply if a *PE conductor* is passed through the equipment to equipment series-connected beyond it.

In the latter case the *PE conductor* and its means for connection shall be separated from:

- accessible surface of the equipment; and
- circuits which employ *protective separation*

with at least *simple separation* according to the requirement in 4.4.4.6.

The *simple separation* shall be designed according to the rated voltage of the series-connected equipment.

Equipment of *protective class II* may have provision for the connection of an earthing conductor for functional reasons or for the damping of overvoltages. In this case, the functional earthing conductor shall be separated from:

- accessible surface of the equipment; and
- circuits which employ *protective separation* according to 4.4.5.3

with at least *protective separation* according to the requirement in 4.4.5.3.

Equipment of *protective class II* shall be marked according to 6.3.7.3.3.

Compliance is checked by inspection.

4.4.6.4 Protective measures for *protective class III* equipment or circuits

4.4.6.4.1 General

Protective measures shall be achieved by *protective separation* by one of the following means:

- *basic insulation* and *supplementary insulation (double insulation*) according to 4.4.3.2 and 4.4.4.5;
- *reinforced insulation* according to 4.4.5.2;
- *electrically protective screening* and *simple separation* according to 4.4.4.7; or
- a combination of these provisions;

used in combination with one of the following means:

- *protective impedance* according to 4.4.5.4 comprising limitation of discharge energy and of current; or
- limitation of voltage according to 4.4.3.5.

The *protective separation* shall be fully and effectively maintained under all conditions of intended use of the *PECS*.

4.4.6.4.2 Connection to *PELV* and *SELV* circuits

If a *port* is intended for connection of an external *PELV* or *SELV* circuit with a higher voltage than *DVC As*:

- measures to limit the voltage to that of *DVC As* shall be taken (see Annex A); or
- *basic protection* shall be provided.

For connectors containing pins with very small contact area (< 1 mm²), the next higher voltage level for DVC *As,* of Table 5, is permitted. Example: if *DVC A1* is *DVC As*, then *DVC A2* is permitted at pins of signal connectors.

The connection of external *PELV* or *SELV* circuits to an internal circuit is permitted with the following consideration:

- without measures: only if the *DVC* of the *PELV* and *SELV* voltage are lower than or equal to the *DVC* selected from Table 5 for the internal circuit under consideration; and
- with measures: if the *DVC* of the *PELV* and *SELV* voltage are higher than the *DVC* selected from Table 5 for the internal circuit under consideration.

The possibility of an addition of the voltages of the circuits under consideration to a higher level under fault conditions shall be considered.

For marking, see 6.3.7.1.

Consideration needs to be given to factors such as whether the circuits involved are earthed or not, what the voltages involved are, whether or not direct contact with live parts is possible, single faults in either equipment or the interconnections, etc.

4.4.7 Insulation

4.4.7.1 General

4.4.7.1.1 Influencing factors

This subclause gives minimum requirements for *insulation*, based on the principles of IEC 60664.

Manufacturing tolerances shall be taken into account for the requirements in 4.4.7.

Insulation shall be selected after consideration of the following influences:

- pollution degree;
- overvoltage category;
- supply *system* earthing;
- impulse withstand voltage, *temporary overvoltage* and *working voltage*;
- location of *insulation*;
- type of *insulation*.

Verification of *insulation* shall be made according to 5.2.2.1, 5.2.3.2, 5.2.3.4, and 5.2.3.5.

4.4.7.1.2 Pollution degree

Insulation, especially when provided by clearances and creepage distances, is affected by pollution which occurs during the *expected lifetime* of the *PECS*. The micro-environmental conditions for *insulation* shall be applied according to Table 8.

Table 8 – Definitions of pollution degrees

Pollution degree	Description
1	No pollution or only dry, non-conductive pollution occurs. The pollution has no influence.
2	Normally, only non-conductive pollution occurs. Occasionally, however, a temporary conductivity caused by condensation is to be expected.
3	Conductive pollution or dry non-conductive pollution occurs which becomes conductive due to condensation which is to be expected.
4	The pollution generates persistent conductivity caused, for example by conductive dust or rain or snow.

The pollution degree shall be determined according to the environmental condition for which the product is specified. See Table 18 for selection of pollution degree according to environmental classification of the *installation*.

The *insulation* may be determined according to pollution degree 2 if one of the following applies:

a) instructions are provided with the *PECS* indicating that it shall be installed in a pollution degree 2 environment; or
b) the specific *installation* application of the *PECS* is known to be a pollution degree 2 environment; or
c) the *PECS enclosure* or coatings applied within the *PECS* according to 4.4.7.8.4.2 or 4.4.7.8.6 provide adequate protection against what is expected in pollution degree 3 and 4 (conductive pollution and condensation).

The *PECS* manufacturer shall state in the documentation the pollution degree for which the *PECS* has been designed.

If operation in a pollution degree 4 environment is required, protection against conductive pollution shall be provided by means of a suitable *enclosure*.

NOTE 1 See Annex B for further information about the reduction of pollution degree.

NOTE 2 The dimensions for creepage distance cannot be specified where permanently conductive pollution is present (pollution degree 4). For temporarily conductive pollution (pollution degree 3), the surface of the *insulation* may be designed to avoid a continuous path of conductive pollution, e.g. by means of ribs and grooves. Annex D provides further information about the evaluation of clearance and creepage distances.

4.4.7.1.3 Overvoltage category (OVC)

The concept of overvoltage categories (based on IEC 60364-4-44 and IEC 60664-1) is used for equipment energized from the supply mains, and addresses the level of overvoltage protection expected. The OVC for *non-mains supply* is determined by taking into account whether control of overvoltages is provided or not, and whether the *PECS* is connected to outdoor lines or not, and if so, the length of the lines.

Four categories are considered.

- Equipment of overvoltage category IV (OVC IV) is for use at the origin of the *installation*.

  NOTE 1 Examples of such equipment are electricity meters and primary overcurrent protection equipment and other equipment connected directly to outdoor open lines.

- Equipment of overvoltage category III (OVC III) is equipment in fixed *installations* and for cases where the reliability and the availability of the equipment are subject to special requirements.

  NOTE 2 Examples of such equipment are switches in the fixed *installation* and equipment for industrial use with permanent connection to the fixed *installation*.

- Equipment of overvoltage category II (OVC II) is energy-consuming equipment to be supplied from the fixed *installation*.

  NOTE 3 Examples of such equipment are appliances, portable tools and other household and similar loads.

  If such equipment is subjected to special requirements with regard to reliability and availability, overvoltage category III applies.

- Equipment of overvoltage category I (OVC I) is equipment for connection to circuits in which measures are taken to limit transient overvoltages to an appropriately low level.

  NOTE 4 Examples of such equipment are those containing electronic circuits protected to this level.

NOTE 5 Unless the circuits are designed to take the *temporary overvoltage*s into account, equipment of overvoltage category 1 cannot be directly connected to the supply mains.

The measures for reduction of the impulse voltage shall ensure that the *temporary overvoltage*s that could occur are sufficiently limited so that their peak value does not exceed the relevant rated impulse voltage of Table 9 and shall meet the requirement of 4.4.7.2.2, 4.4.7.2.3 and 4.4.7.3 as applicable.

Annex I shows examples of overvoltage category considerations for *insulation* requirements.

For *PECS* and circuits not intended to be powered from the supply mains, the appropriate overvoltage category shall be determined as required by the application based on the overvoltage control provided on the supply to the equipment or circuit.

NOTE 6 Product committees using this standard as a reference document should consider the determination of overvoltage catagories for special applications.

4.4.7.1.4 Supply *system* earthing

The following three basic types of *system* earthing are described in IEC 60364-1.

- TN *system*: has one point directly earthed, the accessible conductive parts of the *installation* being connected to that point by protective conductors. Three types of TN *system*, TN-C, TN-S and TN-C-S, are defined according to the arrangement of the neutral and protective conductors.
- TT *system*: has one point directly earthed, the accessible conductive parts of the *installation* being connected to earth electrodes electrically independent of the earth electrodes of the power *system*.
- IT *system*: has all *live parts* isolated from earth or one point connected to earth through an impedance, the accessible conductive parts of the *installation* being earthed independently or collectively to the *system* earthing.

4.4.7.1.5 Determination of impulse withstand voltage and *temporary overvoltage*

Table 9 uses the *system voltage* (see 4.4.7.1.6) and overvoltage category of the circuit under consideration to determine the impulse withstand voltage. The *system voltage* is also used to determine the *temporary overvoltage*.

A *PECS* having more than one input or output shall be evaluated according to the input or output which gives the most severe requirements.

Table 9 – Impulse withstand voltage and *temporary overvoltage* versus system voltage

Column 1		2	3	4	5	6
System voltage [a] V (see 4.4.7.1.6) Up to and including		Impulse withstand voltage V				*Temporary overvoltage* [b] V
		Overvoltage category				
		I	II	III	IV	
a.c.	d.c.					r.m.s. / peak
50	75	330	500	800	1 500	1 250 / 1 770
100	150	500	800	1 500	2 500	1 300 / 1 840
150	225	800	1 500	2 500	4 000	1 350 / 1 910
300	450	1 500	2 500	4 000	6 000	1 500 / 2 120
600	900	2 500	4 000	6 000	8 000	1 800 / 2 550
1 000 [c]	1 500	4 000	6 000	8 000	12 000	2 200 / 3 110

[a] Interpolation of *system voltage* is not permitted when determining the impulse withstand voltage for *mains supply*.

[b] The r.m.s. values are derived using the formula (1 200 V + *system voltage*) from IEC 60664-1.

[c] The last row only applies to single-phase *systems*, or to the phase-to-phase voltage in three-phase *systems*.

4.4.7.1.6 Determination of the *system* voltage

4.4.7.1.6.1 For *mains supply*

For *PECS* supplied by an a.c. *mains supply*, the *system* voltage (in column 1 of Table 9) is:

- in TN and TT *systems*, the r.m.s. value of the rated voltage between a phase and earth;

NOTE 1 A corner-earthed *system* is a TN *system* with one phase earthed, in which the *system voltage* is the r.m.s. value of the rated voltage between a non-earthed phase and earth (i.e. the phase-phase voltage).

- in three-phase IT *systems* for determination of impulse voltage:
  - the r.m.s. value of the rated voltage between a phase and an artificial neutral point (an imaginary junction of equal impedances from each phase);

    NOTE 2 For most *systems*, this is equivalent to dividing the phase-to-phase voltage by $\sqrt{3}$.

    NOTE 3 The phase to an artificial neutral point can be accepted due to the well balance *systems*. Under *single fault condition* the *system* voltage will temporary change to phase to phase voltage, but under this *single fault condition* the impulse voltage is allowed to be reduced by one step according to Table 9 and will lead to the same result for the determination of clearance.
  - the r.m.s. value of the rated voltage between phases for *PECS* with increased reliability;
  - for determination of *temporary overvoltage*, the r.m.s. value of the rated voltage between phases;
- in single-phase IT *systems*, the r.m.s. value of the rated voltage between supply conductors.

NOTE 4 For *PECS* having series-connected diode bridges (12-pulse, 18-pulse, etc.), the *system voltage* is the sum of the a.c. voltages at the diode bridges.

When the supply voltage is rectified d.c. derived from the a.c. mains, the *system voltage* is the r.m.s. value of the source a.c. before rectification, taking into account the supply *system* earthing.

NOTE 5 Voltages generated within the *PECS* by the secondaries of transformers providing galvanic isolation from the *mains supply* are also considered to be *system voltages* for the determination of impulse voltages.

See 6.3.7.3 for marking requirements.

4.4.7.1.6.2 For *non-mains supply*

For *PECS* supplied by non-mains a.c. or d.c., the *system voltage* is the r.m.s. value of the supply voltage between phases.

4.4.7.1.7 Components bridging *insulation*

Components bridging *insulation* shall comply with the requirements of the level of *insulation* (e.g. *basic, reinforced, double*) they are bridging.

4.4.7.2 *Insulation* to the surroundings

4.4.7.2.1 General

Insulation for *basic*, *supplementary*, and *reinforced insulation* between a circuit and its surroundings shall be designed according to:

- the impulse withstand voltage; or
- the *temporary overvoltage*; or
- the *working voltage* of the circuit.

For creepage distances, the r.m.s. value of the *working voltage* is used, as described in 4.4.7.5.

For clearance distances and solid *insulation*, the impulse withstand voltage, the temporary overvoltage or the recurring peak value of the *working voltage* is used, as described in 4.4.7.2.2 to 4.4.7.2.4.

NOTE 1 Examples of *working voltage* with the combination of a.c., d.c. and recurring peaks are on the d.c. link of an indirect voltage source converter, or the damped oscillation of a thyristor snubber, or internal voltages of a switch-mode power supply. For more information see A.6.

NOTE 2 The impulse withstand voltage and *temporary overvoltage* depend on the *system* voltage of the circuit, and the impulse withstand voltage also depends on the overvoltage category, as shown in Table 9.

For *PEC* with galvanic isolation between the *mains* and *non-mains* circuits, the impulse voltage withstand ratings of the *mains* and *non-mains* circuits are determined as in 4.4.7.2.2 and 4.4.7.2.3. Thereafter the effect of reduction of the overvoltage categories (OVC) across the isolation is evaluated as follows:

- The magnitude of impulses from the *mains supply* circuit on the *non-mains supply* circuit is determined by reducing the OVC of the *non-mains supply* supplies by one level, and determining the resulting impulse voltage withstand rating based on *mains supply system voltage*.
- The rating to be used on the *non-mains* circuit is the higher of the value in 4.4.7.2.3 and the value determined above.
- The magnitude of impulses from the *non-mains* circuit on the mains circuit is determined by reducing the OVC of the *non-mains* circuit by one level, and determining the resulting impulse voltage withstand rating based on *non-mains supply system voltage*.
- The rating to be used on the *mains* circuit is the higher of the value in 4.4.7.2.2 and the value determined above.

For *PEC* not providing galvanic isolation between the *mains* and *non-mains* circuits, the impulse withstand voltage ratings of the *mains* and *non-mains* circuits are determined as in

4.4.7.2.2 and 4.4.7.2.3 above. The higher of the two impulse withstand voltage ratings is used for the entire combined circuit. For circuits connected to the combined circuit without galvanic isolation, the impulse withstand voltage rating of the combined circuit applies.

NOTE 3 See I.5 for examples.

When circuits of *DVC A* or *B* are supplied from the mains through a transformer providing galvanic isolation working at a frequency higher than that of the supply, the *insulation* between the circuit and the surroundings may be determined according to the *working voltage* of the circuit.

In that case the transformers ability to reduce the impulse voltages to values less than the impulse voltage associated with the *working voltage* determined from Table 10 shall be shown by test, simulation or calculation.

NOTE 4 The ability of a high frequency transformer to reduce impulse voltages originates from the very low coupling capacitance across the galvanic *insulation* compared to a the typical grounding capacitance in the *DVC A* or *B* circuit.

4.4.7.2.2 Circuits connected to *mains supply*

Insulation between the surroundings and circuits which are connected directly to the *mains supply* shall be designed according to the impulse withstand voltage, *temporary overvoltage*, or *working voltage*, whichever gives the most severe requirement.

This *insulation* is normally evaluated to withstand impulses of overvoltage category III, except that overvoltage category IV shall be used when the *PECS* is connected at the origin of the *installation*. Overvoltage category II may be used for plug-in equipment without special requirements with regard to reliability.

If measures are provided which reduce impulses of overvoltage category IV to values of category III, or values of category III to values of category II, *basic* or *supplementary insulation* may be designed for the reduced values. The requirements for *double* or *reinforced insulation* shall not be reduced to values less than those required for *basic insulation* designed to withstand impulses without these measures being present.

If the devices used for this purpose can be damaged by overvoltages or repeated impulses, thus decreasing their ability to reduce impulses, they shall be monitored and an indication of their status provided.

NOTE 1 The determined impulse withstand voltage based on the *system* voltage may be reduced by means of inherent protection or *SPD* internal in the *PECS* or as part of the *installation*. IEC 61643-12 provides information on the selection and use of such *SPD*.

NOTE 2 Circuits which are connected to the supply mains via *protective impedances*, according to 4.4.5.4, are not regarded as connected directly to the supply mains.

4.4.7.2.3 Circuits connected to *non-mains supply*

Insulation between the surroundings and circuits supplied from a *non-mains supply* shall be designed according to:

- the impulse withstand voltage determined from Table 9 using the *system voltage*;
- the *working voltage*;
- the *temporary overvoltage* if known to exist due to the nature of the supply;

whichever gives the more severe requirement.

These values are used to enter Table 10 for the design of clearance.

Temporary overvoltage on a *non-mains supply* shall be determined as follows:

- Without detailed knowledge of the *temporary overvoltage*, it shall be according to Table 9.
- If the *temporary overvoltage* is known this value shall be used.

By the determination of temporary overvoltages on non-mains supply, following situations should be considered:

- loss of the neutral in a non-mains low-voltage system;
- accidential earthing of a non-mains low voltage IT system; and
- short circuit in the non-mains low voltage installation.

For further information, see IEC 60364-4-44-2007, Clause 442.

The overvoltage category for *non-mains supply* shall be overvoltage category II. A higher overvoltage category shall be assigned when control of over-voltage is not provided, and when connected to long outdoor lines. For applications and circuits with a known low level of impulse voltages and for which it can be shown that the impulse voltages remain on a low level even under *single fault condition*, overvoltage category I may be used. This requirement is considered to be met if the expected impulse voltages do not exceed the values given in Table 9 for overvoltage category I at the appropriate *system voltage*.

NOTE 1 The overvoltage category for *non-mains supplies* does not differ between equipment *permanently connected* in fixed *installations* and equipment not *permanently connected* to the fixed *installation*.

Product committees using this standard as a reference document shall determine the appropriate overvoltage category from Table 9, based on the *system voltage* and the maximum impulse voltage likely to occur in their application. Special consideration may be applicable for product specific applications, which have not been considered in this standard.

Communication lines shall be considered as *non-mains supplies*.

If measures are provided which reduce impulses of overvoltage category III to values of category II, or values of category II to values of category I, *basic* or *supplementary insulation* may be designed for the reduced value. The requirements for *double* or *reinforced insulation* shall not be reduced to values less than those required for *basic insulation* designed to withstand impulses without these measures being present.

If the devices used for this purpose can be damaged by overvoltages or repeated impulses, thus decreasing their ability to reduce impulses, they shall be monitored and an indication of their status provided.

NOTE 2 The determined impulse withstand voltage based on the *system* voltage can be reduced by means of inherent protection or *SPD* internal in the PECS or as part of the *installation*. IEC 61643-12 provides information on the selection and use of such *SPD*.

4.4.7.2.4 *Insulation* between circuits

Insulation between two circuits shall be designed according to the circuit having the more severe requirement.

For the design of *simple* and *protective separation* between circuits the *insulation* shall be designed according to:

- the circuit having the more severe requirement; or
- the *working voltage* between the circuits;

whichever gives the most severe requirement.

4.4.7.3 Functional *insulation*

If the failure of *functional insulation* does not produce a hazard (electrical, thermal, fire), no specific requirements apply for the dimensioning of *functional insulation*. In other cases the following requirements apply.

Testing is not required, except where the circuit analysis required by 4.2 shows that failure of the *insulation* could result in a hazard.

For parts or circuits that are significantly affected by external transients, *functional insulation* shall be designed according to the impulse withstand voltage of overvoltage category II, except that overvoltage category III shall be used when the *PECS* is connected at the origin of the *installation*.

Where measures are provided that reduce transient overvoltages within the circuit from category III to values of category II, or values of category II to values of category I, *functional insulation* may be designed for the reduced values.

Where the circuit characteristics can be shown by testing (see 5.2.3.2) to reduce impulse voltages, *functional insulation* may be designed for the highest impulse voltage occurring in the circuit during the tests.

For parts or circuits that are not significantly affected by external transients, *functional insulation* shall be designed according to the *working voltage* across the *insulation*.

4.4.7.4 Clearance distances

4.4.7.4.1 Determination

Clearances for *functional*, *basic* and *supplementary insulation* shall be dimensioned according to Table 10 (see Annex D for examples of the evaluation of clearance distances). Interpolation is permitted, when clearance is determined from *temporary overvoltage* or *working voltage*.

Clearances for *reinforced insulation* shall be dimensioned to withstand an impulse voltage one step higher than the impulse withstand voltage, or 1,6 times the peak *temporary overvoltage* or peak *working voltage*, required for *basic insulation*.

Clearance distances for use in altitudes between 2 000 m and 20 000 m shall be calculated using a correction factor according to Table A.2 of IEC 60664-1:2007, which is reproduced as Table E.1.

A correction factor selected from Table F.2 is also used for determination of clearance distances for approximately homogenous fields when frequencies are greater than 30 kHz, as given in Annex F.

Table 10 – Clearance distances for *functional*, *basic* or *supplementary insulation*

<table>
<tr><th rowspan="2">Impulse withstand voltage [d]
(from Table 9)
V</th><th rowspan="2">Temporary overvoltage [d f]
(peak)
only relevant for determining insulation between surroundings and circuits
(from Table 9)
V</th><th rowspan="2">Working voltage [d f]
(recurring peak) [a]
V</th><th colspan="4">Minimum clearance distances in air up to 2 000 m above sea level
mm</th></tr>
<tr><th colspan="4">Pollution degree</th></tr>
<tr><th></th><th></th><th></th><th>1</th><th>2</th><th>3</th><th>4</th></tr>
<tr><td>330</td><td>330</td><td>260</td><td>0,01</td><td rowspan="3">0,2 [b c]</td><td rowspan="4">0,8 [c]</td><td rowspan="5">1,6 [c]</td></tr>
<tr><td>500</td><td>500</td><td>400</td><td>0,04</td></tr>
<tr><td>800</td><td>710</td><td>560</td><td>0,10</td></tr>
<tr><td>1 500</td><td>1 270</td><td>1 010</td><td>0,5</td><td>0,5</td></tr>
<tr><td>2 500</td><td>2 220</td><td>1 770</td><td>1,5</td><td>1,5</td><td>1,5</td></tr>
<tr><td>4 000</td><td>3 430</td><td>2 740</td><td>3,0</td><td>3,0</td><td>3,0</td><td>3,0</td></tr>
<tr><td>6 000</td><td>4 890</td><td>3 910</td><td>5,5</td><td>5,5</td><td>5,5</td><td>5,5</td></tr>
<tr><td>8 000</td><td>6 060</td><td>4 840</td><td>8,0</td><td>8,0</td><td>8,0</td><td>8,0</td></tr>
<tr><td>12 000</td><td>9 430</td><td>7 540</td><td>14</td><td>14</td><td>14</td><td>14</td></tr>
</table>

[a] This voltage is approximately 0,8 times the voltage required to break down the associated clearance.

[b] For printed wiring board (PWB), the values for pollution degree 1 apply except that the value shall not be less than 0,04 mm.

[c] The minimum clearance distances given for pollution degrees 2, 3 and 4 are based on the reduced withstand characteristics of the associated creepage distance under humidity conditions (see IEC 60664-5).

[d] Interpolation is permitted for *non-mains supply*.

[e] Clearances for *temporary overvoltage* and *working voltage* are derived from Table F.7a of IEC 60664-1:2007.

[f] Interpolation is permitted, when clearance is determined from *temporary overvoltage* and *working voltage*.

NOTE If clearances are stressed with steady-state voltages of 2,5 kV (peak) and above, dimensioning according to the breakdown values in Table 10 may not provide operation without corona (partial discharges), especially for inhomogeneous fields. In order to provide corona-free operation, it is possible either to use larger clearances, as given in Table F.7b of IEC 60664-1:2007, or to improve the field distribution.

Compliance shall be checked by visual inspection (see 5.2.2.1) or by performing the impulse voltage test of 5.2.3.2 and the a.c. or d.c. voltage test of 5.2.3.4.

4.4.7.4.2 Electric field homogeneity

The dimensions in Table 10 correspond to the requirements of an inhomogeneous electric field distribution across the clearance, which are the conditions normally experienced in practice. If a homogeneous electric field distribution is known to exist, the clearance distance for *basic* or *supplementary insulation* may be reduced to not less than that required by Table F.2 (Case B) of IEC 60664-1:2007. In this case, however, the impulse voltage test of 5.2.3.2 shall be performed across the considered clearance.

If the withstand against steady state voltages, recurring peak or *temporary overvoltage*s according to Table 10 is decisive for the dimensioning of clearance and if these clearances are smaller than the values of Table 10 then an a.c. or d.c. voltage test according to 5.2.3.4 is required. Clearance distances for *reinforced insulation* shall not be reduced for homogeneous fields.

4.4.7.4.3 Clearance to conductive *enclosure*s

The clearance between any non-insulated *live part* and the walls of a metal *enclosure* shall be in accordance with 4.4.7.4.1 during and following the deflection tests of 5.2.2.4.2.

Compliance is checked by inspection and by test of 5.2.2.4.2.

If the design clearance distance is at least 12,7 mm and the clearance distance required by 4.4.7.4.1 does not exceed 8 mm, the deflection tests may be omitted.

4.4.7.5 Creepage distances

4.4.7.5.1 Insulating material groups

Insulating materials are classified into four groups corresponding to their comparative tracking index (CTI) when tested according to 6.2 of IEC 60112:2003:

- Insulating material group I: CTI ≥ 600;
- Insulating material group II: 600 > CTI ≥ 400;
- Insulating material group IIIa: 400 > CTI ≥ 175;
- Insulating material group IIIb: 175 > CTI ≥ 100.

Creepage distance requirements for PWBs exposed to pollution degree 3 environmental conditions shall be determined based on Table 11 pollution degree 3 under “Other insulators”.

If the creepage distance is ribbed, then the creepage distance of insulating material of group I may be applied using insulating material of group II and the creepage distance of insulating material of group II may be applied using insulating material of group III. The spacing of the ribs shall equal or exceed the dimension ‘X’ in Table D.1. For pollution degree 2 and 3, the ribs shall be at least 2 mm high.

For inorganic insulating materials, for example glass or ceramic, which do not track, the creepage distance may equal the associated clearance distance, as determined from Table 10.

4.4.7.5.2 Determination

Creepage distances for *functional*, *basic* and *supplementary insulation* shall be dimensioned according to Table 11. Interpolation is permitted. Creepage distances for *reinforced insulation* shall be twice the distances required for *basic insulation*.

Table 11 – Creepage distances (in millimetres)

Column 1	2	3	4	5	6	7	8	9	10	11	12
***Working voltage* (r.m.s.)**	**PWBs** [a]		**Other insulators**								
	Pollution degree		**Pollution degree**								
	1	**2**	**1**	**2**				**3**			
V	All material groups	All material groups except IIIb	All material groups	**Insulating material group**				**Insulating material group**			
				I	**II**	**IIIa**	**IIIb**	**I**	**II**	**IIIa**	**IIIb**
≤ 2	0,025	0,04	0,056	0,35	0,35	0,35		0,87	0,87	0,87	
5	0,025	0,04	0,065	0,37	0,37	0,37		0,92	0,92	0,92	
10	0,025	0,04	0,08	0,40	0,40	0,40		1,0	1,0	1,0	
25	0,025	0,04	0,125	0,50	0,50	0,50		1,25	1,25	1,25	
32	0,025	0,04	0,14	0,53	0,53	0,53		1,3	1,3	1,3	
40	0,025	0,04	0,16	0,56	0,80	1,1		1,4	1,6	1,8	
50	0,025	0,04	0,18	0,60	0,85	1,20		1,5	1,7	1,9	
63	0,04	0,063	0,20	0,63	0,90	1,25		1,6	1,8	2,0	
80	0,063	0,10	0,22	0,67	0,95	1,3		1,7	1,9	2,1	
100	0,10	0,16	0,25	0,71	1,0	1,4		1,8	2,0	2,2	
125	0,16	0,25	0,28	0,75	1,05	1,5		1,9	2,1	2,4	
160	0,25	0,40	0,32	0,80	1,1	1,6		2,0	2,2	2,5	
200	0,40	0,63	0,42	1,0	1,4	2,0		2,5	2,8	3,2	
250	0,56	1,0	0,56	1,25	1,8	2,5		3,2	3,6	4,0	
320	0,75	1,6	0,75	1,6	2,2	3,2		4,0	4,5	5,0	
400	1,0	2,0	1,0	2,0	2,8	4,0		5,0	5,6	6,3	
500	1,3	2,5	1,3	2,5	3,6	5,0		6,3	7,1	8,0	
630	1,8	3,2	1,8	3,2	4,5	6,3		8,0	9,0	10,0	
800	2,4	4,0	2,4	4,0	5,6	8,0		10,0	11	12,5	[b]
1 000	3,2	5,0	3,2	5,0	7,1	10,0		12,5	14	16	
1 250	4,2	6,3	4,2	6,3	9	12,5		16	18	20	
1 600	[c]	[c]	5,6	8,0	11	16		20	22	25	
2 000			7,5	10,0	14	20		25	28	32	
2 500			10,0	12,5	18	25		32	36	40	
3 200			12,5	16	22	32		40	45	50	
4 000			16	20	28	40		50	56	63	
5 000			20	25	36	50		63	71	80	
6 300			25	32	45	63		80	90	100	
8 000			32	40	56	81		100	110	125	
10 000 [d]			40	50	71	100		125	140	160	

Interpolation is permitted.

[a] These columns also apply to components and parts on PWBs, and to other creepage distances with a comparable control of tolerances.

[b] Insulating materials of group IIIb are not normally recommended for pollution degree 3 above 630 V.

[c] Above 1 250 V use the values from columns 4 to 11, as appropriate.

[d] For higher voltages, creepage distances should be dimensioned according to Table F.4 of IEC 60664-1:2007

When the creepage distance requirement determined from Table 11 is less than the clearance distance required by 4.4.7.4.1 or the clearance distance determined by impulse testing (see 5.2.3.2), then the creepage distance shall be increased to the clearance distance.

Compliance of creepage distances shall be checked by measurement or inspection (see 5.2.2.1) (see Annex D for examples of the evaluation of creepage distances).

4.4.7.6 Coating

A coating may be used to provide *insulation*, to protect a surface against pollution, and to allow a reduction in creepage and clearance distances (see 4.4.7.8.4.2 and 4.4.7.8.6).

4.4.7.7 PWB spacings for functional *insulation*

Spacings for *functional insulation* shall comply with the requirement of 4.4.7.4 and 4.4.7.5.

Decreased spacings on PWB are permitted when all the following are satisfied:

- the PWB has flammability rating of V-0 (see IEC 60695-11-10);
- the PWB base material has a minimum CTI of 100;
- the equipment complies with the PWB short circuit test (see 5.2.4.7).

Decreased spacings for components assembled on PWB are permitted when used in:

- pollution degree 1 or 2 environment; and
- not more than overvoltage category I.

In this case the manufacture specification may be used.

Compliance is checked by inspection and by test of 5.2.4.7 if applicable.

4.4.7.8 Solid *insulation*

4.4.7.8.1 General

Materials selected for solid *insulation* shall be able to withstand the stresses occurring. These include mechanical, electrical, thermal, climatic and chemical stresses which are to be expected in normal use. *Insulation* materials shall also be resistant to ageing during the *expected lifetime* of the *PECS*.

Tests shall be performed on components and sub-assemblies using solid *insulation*, in order to ensure that the *insulation* performance has not been compromised by the design or manufacturing process.

4.4.7.8.2 Material requirements

The insulating material shall have a CTI of 100 or greater.

The insulating material shall be suitable for the maximum temperature it attains as determined by the temperature rise test of 5.2.3.10. Consideration shall be given as to whether or not the insulating material additionally provides mechanical strength and whether or not the part can be subject to impact during use.

The insulating material in contact with *live parts* higher than *DVC As* shall comply with:

- the glow-wire test described in 5.2.5.3 at a test temperature of 850 °C; or
- the glow-wire test described in 5.2.5.3, at a lower test temperature, but not less than 550 °C, depending on the classification of the use of the *PECS*, according to Table A.1 of IEC 60695-2-11:2011; or
- the alternative hot wire ignition test of 5.2.5.4.

Thermoplastic insulating materials used in contact with *live parts* higher than *DVC As* or used as part of the *enclosure* shall comply with the ball pressure test as abnormal heat test according to IEC 60695-10-2.

Where an insulating material is used in a *PECS* that incorporates switching contacts, and is within 12,7 mm of the contacts, it shall comply with the high current arcing ignition test of 5.2.5.2.

In case the manufacturer of the insulating material provides data to demonstrate compliance with the above requirements no further testing is required.

No further evaluation is required when generic materials are used according to Table 12.

Table 12 – Generic materials for the direct support of uninsulated *live parts*

Generic material	Minimum thickness mm	Maximum temperature °C
Any cold-moulded composition	No limit	No limit
Ceramic, porcelain	No limit	No limit
Diallyl phthalate	0,7	105
Epoxy	0,7	105
Melamine	0,7	130
Melamine-phenolic	0,7	130
Phenolic	0,7	150
Unfilled nylon	0,7	105
Unfilled polycarbonate	0,7	105
Urea formaldehyde	0,7	100

Compliance is checked by inspection and by test of 5.2.3.10 and 5.2.5.3 or 5.2.5.2.

4.4.7.8.3 Thin sheet or tape material

4.4.7.8.3.1 General

4.4.7.8.3 applies to the use of thin sheet or tape materials in assemblies such as wound components and bus-bars.

Insulation consisting of thin (less than 0,75 mm) sheet or tape materials is permitted, provided that it is protected from damage and is not subject to mechanical stress under normal use.

Where more than one layer of *insulation* is used, there is no requirement for all layers to be of the same material.

NOTE 1 One layer of *insulation* tape wound with more than 50 % overlap is considered to constitute two layers.

NOTE 2 *Basic*, *supplementary* and *double insulation* can be applied as a pre-assembled *system* of thin materials.

4.4.7.8.3.2 Material thickness equal to or more than 0,2 mm

- *Basic* or *supplementary insulation* shall consist of at least one layer of material, which will meet the requirements of 4.4.7.8.1 and 4.4.7.10.1.
- *Double insulation* shall consist of at least two layers of material, each of which will meet the requirements of 4.4.7.8.1, 4.4.7.10.1, and the partial discharge requirements of

4.4.7.10.2, and both layers together will meet the impulse and a.c. or d.c. voltage requirements of 4.4.7.10.2.

- *Reinforced insulation* shall consist of a single layer of material, which will meet the requirements of 4.4.7.8.1 and 4.4.7.10.2.

NOTE The requirements of this subclause indicate that *double insulation* can be at least 0,4 mm thick, while *reinforced insulation* is permitted to be 0,2 mm thick.

4.4.7.8.3.3 Material thickness less than 0,2 mm

Basic or *supplementary insulation* shall consist of at least two layers of material, which will meet the requirements of 4.4.7.8.1 and 4.4.7.10.1.

Double insulation shall consist of at least three layers of material. Each layer shall meet the requirements of 4.4.7.8.1 and 4.4.7.10.1, and any two layers together shall meet the requirements of 4.4.7.10.2.

Reinforced insulation consisting of a single layer of material is not permitted.

4.4.7.8.3.4 Compliance

Compliance shall be checked by the tests described in 5.2.3.1 to 5.2.3.5.

When a component or sub-assembly makes use of thin sheet insulating materials, it is permitted to perform the tests on the component rather than on the material.

4.4.7.8.4 Printed wiring boards (PWBs)

4.4.7.8.4.1 General

Insulation between conductor layers in double-sided single-layer PWBs, multi-layer PWBs and metal core PWBs, shall meet the requirements of 4.4.7.8.1. *Basic*, *supplementary*, *double* and *reinforced insulation* shall meet the appropriate requirements of 4.4.7.10.1 or 4.4.7.10.2. *Functional insulation* in PWBs shall meet the requirements of 4.4.7.7.

For the inner layers of multi-layer PWBs, the *insulation* between adjacent tracks on the same layer shall be treated as either:

- a creepage distance for pollution degree 1 and a clearance as in air (see Example D.14); or
- solid *insulation*, in which case it shall meet the requirements of 4.4.7.8.1 and 4.4.7.10.

4.4.7.8.4.2 Use of coating materials

A coating material used to provide *functional*, *basic*, *supplementary* and *reinforced insulation* shall meet the requirement as specified below.

Type 1 protection (as defined in IEC 60664-3) improves the microenvironment of the parts under protection. The clearance and creepage distance of Table 10 and Table 11 for pollution degree 1 apply under the protection. Between two conductive parts, it is a requirement that one or both conductive parts, together with all the spacing between them, are covered by the protection.

Type 2 protection is considered to be similar to solid *insulation*. Under the protection, the requirements for solid *insulation* specified in 4.4.7.8 are applicable, including the coating material itself, and spacings shall not be less than those specified in Table 1 of IEC 60664-3:2003. The requirements for clearance and creepage in Table 10 and Table 11 do not apply. Between two conductive parts, it is a requirement that both conductive parts, together with the spacing between them, are covered by the protection so that no airgap exists between the protective material, the conductive parts and the printed boards.

The coating material used to provide Type 1 and Type 2 protection shall be designed to withstand the stresses anticipated to occur during the *expected lifetime* of the *PECS*. A *type test* on representative PWBs shall be conducted according to Clause 5 of IEC 60664-3:2003. For the cold test (5.7.1 of IEC 60664-3:2003), a temperature of -25 °C shall be used, and for the rapid change of temperature test (5.7.3 of IEC 60664-3:2003): -25 °C to +125 °C. No *routine test* is required.

4.4.7.8.5 Wound components

Varnish or enamel *insulation* of wires shall not be used for *basic*, *supplementary*, *double* or *reinforced insulation*.

Wound components shall meet the requirements of 4.4.7.8.1 and 4.4.7.10.

The component itself shall pass the requirements given in 4.4.7.8.1 and 4.4.7.10.2. If the component has *reinforced* or *double insulation*, the a.c. or d.c. voltage test of 5.2.3.4 shall be performed as a *routine test*.

4.4.7.8.6 Potting materials

A potting material may be used to provide solid *insulation* or to act as a coating to protect against pollution. If used as solid *insulation* for *basic, fault* and *enhanced protection*, it shall comply with the requirements of 4.4.7.8.1 and 4.4.7.10. If used to protect against pollution, the requirements for type 1 protection in 4.4.7.8.4.2 apply.

4.4.7.9 Connection of parts of *solid insulation* (cemented joints)

The creepage and clearance path in the presence of a cemented joint between two insulating parts, are determined as follows.

- Type 1 or type 2 protection as described in 4.4.7.8.4.2 apply.
- A cemented joint that is not evaluated as providing protection of type 1 or type 2, is neither considered solid *insulation* nor to reduce pollution degree. The clearance and creepage distances of Table 10 and Table 11 apply for the pollution degree of the environment around the joint. See 5.2.5.7 for test.

As an example, see Example D.9.

4.4.7.10 Requirements for electrical withstand capability

4.4.7.10.1 *Basic* or *supplementary insulation*

Basic or *supplementary insulation* shall be tested as follows:

- Test with impulse withstand voltage according to 5.2.3.2; and
- Test with a.c. or d.c. voltage according to 5.2.3.4.

4.4.7.10.2 *Double* or *reinforced insulation*

Double or *reinforced insulation* shall be tested as follows:

- Test with impulse withstand voltage according to 5.2.3.2; and
- Test with a.c. or d.c. voltage according to 5.2.3.4.

For solid *insulation*, the partial discharge test according to 5.2.3.5 shall be performed in addition to the above tests, if the recurring peak *working voltage* across the *insulation* is greater than 750 V and the voltage stress on the *insulation* is greater than 1 kV/mm.

NOTE The voltage stress is the recurring peak voltage divided by the distance between two parts of different potential.

The partial discharge test shall be performed as a *type test* on all components, sub-assemblies and PWB. In addition, a *sample test* shall be performed if the *insulation* consists of a single layer of material.

Double insulation shall be designed so that failure of the *basic insulation* or of the *supplementary insulation* will not result in reduction of the *insulation* capability of the remaining part of the *insulation*.

4.4.7.11 *Insulation* requirements above 30 kHz

Where voltages across *insulation* have fundamental frequencies greater than 30 kHz, further considerations apply.

Annex F contains requirements for the determination of clearance and creepage distances under these circumstances.

Compliance of creepage and clearance distances shall be checked by measurement or inspection according to Annex F.

4.4.8 Compatibility with residual current-operated protective devices (RCD)

Some domestic and industrial *installations* provide RCD as additional protection against *insulation* faults, in addition to the *basic* and *fault protection* provided by *PECS*.

An *insulation* fault or direct contact with certain types of *PECS* circuits can cause failure current with a d.c. component to flow in the *PE conductor* and thus reduce the ability of an RCD of type A or AC (see IEC 60755) to provide this protection for other equipment in the *installation*.

To ensure the intended work of an RCD provided by the *installation PECS* shall satisfy one of the following conditions.

a) A Pluggable Type A single-phase *PECS*, shall be designed so that, under normal and fault conditions any resulting d.c. component of the current in the *PE conductor* does not exceed the d.c. current withstand requirements in IEC 60755 for RCD of type A.

   NOTE At the time of writing, the requirement in IEC 60755 is for type A RCD to be able to tolerate 6 mA of d.c. current while still maintaining their protective functionality.

b) For *PECS* that are Pluggable Type B or intended for *permanent connection*, d.c. current in the *PE conductor* is not limited if the information and marking requirements of 6.3.7.4 are complied with.

For the design and construction of electrical *installations*, care should be taken with RCD of Type B. All the RCD upstream from an RCD of Type B up to the supply transformer shall be of Type B.

Compliance with RCD provided by the *installation* shall be checked by simulation or calculation of current in the *PE conductor* under normal and *single fault conditions* according to the guideline provided in Annex H.

See 6.3.7.4 for information and marking requirements.

4.4.9 Capacitor discharge

For protection against shock hazard, capacitors within a *PECS* shall be discharged to a voltage less than *DVC As*, or to a residual charge less than 50 μC, after the removal of power from the *PECS:*

- For pluggable *PECS* type A and B the discharge time shall not exceed 1 s or the hazardous *live parts* shall be protected against direct contact by at least IPXXB (see 4.4.3.3).
- For *permanently connected PECS* the discharge time shall not exceed 5 s.

For pluggable *PECS* type A and B and *permanently connected PECS,* which do not meet the above requirements, access shall only be possible by means of a tool or key and the information and marking requirements of 6.5.2 apply.

Compliance is checked by test of 5.2.3.8.

NOTE 1 This requirement also applies to capacitors used for power factor correction, filtering, etc.

NOTE 2 Product committees using this document as reference document can consider the charge level 0,5 μC as threshold of perception as recommended by IEC 61140.

4.5 Protection against electrical energy hazards

4.5.1 Operator access areas

4.5.1.1 General

Equipment shall be so designed that there is no risk of electrical energy hazard in operator access areas from accessible circuits by fulfilling requirement of 4.2.

A risk of injury due to an electrical energy hazard exists if it is likely that two or more bare parts (one of which may be earthed) between which a hazardous energy level exists, will be bridged by a metallic object.

The likelihood of bridging the parts under consideration is determined by means of the test finger of Figure 1 of IEC 60529:1989, in a straight position. If it is possible to bridge the parts with this test finger, a hazardous energy level shall not exist.

Barriers, guards, and similar means preventing unintentional contact may be provided as an alternative to limiting the energy.

Compliance is checked by inspection or test of 5.2.2.2.

4.5.1.2 Determination of hazardous electrical energy level

A hazardous electrical energy level is considered to exist if:

- the voltage is 2 V or more;

and

- power available exceeds 240 VA after 60 s; or
- the energy exceeds 20 J.

Compliance shall be checked with the test in 5.2.3.9 or by calculation as follows:

in case of a capacitor the stored energy in the capacitor is at a voltage of 2 V or more, and the stored energy calculated from the following equation, exceeds 20 J:

$$E = 0{,}5\ CU^2$$

where

E is the energy, in joules (J);

C is the capacitance, in farads (F);

U is the measured voltage on the capacitor, in volts (V).

4.5.2 Service access areas

Capacitors located behind panels that are removable for servicing, installation, or disconnection shall present no risk of electric energy hazard from charge stored on capacitors after disconnection of the *PECS*.

Capacitors within a *PECS* shall be discharged to an energy level less than 20 J, as in 4.5.1.2, within 5 s after the removal of power from the *PECS*. If this requirement is not achievable for functional or other reasons, the information and marking requirements of 6.5.2 apply.

Compliance is checked by inspection of the equipment and relevant circuit diagrams, taking into account the possibility of disconnection with any "ON"/"OFF" switch in either position and non-operation of periodic power consuming devices or components within the PECS. If the capacitor discharge time can not be accurately calculated, the discharge time shall be measured.

4.6 Protection against fire and thermal hazards

4.6.1 Circuits representing a fire hazard

The following types of circuits are considered a fire hazard:

- circuits directly connected to the mains;
- circuits that are not directly connected to the mains but exceed the limits for limited power sources in 4.6.5;
- components having unenclosed arcing parts.

4.6.2 Components representing a fire hazard

4.6.2.1 General

The risk of ignition due to high temperature shall be minimized by the appropriate selection and use of components and by suitable construction.

Electrical components shall be used in such a way that their maximum working temperature under normal or *single fault conditions* is less than that necessary to cause ignition of the surrounding materials with which they are likely to come into contact. Under normal conditions the limits in Table 14 shall not be exceeded for components or their surrounding material.

Where it is not practical to protect components against overheating under fault conditions, all materials in contact with such components shall be of flammability class V-1, according to IEC 60695-11-10, or better.

Compliance with 4.6.2 and 4.6.3 shall be confirmed by inspection of component and material data sheets and, where necessary, by test.

4.6.2.2 Components within a circuit representing a fire hazard

Inside *fire enclosures*, materials for components and other parts and all materials in contact with such parts shall comply with flammability class V-2 as classified in IEC 60695-11-10 or flammability class HF-2 as classified in ISO 9772 or better.

In case the manufacturer of components provides data to demonstrate compliance with the above requirements no further testing is required.

The above requirement does not apply to any of the following:

- electrical components which do not present a fire hazard under abnormal operating conditions when tested according to 5.2.4.6;
- materials and components within an *enclosure* of 0,06 m^3 or less, consisting totally of metal and having no ventilation openings, or within a sealed unit containing an inert gas;
- electronic components, such as integrated circuit packages, opto-coupler packages, capacitors and other small parts that are mounted on material of flammability class V-1 or better;
- wiring, cables and connectors insulated with PVC, TFE, PTFE, FEP, neoprene or polyimide;
- the following parts, provided that they are separated from electrical parts (other than insulated wires and cables) which under fault conditions are likely to produce a temperature that could cause ignition, by at least 13 mm of air or by a solid barrier of material of flammability class V-1 or better:
  – other small parts which would contribute negligible fuel to a fire, including, labels, mounting feet, key caps, knobs and the like;
  – tubing for air or any fluid *systems*, containers for powders or liquids and foamed plastic parts, provided that they are of flammability class HB.

4.6.2.3 Components within a circuit not representing a fire hazard

For components within a circuit not representing a fire hazard 4.6.2 does not apply.

4.6.3 *Fire enclosures*

4.6.3.1 General

Fire enclosures are used to reduce the risk of fire to the environment, independent of the location where they are installed.

A *fire enclosure* shall be provided for all *PECS* unless:

- the product committee specifies that a *fire enclosure* is not required; or
- there is an agreement between the user and the manufacturer; or
- the *PECS* is intended to be used only in areas without combustible materials and is marked according to 6.3.5.

4.6.3.2 Flammability of *enclosure* materials

Materials used for *fire enclosures* of *PECS* shall meet the flammability test requirements of 5.2.5.5, except for those portions of the *enclosure* that enclose only circuits not representing a fire hazard.

Materials are considered to comply without test if, in the minimum thickness used, the material is of flammability class 5VA or better, according to IEC 60695-11-20.

Metals, ceramic materials, and glass which is heat-resistant tempered, wired or laminated, are considered to comply without test.

Materials for components that fill an opening in a *fire enclosure* shall:

- be of at least V-1 class material and no larger than 100 mm in any dimension; or
- be of at least V-2 class material and either
  – not larger than 25 mm in any dimension; or

   - not larger than 100 mm in any dimension and located at least 100mm from any part that is a source of fire hazard; or
- be of at least V-2 class material and there is a barrier or device(s) that forms a barrier made of a V-0 class material between the part and a source of fire hazard; or
- comply with a relevant IEC component standard that includes flammability requirements for components that are intended to form part of, or fill openings in, a *fire enclosure*.

NOTE Examples of these components are fuse-holders, switches, pilot lights, connectors and appliance inlets.

Polymeric materials that serve as the outer *enclosure* and have surface area greater than 1 m^2 or a single dimension larger than 2 m, shall have a maximum flame spread index of 100 as determined by ASTM E162 or ANSI/ASTM E84.

The manufacturer may provide data from the *fire enclosure* material supplier to demonstrate compliance with the above requirements. In this case, no further testing is required.

Compliance shall be checked by visual inspection and, where necessary, by test.

4.6.3.3 Openings in *fire enclosures*

4.6.3.3.1 General

For equipment that is intended to be used or installed in more than one orientation as specified in the product documentation, the requirements in 4.6.3.3.2 to 4.6.3.3.4 apply in each orientation.

These requirements are in addition to requirements regarding openings, in other sections of this standard.

NOTE For example the sections regarding *basic protection* with *live parts* or hazardous moving parts are additional to the requirements in this section.

4.6.3.3.2 Openings in the top and side of *fire enclosures*

Openings in the top surfaces of *fire enclosures* shall be designed to prevent an external object falling vertically or at up to 5° from vertically from entering the *enclosure* in an area that could lead to a fire hazard.

This requirement applies to all sides of moveable equipment with no defined top and bottom, unless top and bottom surfaces can be suitably demonstrated in the installation instructions.

Compliance shall be checked by test of 5.2.2.2.

Openings in the top surfaces of *fire enclosures* not located vertically above or within 5° from vertical of a circuit representing a fire hazard as defined in 4.6.1 are not subject to the test of 5.2.2.2 and can be of any construction if the construction prevents access to parts greater than *DVC As* with the IP3X probe as detailed in 4.4.3.3.

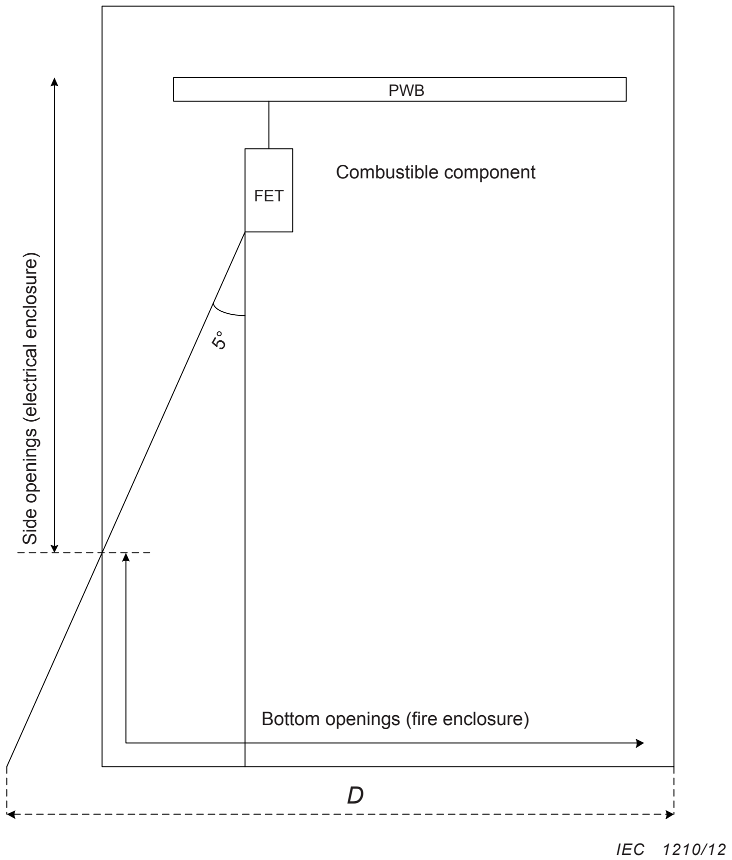
Where a portion of the side of a *fire enclosure* falls within the area traced out by the 5° angle in Figure 6, the limitations in 4.6.3.3.3 regarding openings in bottoms of *fire enclosures* also apply to this portion of the side.

Compliance shall be checked by visual inspection.

4.6.3.3.3 Openings in the bottom of a *fire enclosure*

The bottom of a *fire enclosure* or individual barriers shall provide protection against emission of flaming or molten material under all internal parts, including partially enclosed components or assemblies, located in a circuit representing a fire hazard.

The location and size of the bottom or barrier shall cover area D in Figure 6 and shall be horizontal, lipped or otherwise shaped to provide equivalent protection. The area shall be free of openings, except for those protected by a baffle, screen or other means so that molten metal and burning material are unlikely to fall outside the *fire enclosure*.



NOTE Figure 6 shows an example of a cutaway side view of a product containing a PWB with its components facing the bottom of the *enclosure*. If the PWB contains components in primary circuitry (e.g. Field Effect Transistors), it is considered a source of ignition.

The bottom *enclosure* is considered a *fire enclosure* so openings in it shall be restrictive, e.g. see Table 12.

Besides providing protection against electrical shocks, the side openings (electrical *enclosure*) located below the 5 ° projection from the source of ignition provide protection against spread of fire.

Figure 6 – *Fire enclosure* bottom openings below an unenclosed or partially enclosed fire-hazardous component

The following constructions are considered to satisfy the requirement without test:

- no opening in the bottom of a *fire enclosure*;
- openings in the bottom of any size under an internal barrier, screen or the like, which itself complies with the requirements for a *fire enclosure*;
- openings in the bottom, each not larger than 40 mm^2, under components and parts meeting the flammability requirements of V-1 class as classified in IEC 60695-11-10, or the flammability requirements of HF-1 class as classified in ISO 9772 or under small

components that pass the needle-flame test of IEC 60695-11-5 with the flame applied for a duration of 30 s;

- baffle plate construction as illustrated in Figure 7;
- metal bottoms of *fire enclosures* conforming to the dimensional limits of any line in Table 13;
- metal bottom screens having a mesh with nominal openings not greater than 2 mm between centre lines and with wire diameters of not less than 0,45 mm.

Compliance is checked by inspection or with the hot flaming oil test in 5.2.5.6, in case the fire enclosure is designed differently than as described above.

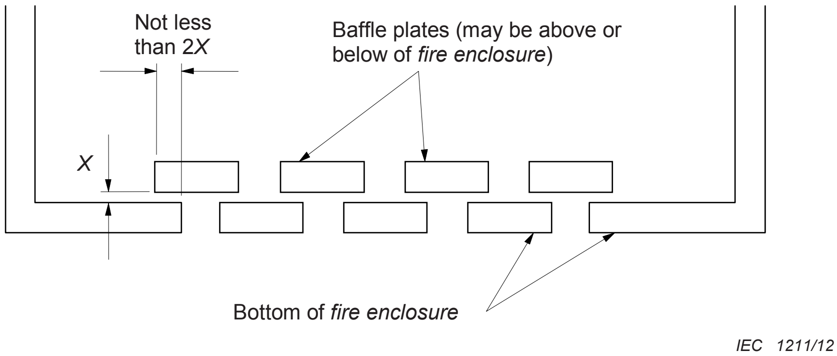


Figure 7 – *Fire enclosure* baffle construction

Table 13 – Permitted openings in *fire enclosure* bottoms

Applicable to circular holes			Applicable to other shaped openings	
Metal bottoms minimum thickness mm	**Maximum diameter of holes** mm	**Minimum spacing of holes centre to centre** mm	**Maximum area** mm^2	**Minimum spacing of openings border to border** mm
0,66	1,1	1,7	1,1	0,56
0,66	1,2	2,3	1,2	1,1
0,76	1,1	1,7	1,1	0,55
0,76	1,2	2,3	1,2	1,1
0,81	1,9	3,1	2,9	1,1
0,89	1,9	3,1	2,9	1,2
0,91	1,6	2,7	2,1	1,1
0,91	2,0	3,1	3,1	1,2
1,0	1,6	2,7	2,1	1,1
1,0	2,0	3,0	3,2	1,0

4.6.3.3.4 Doors or covers in *fire enclosures*

If part of a *fire enclosure* consists of a door or a cover leading to an operator access area, it shall comply with one of the following requirements:

- the door or cover shall be provided with a safety interlock; or
- a door or cover, intended to be routinely opened by the user, shall comply with both of the following conditions:

– it shall not be removable from other parts of the *fire enclosure* by the user; and
– it shall be provided with a means to keep it closed during normal operation.

A door or cover intended only for occasional use by an installer, such as for the installation of accessories, is permitted to be removable provided that the equipment instructions include directions for correct removal and reinstallation of the door or cover.

Compliance is checked by inspection.

4.6.4 Temperature limits

4.6.4.1 Internal parts

Equipment and its component parts shall not attain temperatures in excess of those in Table 14 when tested in accordance with the ratings of the equipment.

Compliance is checked by test of 5.2.3.10.

Table 14 – Maximum measured total temperatures for internal materials and components

	Materials and components	Thermocouple method °C	Rise of resistance method °C
1	Rubber- or thermoplastic-insulated conductors [a]	75	
2	Field wiring terminals and other parts that may contact the *insulation* of field wiring [b]	[b]	
3	Copper bus bars and connecting straps	[c]	
4	*Insulation systems* on magnetic components [d]	[e]	[e]
	Class A (105)	90	100
	Class E (120)	105	115
	Class B (130)	110	120
	Class F (155)	130	140
	Class H (180)	155	165
	Class N (200)	165	175
	Class R (220)	180	190
	Class S (240)	195	205
5	Phenolic composition [a]	165	
6	On bare resistor material	415	
7	Capacitor	[f]	
8	*Power electronic devices*	[g]	
9	PWBs	[h]	
10	Components bridging at least *basic protection*	[f]	
11	Liquid cooling medium	[i]	

[a] The limitation on phenolic composition and on rubber and thermoplastic *insulation* does not apply to compounds which have been investigated and found to meet the requirements for a higher temperature.

[b] The maximum terminal temperature should not exceed the temperature rating of the terminal and the *insulation* temperature rating of the conductor or cable specified by the manufacturer (see 6.3.6.4).

[c] The maximum permitted temperature is determined by the temperature limit of support materials or *insulation* of connecting wires or other components. A maximum temperature of 140 ºC is recommended.

[d] The maximum temperatures on *insulation* of magnetic components assume thermocouples are applied on the surface of coils, and are therefore not located on hot-spots. Rise of resistance method results in a measurement of the average temperature of the winding.

[e] These limits are extracted from the group safety standards IEC 61558-1 and IEC 61558-2-16 (safety of power transformers, power supplies, reactors and similar products). For magnetic components, not covered by the scope of IEC 61558 series, commitees for product standards may define other limits in accordance with IEC 60085 and IEC 60216.

[f] For a component, the maximum temperature specified by the manufacturer should not be exceeded.

[g] The maximum temperature on the case should be the maximum case temperature for the applied power dissipation specified by the manufacturer of power electronic devices.

[h] The maximum operating temperature of the PWB shall not be exceeded.

[i] The maximum temperature of the cooling medium, specified by the manufacturer of the medium or determined from the known characteristics of the medium, should not be exceeded.

The resistance method for temperature measurement as specified in Table 14 consists of the calculation of the temperature rise of a winding using the equation:

$$\Delta t = \frac{r2}{r1}(k + t1) - (k + t2)$$

where:

Δt is the temperature rise;

r_2 is the resistance at the end of the test in ohms;

r_1 is the resistance at the beginning of the test in ohms;.

t_1 is the ambient temperature at the beginning of the test (ºC);

t_2 is the ambient temperature at the end of the test (ºC);

k is 234,5 for copper, 225,0 for electrical conductor grade (EC) aluminium; values of the constant for other conductors shall be determined.

4.6.4.2 Accessible parts

In order to limit the touch temperatures of accessible parts of *PECS*, and to protect against long-term degradation of building materials, the maximum temperature for accessible parts of the *PECS* shall be in compliance with Table 15.

When surface temperatures of the *PECS,* close to mounting surfaces, exceed the limit of Table 15, a warning according to 6.3.5 shall be provided.

It is permitted that accessible parts that are required to get hot as part of their intended function (for example heatsinks) may have temperatures up to 100 °C, if the parts are not in contact with building materials upon installation, and are marked with the warning given in 6.4.3.4. For products only for use in a *restricted access area*, the temperature may exceed 100 °C.

Product committees using this standard as a reference document shall consider the steady state temperature limits for specific products and environmental conditions.

These limits are in addition to applicable limits in 4.6.4.1.

Table 15 – Maximum measured temperatures for accessible parts of the *PECS*

Part	Limit °C					
	(Coated) metal[b]				Glass, porcelain and vitreous material	Plastic and rubber
	1	2	3	4		
User operated devices (knobs, handles, switches, displays, etc.). which are held continuously during normal and *single fault condition* (approx. 10 s)	55	55	55	60	65	70
User operated devices (knobs, handles, switches, displays, etc.). which are held for short periods only, during normal and *single fault condition* (approx. 1 s)[a]	60	70	65	85	75	80
Accessible *enclosure* parts likely to be touched (approx. 1 s) [a]	65	75	70	90	80	85
Enclosure parts where they contact building materials upon installation (continuously)	90					

NOTE 1 In Table 15, the values for accessible parts are taken from IEC Guide 117 (burn threshold). For short-duration contact with user operated devices the values were reduced by 5 °C to allow for some margin. IEC Guide 117 also provides values for burn thresholds for other coatings or materials.

NOTE 2 The main figures of IEC Guide117 are reproduced in Annex J for information.

[a] For products intented and expected to be operated by children and elderly persons the contact period of IEC Guide 117:2010 Clause 6, Table 2 should be considered.

[b] Coating of metal surfaces:

1: none (bare metal)

2: lac (50 μm)

3: porcelain enamel (160 μm) / powder (60 μm)

4: polyamide 11 or 12 (400 μm)

4.6.5 Limited power sources

Where a limited power source is required, the source shall comply with Table 16 or Table 17 as applicable.

A limited power source shall comply with one of the following requirements:

a) the output is inherently limited in compliance with Table 16; or

b) a linear or non-linear impedance limits the output in compliance with Table 16. If a positive temperature coefficient device (e.g. PTC) is used, it shall pass the applicable tests specified in IEC 60730-1; or

c) a regulating network limits the output in compliance with Table 16, both with and without a single fault in the regulating network; or

d) an overcurrent protective device is used and the output is limited in compliance with Table 17.

Where an overcurrent protective device is used, it shall be a fuse or a non-adjustable, non-autoreset, electromechanical device.

A limited power source operated from an a.c. *mains supply*, or a battery-operated limited power source that is recharged from an a.c. *mains supply* while supplying the load, shall incorporate an isolating transformer.

Compliance to determine the maximum available power is checked by test of 5.2.3.9.

Table 16 – Limits for sources without an overcurrent protective device

Output voltage[a] U_{oc}		Output current [b d] I_{sc}	Apparent power [c d] S
V a.c.	V d.c.	A	VA
≤ 30 V r.m.s.	≤ 30 V d.c.	≤ 8	≤ 100
-	$30 < U_{oc} \leq 60$	$\leq 150 / U_{oc}$	≤ 100

[a] U_{oc}: Output voltage measured in accordance with 5.1.5.3 with all load circuits disconnected. Voltages are for substantially sinusoidal a.c. and ripple-free d.c. For non-sinusoidal a.c. and d.c. with ripple greater than 10 % of the peak, the peak voltage shall not exceed 42,4 V.

[b] I_{sc}: Maximum output current with any non-capacitive load, including a short circuit.

[c] S (VA): Maximum output apparent power in VA with any non-capacitive load.

[d] Measurement of I_{sc} and S are made 5 s after application of the load if protection is by an electronic circuit or a positive temperature coefficient device (e.g. PTC), and 60 s in other cases.

Table 17 – Limits for power sources with an overcurrent protective device

Output voltage[a] U_{oc}		Output current [b d] I_{sc}	Apparent power [c d] S	Current rating of overcurrent protective device [e]
V a.c.	V d.c.	A	VA	A
≤ 20	≤ 20	$\leq 1\,000/U_{oc}$	≤ 250	≤ 5,0
$20 < U_{oc} \leq 30$	$20 < U_{oc} \leq 30$			$\leq 100/U_{oc}$
–	$30 < U_{oc} \leq 60$			$\leq 100/U_{oc}$

[a] U_{oc}: Output voltage measured in accordance with 5.1.5.3 with all load circuits disconnected. Voltages are for substantially sinusoidal a.c. and ripple free d.c. For non-sinusoidal a.c. and for d.c. with ripple greater than 10 % of the peak, the peak voltage shall not exceed 42,4 V.

[b] I_{sc}: Maximum output current with any non-capacitive load, including a short circuit, measured 60 s after application of the load.

[c] S (VA): Maximum output VA with any non-capacitive load measured 60 s after application of the load.

[d] Current limiting impedances remain in the circuit during measurement, but overcurrent protective devices are bypassed.

NOTE The reason for making measurements with overcurrent protective devices bypassed is to determine the amount of energy that is available to cause possible overheating during the operating time of the overcurrent protective devices.

[e] The current ratings of overcurrent protective devices that break the circuit within 120 s with a current equal to 210 % of the current rating specified in the table.

4.7 Protection against mechanical hazards

4.7.1 General

Failure of any component within the *PECS* shall not release sufficient energy to lead to a hazard, for example, expulsion of material into an area occupied by personnel.

4.7.2 Specific requirements for liquid cooled *PECS*

4.7.2.1 General

NOTE Sealed heat-pipe cooling *systems*, used to transfer heat from a hot component to a heat sink, are not considered to be liquid cooling *systems* in this standard. However, the possible failure of such components should be considered during the circuit analysis of 4.2.

4.7.2.2 Coolant

The specified coolant (see 6.2) shall be suitable for the anticipated ambient temperatures during storage and operation. Coolant temperature in operation shall not exceed the limit specified in Table 14.

The coolant used in a cooling *system* shall be a refrigerant investigated for the purpose, water, glycol, a mixture of water and glycol or non flammable synthetic oils.

Compliance is checked by inspection and test of 5.2.3.10.

NOTE Flammable coolants used in cooling *systems* are not covered by this standard.

4.7.2.3 Design requirements

4.7.2.3.1 General

The liquid containment *system* components shall be compatible with the liquid to be used.

Equipment using liquids shall be so constructed that it is unlikely that either a dangerous concentration of these materials or a hazard in the meaning of this standard will be created by condensation, vaporization, leakage, spillage or corrosion during normal operation, storage, filling or emptying.

Compliance is checked by inspection.

The flexible hoses should be made of material free of conductive contaminents such as carbon.

4.7.2.3.2 Corrosion resistance

All cooling *system* components shall be suitable for use with the specified coolant. They shall be corrosion resistant and shall not corrode as a result of prolonged exposure to the coolant and/or air.

Compliance is checked by inspection.

4.7.2.3.3 Tubing, joints and seals

Cooling *system* tubing, joints and seals shall be designed to prevent leakage during excursions of pressure over the life of the equipment. The entire cooling *system* including tubing shall satisfy the requirements of the hydrostatic pressure test of 5.2.7.

4.7.2.3.4 Provision for condensation

Where internal condensation occurs during normal operation or maintenance, measures shall be taken to prevent degradation of *insulation*. In those areas where such condensation is expected, clearance and creepage distances of Table 10 and Table 11 shall be evaluated at least for a pollution degree 3 environment (see Table 8), and provision shall be made to prevent accumulation of water (for example by providing a drain).

Compliance is checked by inspection.

4.7.2.3.5 Leakage of coolant

Measures shall be taken to prevent leakage of coolant onto *live parts* as a result of normal operation, servicing, or loosening or detachment of hoses or other cooling *system* parts during the *expected lifetime*. If a pressure relief mechanism is provided, this shall be located so that there shall be no leakage of coolant onto *live parts* when it is activated.

During a leakage measures has to ensure that coolant will not result in wetting of *live parts* or electrical *insulation*.

Compliance is checked by inspection.

4.7.2.3.6 Loss of coolant

Loss of coolant from the cooling *system* shall not result in thermal hazards, explosion, or shock hazard. The requirements of the loss of coolant test of 5.2.4.9.4 shall be satisfied.

4.7.2.3.7 Conductivity of coolant

When the coolant is intentionally in contact with *live parts* (for example non-earthed heatsinks), the conductivity of the coolant shall be continuously monitored and controlled, in order to avoid hazardous current flow through the coolant.

4.7.2.3.8 *Insulation* requirements for coolant hoses

When the coolant is intentionally in contact with *live parts* (for example non-earthed heatsinks), the coolant hoses form a part of the *insulation system*. Depending on the location of the hoses, the requirements of 4.4.7 for *functional* or *simple* or *protective separation* shall be applied where relevant.

4.8 Equipment with multiple sources of supply

If equipment is provided with more than one supply connection (for example, with different voltages or frequencies or as backup power), the design shall be such that all of the following conditions are met:

- separate means of connection are provided for different circuits; and
- supply plug connections, if any, are not interchangeable if a hazard could be created by incorrect plugging; and
- hazards, within the meaning of this standard, shall not be present under normal or *single fault conditions* due to the presence of multiple sources of supply. Actions such as disconnection or de-energizing of a supply are considered a normal condition.

Compliance is checked by the evaluation of 4.2.

Information is to be provided with the equipment indicating the presence of multiple sources of supply and disconnection procedures (see 6.5.5).

Examples of the types of hazards that should be considered are:

a) Backfeed prevention – preventing voltage or energy available within the PECS or one of its sources from being fed back to any of the input terminals for another source, either directly or by a leakage path.
b) Protection against unintentional islanding.
c) Touch current levels may be higher with multiple sources connected simultaneously (if that is a normal condition for the equipment).
d) Hazard resulting from damage to one or more connected sources (for example, a generator) due to energy from another source, for example the mains.

e) Damage to wiring due to currents higher than the wiring is designed for flowing from another source.

4.9 Protection against environmental stresses

The manufacturer has to specify the following service conditions for operation, storage and transportation:

- coolant temperature (min/max);
- ambient temperature (min/max);
- humidity (min/max);
- pollution degree;
- vibration;
- UV resistance;
- OVC (overvoltage category);
- altitude for thermal consideration, if rated for operation above 1 000 m;
- altitude for *insulation* coordination considerations, if rated for operation above 2 000 m.

NOTE Environmental categories as specified in the IEC 60721 series can be used where appropriate.

The manufacturer shall state the environmental service condition for the *PECS* according to Table 18.

Where the *PECS* complies with the requirements of this standard only at conditions higher than the minimum values or lower than the maximum values given in Table 18, then this shall be by agreement between the supplier and the customer. The specific conditions shall be identified in the operating manual and on the product as specified in 6.3.3.

Table 18 – Environmental service conditions

Condition	Indoor conditioned IEC 60721-3-3	Indoor unconditioned IEC 60721-3-3	Outdoor unconditioned IEC 60721-3-4
Climatic	**class 3K2** (Temperature: +15 °C to 30 °C) (Humidity: 10 to 75 % R.H. non-condensing)	**class 3K3** (Temperature: +5 °C to 40 °C) (Humidity: 5 to 85 % R.H. / non-condensing)	**class 4K6** (Temperature: -20 °C to 55 °C) (Humidity: 4 to100 % R.H. / condensing)
Pollution degree	**2**	**3**[b]	**4**[c]
Humidity condition of the skin	**dry**	**waterwet**[a]	**salt water wet**[a]
Chemically active substances	**class 3C1** (No salt mist)	**class 3C1** (No salt mist)	**class 4C2** (Salt mist)[a]
Mechanically active substances	**class 3S1** (No requirement)	**class 3S1** (No requirement)	**class 4S2** (Dust and sand)
Mechanical	**class 3M1** (Vibration: 1 m/s^2)	**class 3M1** (Vibration: 1 m/s^2)	**class 4M1** (Vibration: 1 m/s^2)
Biological	**class 3B1** (No requirement)	**class 3B1** (No requirement)	**class 4B2** (Mould/fungus/rodents/termites)

[a] Where it is ensured that the equipment will not be used in water wet or salt water wet condition, the manufacturer may choose to rate the equipment for a less severe condition. In this case the rating shall be indicated in the documentation, according to 6.3.3.

[b] Pollution degree 2 may be provided if the conditions in 4.4.7.1.2 are satisfied

c	Pollution degree 2 or 3 may be provided if the *enclosure* provides sufficient protection against conductive pollution and the conditions in 4.4.7.1.2 are satisfied

Compliance is checked by test of 5.2.6.

4.10 Protection against sonic pressure hazards

4.10.1 General

The equipment shall provide protection against the effects of sonic pressure. Compliance tests are carried out if the equipment is likely to cause such hazards.

4.10.2 Sonic pressure and sound level

If equipment produces noise at a level which could cause a hazard, the noise shall be measured to determine the maximum sound pressure level which the equipment can produce (except that sounds from alarms are not included). If the measured sound pressure exceeds 70 dBA the documentation shall provide information regarding the sound level of the equipment.

Compliance is checked by inspection, measurement, and calculation of the maximum sound pressure level in accordance with ISO 3746 or ISO 9614-1.

4.11 Wiring and connections

4.11.1 General

The wiring and connections between parts of the equipment and within each part shall be protected from mechanical damage during installation. The *insulation*, conductors and routing of all wires of the equipment shall be suitable for the electrical, mechanical, thermal and environmental conditions of use. Conductors which are able to contact each other shall be provided with *insulation* rated for the *DVC* requirements of the relevant circuits.

The compliance with 4.11.2 to 4.11.8 shall be checked by inspection (see 5.2.1) of the overall construction and datasheets if applicable.

4.11.2 Routing

A hole through which insulated wires pass in a sheet metal wall within the *enclosure* of the equipment shall be provided with a smooth, well-rounded bushing or grommet or shall have smooth, well-rounded surfaces upon which the wires bear to reduce the risk of abrasion of the *insulation*.

Wires shall be routed away from sharp edges, screw threads, burrs, fins, moving parts, drawers, and similar parts, which abrade the wire *insulation*. The minimum bend radius specified by the wire manufacturer shall not be violated.

Clamps and guides, either metallic or non-metallic, used for routing stationary internal wiring shall be provided with smooth, well-rounded edges. The clamping action and bearing surface shall be such that abrasion, or deformation of the *insulation* does not occur. If a metal clamp is used for conductors having thermoplastic *insulation* less than 0,8 mm thick, non-conducting mechanical protection shall be provided.

4.11.3 Colour coding

Insulated conductors, other than those which are integral to ribbon cable or multi-cord signal cable, identified by the colour green with or without one or more yellow stripes shall only be used for *protective equipotential bonding*.

NOTE The choice of green or green/yellow for the *protective equipotential bonding* is covered by national regulations.

4.11.4 Splices and connections

All splices and connections shall be mechanically secured and shall provide electrical continuity.

Electrical connections shall be soldered, welded, crimped, or otherwise securely connected. A soldered joint, other than a component on a PWB, shall additionally be mechanically secured.

NOTE Stranded wire should not be consolidated with solder where secured in a terminal that relies on pressure for contact or equivalent

When stranded internal wiring is connected to a wire-binding screw, the construction shall be such that loose strands of wire do not contact:

- other uninsulated *live parts* not always of the same potential as the wire;
- de-energized metal parts.

When screw terminal connections are used, the resulting connections may require routine maintenance (tightening). Appropriate reference shall be made in the maintenance manual (see 6.5.1).

4.11.5 Accessible connections

In addition to measures given in 4.4.6.4 it shall be ensured that neither insertion error nor polarity reversal of connectors can lead to a voltage on an accessible connection higher than the maximum of *DVC As*. This applies for example to plug-in sub-assemblies or other plug-in devices which can be plugged in without the use of a tool or key or which are accessible without the use of a tool or key. This does not apply to equipment intended to be installed in *restricted access areas*.

If relevant, non-interchangeability and protection against polarity reversal of connectors, plugs and socket outlets shall be confirmed by inspection and trial insertion.

4.11.6 Interconnections between parts of the *PECS*

In addition to complying with the requirements given in 4.11.1 to 4.11.5, the means provided for the interconnection between parts of the *PECS* shall comply with the following requirements or those of 4.11.7.

Cable assemblies and flexible cords provided for interconnection between sections of equipment or between units of a *system* shall be suitable for the service or use involved. Cables shall be protected from physical damage as they leave the *enclosure* and shall be provided with mechanical strain relief.

Misalignment of male and female connectors, insertion of a multipin male connector in a female connector other than the one intended to receive it, and other manipulations of parts which are accessible to the operator shall not result in mechanical damage or a risk of thermal hazards, electric shock, or injury to persons.

When external interconnecting cables terminate in a plug which mates with a receptacle on the external surface of an *enclosure*, no risk of electric shock shall exist at accessible contacts of either the plug or receptacle when disconnected.

NOTE An interlock circuit in the cable to de-energize the accessible contacts whenever an end of the cable is disconnected meets the intent of these requirements.

4.11.7 Supply connections

The connection points provided shall be of appropriate construction to preclude the possibility of loose strands reducing the spacing between conductors when careful attention is paid to installation.

See 6.3.6.4 for marking requirement and documentation.

4.11.8 Terminals

4.11.8.1 Construction requirements

All parts of terminals which maintain contact and carry current shall be of metal having adequate mechanical strength.

Terminal connections shall be such that the conductors can be connected by means of screws, springs or other equivalent means so as to ensure that the necessary contact pressure is maintained.

Terminals shall be so constructed that the conductors can be clamped between suitable surfaces without any significant damage either to conductors or terminals.

Terminals shall not allow the conductors to be displaced or be displaced themselves in a manner detrimental to the operation of equipment and the *insulation* shall not be reduced below the rated values.

The requirements of this subclause are met by using terminals complying with IEC 60947-7-1 or IEC 60947-7-2, as appropriate.

4.11.8.2 Connecting capacity

Terminals shall be provided which accommodate the conductors specified in the installation and maintenance manuals (see 6.3.6.4) and cables in accordance with the wiring rules applicable at the *installation*. The terminals shall meet the temperature rise test of 5.2.3.10.

Information regarding the permitted wire sizes shall be given in the installation manual.

Standard values of cross-section of round copper conductors are shown in Annex G, which also gives the approximate relationship between ISO metric and AWG/MCM sizes.

4.11.8.3 Connection

Terminals for connection to external conductors shall be readily accessible during installation.

Sets of terminals for connection to the same input or output shall be grouped together and shall be located in proximity to each other and to the main *protective earthing* terminal, if any. If the installation instructions provide detail on the proper earthing of the *system*, the *protective earthing* terminal need not be placed in proximity to the terminals.

Clamping screws and nuts shall not serve to fix any other component although they may hold the terminals in place or prevent them from turning.

4.11.8.4 Wire bending space for wires 10 mm^2 and greater

The distance between a terminal for connection to the main supply, or between major parts of the *PECS* (for example a transformer), and an obstruction toward which the wire is directed upon leaving the terminal shall be at least that specified in Table 19.

Table 19 – Wire bending space from terminals to *enclosure*

Size of wire mm²	Minimum bending space, terminal to *enclosure* mm		
	Wires per terminal		
	1	**2**	**3**
10 to 16	40	-	-
25	50	-	-
35	65	-	-
50	125	125	180
70	150	150	190
95	180	180	205
120	205	205	230
150	255	255	280
185	305	305	330
240	305	305	380
300	355	405	455
350	355	405	510
400	455	485	560
450	455	485	610

4.12 *Enclosures*

4.12.1 General

The following requirements are in addition to *enclosure* requirements given in other sections relating to specific hazards, for example electric shock hazard in 4.4 and fire hazard in 4.6.

Enclosures shall be suitable for use in their intended environments. The manufacturer shall specify the intended environment (see 6.3.3) and the IP rating of the *enclosure* (see 5.2.2.3 for test).

Equipment shall have adequate mechanical strength and shall be so constructed that no hazard occurs when subjected to handling as may be expected.

Mechanical strength tests are not required on an internal barrier, screen or the like, provided to meet the requirements of 4.6.3, if the *enclosure* provides mechanical protection.

An *enclosure* shall be sufficiently complete to contain or deflect parts which, because of failure or for other reasons, might become loose, separated or thrown from a moving part.

Compliance shall be checked by the relevant tests of 5.2.2.4 to 5.2.2.7 as specified. If the *enclosure* complies with the applicable thickness requirement of 4.12.3 or 4.12.4 the test in 5.2.2.4.2 and 5.2.2.4.3 can be waived.

For *open type* equipment the tests of 5.2.2.4 to 5.2.2.7 are not required.

4.12.2 Handles and manual controls

Handles, knobs, grips, levers and the like shall be reliably fixed so that they will not work loose in normal use, if this could result in a hazard. Sealing compounds and the like, other than self-hardening resins, shall not be used to prevent loosening. If handles, knobs and the like are used to indicate the position of switches or similar components, it shall not be possible to fix them in a wrong position if this could result in a hazard.

Compliance shall be checked by inspection, and as applicable by the tests of 5.2.2.7.

4.12.3 Cast metal

Die-cast metal, except at threaded holes for conduit, where a minimum of 6,4 mm thickness is required, shall be:

- not less than 2,0 mm thick for an area larger than 155 cm^2 or having any dimension larger than 150 mm;
- not less than 1,2 mm thick for an area of 155 cm^2 or less and having no dimension larger than 150 mm.

The area under evaluation may be bounded by reinforcing ribs subdividing a larger area.

Malleable iron or permanent-mould cast aluminium, brass, bronze, or zinc, except at threaded holes for conduit, where a minimum of 6,4 mm thickness is required, shall be:

- at least 2,4 mm thick for an area greater than 155 cm^2 or having any dimension more than 150 mm;
- at least 1,5 mm thick for an area of 155 cm^2 or less having no dimension more than 150 mm.

A sand-cast metal *enclosure* shall be a minimum of 3,0 mm thick except at locations for threaded holes for conduit, where a minimum of 6,4 mm is required.

4.12.4 Sheet metal

The thickness of a sheet-metal *enclosure* at points to which a wiring *system* is to be connected shall be not less than 0,8 mm thick for uncoated steel, 0,9 mm thick for zinc-coated steel, and 1,2 mm thick for non-ferrous metal.

Enclosure thickness at points other than where a wiring *system* is to be connected shall be not less than that specified in Table 20 or Table 21.

With reference to Table 20 or Table 21, a supporting frame is a structure of angle or channel or folded section of sheet metal, which is attached to and has the same outside dimensions as the *enclosure* surface, and which has torsional rigidity to resist the bending moments that are applied by the *enclosure* surface when it is deflected. A structure which is as rigid as one built with a frame of angles or channels has equivalent reinforcing.

Constructions without supporting frame include:

- a single sheet with single formed flanges – formed edges;
- a single sheet which is corrugated or ribbed;
- an *enclosure* surface loosely attached to a frame, for example, with spring clips; and
- an *enclosure* surface having an unsupported edge.

See Figure 8 for supported and unsupported *enclosure* surfaces.

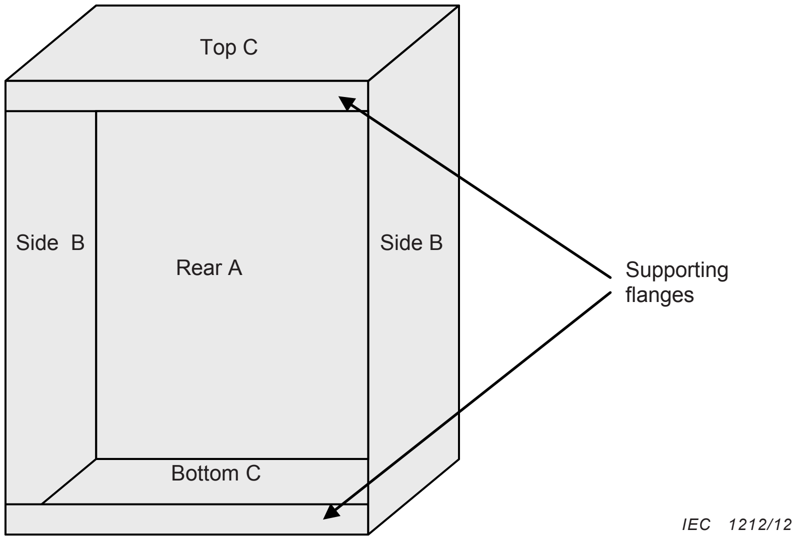


Figure 8 – Supported and unsupported *enclosure* parts

Each *enclosure* surface is evaluated individually based on the length and width dimensions. For each set of surface dimensions, A, B or C, the width is the smaller dimension regardless of its orientation to other surfaces. In Table 20 and Table 21, there are two sets of dimensions that correspond to a single metal thickness requirement and the following describes the applicable procedure for determining the minimum metal thickness for each surface.

For a supported surface, all of the table dimensions, including the “not limited” lengths, are able to be applied. The rear surface “A”, top and bottom surfaces “C”, are supported either by adjacent surfaces of the *enclosure* or by a 12,7 mm (1/2 inch) wide flange. To determine required metal thickness for supported surfaces, the width is to be measured and compared with the table value in the maximum width column that is equal to or greater than the measured width. When the corresponding length in the maximum length column is “not limited”, the minimum thickness in the far right column is to be used. When the corresponding length in the maximum length column is a numerical value, and the measured length of the side does not exceed this value, the minimum thickness from the far right column is to be used. When the measured length of the side exceeds the numerical value, the next line in the Table 20 and Table 21 is to be used.

For an unsupported surface, only the table dimensions that include a specific length requirement are applied. The dimensions with a “not limited” length do not apply. The front edge of the left and right surfaces “B”, are not supported by an adjacent surface or by a flange. To determine the required metal thickness for unsupported surfaces, the length is to be measured and compared with the table value in the maximum length column that is not less than the measured length, ignoring the “not limited” entries. When the corresponding width in the maximum width column is not less than the measured width, the minimum thickness from the far right column is to be used. When the measured width of the surface exceeds the value in the maximum width column, the next line in the Table 20 and Table 21 is to be used.

Table 20 – Thickness of sheet metal for *enclosures*: carbon steel or stainless steel

Without supporting frame [a]		With supporting frame [a]		Minimum thickness
Maximum width mm [b]	Maximum length mm [c]	Maximum width mm [c]	Maximum length mm [c]	mm
100	Not limited	160	Not limited	0,6 [d]
120	150	170	210	
150	Not limited	240	Not limited	0,75 [d]
180	220	250	320	
200	Not limited	310	Not limited	0,9
230	290	330	410	
320	Not limited	500	Not limited	1,2
350	460	530	640	
460	Not limited	690	Not limited	1,4
510	640	740	910	
560	Not limited	840	Not limited	1,5
640	790	890	1 090	
640	Not limited	990	Not limited	1,8
740	910	1 040	1 300	
840	Not limited	1 300	Not limited	2,0
970	1 200	1 370	1 680	
1 070	Not limited	1 630	Not limited	2,5
1 200	1 500	1 730	2 130	
1 320	Not limited	2 030	Not limited	2,8
1 520	1 880	2 130	2 620	
1 600	Not limited	2 460	Not limited	3,0
1 850	2 290	2 620	3 230	

[a] See 4.12.4.

[b] The width is the smaller dimension of a rectangular piece of sheet metal which is part of an *enclosure*. Adjacent surfaces of an *enclosure* are able to have supports in common and be made of a single sheet.

[c] Not limited applies only when the edge of the surface is flanged at least 12,7 mm or fastened to adjacent surfaces not normally removed in use.

[d] Sheet steel for an *enclosure* intended for outdoor use should be not less than 0,86 mm thick.

Table 21 – Thickness of sheet metal for *enclosures*: aluminium, copper or brass

Without supporting frame [a]		With supporting frame [a]		Minimum thickness
Maximum width, mm [b]	Maximum length, mm [c]	Maximum width, mm [b]	Maximum length, mm [c]	mm
75 90	Not limited 100	180 220	Not limited 240	0,6 [d]
100 125	Not limited 150	250 270	Not limited 340	0,75
150 165	Not limited 200	360 380	Not limited 460	0,9
200 240	Not limited 300	480 530	Not limited 640	1,2
300 350	Not limited 400	710 760	Not limited 950	1,5
450 510	Not limited 640	1 100 1 150	Not limited 1 400	2,0
640 740	Not limited 1 000	1 500 1 600	Not limited 2 000	2,4
940 1 100	Not limited 1 350	2 200 2 400	Not limited 2 900	3,0
1 300 1 500	Not limited 1 900	3 100 3 300	Not limited 4 100	3,9

[a] See 4.12.4.

[b] The width is the smaller dimension of a rectangular piece of sheet metal which is part of an *enclosure*. Adjacent surfaces of an *enclosure* are able to have supports in common and be made of a single sheet.

[c] Not limited applies only when the edge of the surface is flanged at least 12,7 mm or fastened to adjacent surfaces not normally removed in use.

[d] Sheet aluminium, copper or brass for an *enclosure* intended for outdoor use should be not less than 0,74 mm thick.

4.12.5 Stability test for *enclosure*

Under conditions of normal use, units and equipment shall not become physically unstable to the degree that they could become a hazard to an operator or to a service person.

If units are designed to be fixed together on site and not used individually, the stability of each individual unit is exempt from the requirements of 4.12.5.

The requirements of 4.12.5 are not applicable if the installation instructions for a unit specify that the equipment is to be secured to the building structure before operation.

Under conditions of operator use, a stabilizing means, if needed, shall be automatic in operation when drawers, doors, etc., are opened.

During operations performed by a service person, the stabilizing means, if needed, shall either be automatic in operation, or a marking shall be provided to instruct the service person to deploy the stabilizing means.

Compliance is checked by test of 5.2.2.5.

5 Test requirements

5.1 General

5.1.1 Test objectives and classification

Testing, as defined in this Clause 5, is required to demonstrate that *PECS* is fully in accordance with the requirements of this standard. Testing may be waived if permitted by the relevant requirements subclause of Clause 4.

The subclauses in this Clause 5 describe the procedures to be adopted for the testing of *PECS*. The tests are classified as:

- type tests;
- routine tests;
- sample tests.

The manufacturer and/or test house shall ensure that the specified maximum and/or minimum environment (or test) values are imposed, taking tolerances and measurement uncertainties fully into account.

WARNING! These tests can result in hazardous situations. Suitable precautions shall be taken to avoid injury.

5.1.2 Selection of test samples

When testing a range or series of similar products, it may not be necessary to test all models in the range. Each test should be performed on a model or models having mechanical and electrical characteristics that adequately represent the entire range for that particular test.

NOTE For example, tests on *enclosures* of the same material but different sizes can be represented by a single *enclosure* but tests on power components that are different ratings often cannot be represented by testing on one particular model.

5.1.3 Sequence of tests

In general, there is no requirement for tests to be performed in a set sequence, nor is it required that they are all performed on the same sample of equipment. However, the pass criteria for some of the tests require that they are followed by one or more further tests.

5.1.4 Earthing conditions

Test requirements shall be determined using the worst-case (most stressful) *system* earthing allowed by the manufacturer. *System*s earthing may include:

- neutral to earth;
- line to earth;
- neutral to earth through high impedance;
- isolated (not earthed).

5.1.5 General conditions for tests

5.1.5.1 Application of tests

Unless otherwise stated, upon conclusion of the tests, the equipment need not be operational.

5.1.5.2 Test samples

Unless otherwise specified, the sample or samples under test shall be representative of the equipment the user would receive, or shall be the actual equipment ready for shipment to the user.

As an alternative to carrying out tests on the complete equipment, tests may be conducted separately on circuits, components or sub-assemblies outside the equipment, provided that inspection of the equipment and circuit arrangements indicates that the results of such testing will be representative of the results of testing the assembled equipment. If any such test indicates a likelihood of non-conformance in the complete equipment, the test shall be repeated in the equipment.

Where in this standard compliance of materials, components or sub-assemblies is checked by inspection or by testing of properties, it is permitted to confirm compliance by reviewing any relevant data or previous test results that are available instead of carrying out the specified *type tests*. See also 4.1

5.1.5.3 Operating parameters for tests

Except where specific test conditions are stated elsewhere in the standard and where it is clear that there is a significant impact on the results of the test, the tests shall be conducted under the most unfavourable combination within the manufacturer's operating specifications of the following parameters:

- supply voltage;
- supply frequency;
- operating temperature taking derating and cooling control characteristic into account;
- physical location of equipment and position of movable parts;
- operating mode;
- load conditions;
- adjustment of thermostats, regulating devices or similar controls in *restricted access area*, which are:
  - adjustable without the use of a tool or key; or
  - adjustable using a means, such as a key or a tool, deliberately provided for the operator.

NOTE In determining the most unfavourable frequency for the power to energize the equipment under test, different rated frequencies within the rated frequency range should be taken into account (for example, 50 Hz and 60 Hz) but consideration of the tolerance on a rated frequency (for example, 50 Hz ± 0,5 Hz) is not normally necessary.

5.1.6 Compliance

Compliance with this standard shall be verified by carrying out the appropriate tests specified in this Clause 5.

Compliance may only be claimed if all relevant tests have been passed.

Compliance with construction requirements and information to be provided by the manufacturer shall be verified by suitable examination, visual inspection, and/or measurement.

Whenever design or component changes have potential impact upon compliance, new *type testing* shall be performed to confirm compliance. It is desirable that the modified product should be identified, for example by using a suitable date code or serial number as described in 6.2.

5.1.7 Test overview

Table 22 provides an overview of the *type*, *routine* and *sample testing* of electronic components, equipment and *PECS*.

Table 22 – Test overview

Test	*Type*	*Routine*	*Sample*	Requirement(s)	Specification
Visual inspection	X	X			5.2.1
Mechanical tests					5.2.2
Clearance and creepage distances test	X			4.4.7.1, 4.4.7.5	5.2.2.1
Non-accessibility test	X			4.4.3.3, 4.5.1.1, 4.6.3.3.2	5.2.2.2
Ingress protection test (IP rating)	X			4.12.1	5.2.2.3
Enclosure integrity test	X			4.12.1	5.2.2.4
Deflection test	X			4.12.1	5.2.2.4.2
Steady force test, 30N	X			4.12.1	5.2.2.4.2.2
Steady force test, 250N	X			4.12.1	5.2.2.4.2.3
Impact test	X			4.12.1	5.2.2.4.3
Drop test	X			4.12.1	5.2.2.4.4
Stress relief test	X			4.12.1	5.2.2.4.5
Stability test	X			4.12.1	5.2.2.5
Wall or ceiling mounted equipment test	X			4.12.1	5.2.2.6
Handles and manual control securement test	X			4.12.1	5.2.2.7
Electrical tests				4.4.7.10	5.2.3
Impulse voltage test	X		X	4.4.3.2, 4.4.5.4, 4.4.7.1, 4.4.7.10.1, 4.4.7.10.2, 4.4.7.8.3	5.2.3.2
a.c. or d.c. voltage test	X	X		4.4.3.2, 4.4.5.4, 4.4.7.1, 4.4.7.10.1, 4.4.7.10.2, 4.4.7.8.4.2	5.2.3.4
Partial discharge test	X		X	4.4.7.1, 4.4.7.10.2, 4.4.7.8.3	5.2.3.5
Protective impedance test	X	X		4.4.5.4	5.2.3.6
Touch current measurement test	X			4.4.4.3.3	5.2.3.7
Capacitor discharge test	X			4.4.9	5.2.3.8
Limited power source test	X			4.5.1.2, 4.6.5	5.2.3.9
Temperature rise test	X			4.6.4	5.2.3.10
Protective equipotential bonding test	X	X		4.4.4.2.2	5.2.3.11
Abnormal operation tests				4.2	5.2.4
Output Short circuit test	X			4.3	5.2.4.4
Output overload test	X			4.3	5.2.4.5
Breakdown of components test	X			4.2	5.2.4.6
PWB short circuit test	X			4.4.7.7	5.2.4.7
Loss of phase test	X			4.2	5.2.4.8
Cooling failure tests	X			4.2, 4.7.2.3.6	5.2.4.9
Inoperative blower test	X			4.2	5.2.4.9.2
Clogged filter test	X			4.2	5.2.4.9.3
Loss of coolant test	X			4.7.2.3.6	5.2.4.9.4

Table 22 *(continued)*

Test	*Type*	*Routine*	*Sample*	Requirement(s)	Specification
Material tests					5.2.5
High current arcing ignition test	X			4.4.7.8.2	5.2.5.2
Glow-wire test	X			4.4.7.8.2	5.2.5.3
Hot wire ignition test	X			4.4.7.8.2	5.2.5.4
Flammability test	X			4.6.3	5.2.5.5
Flaming oil test	X			4.6.3.3.3	5.2.5.6
Cemented joints test	X			4.4.7.9	5.2.5.7
Environmental tests	X			4.9	5.2.6
Dry heat test	X			4.9	5.2.6.3.1
Damp heat test	X			4.9	5.2.6.3.2
Vibration test	X			4.9	5.2.6.4
Salt mist test	X			4.9	5.2.6.5
Dust and sand test	X			4.9	5.2.6.6
Hydrostatic pressure test	X	X		4.7.2.3.3	5.2.7

5.2 Test specifications

5.2.1 Visual inspections (*type test*, *sample test* and *routine test*)

Visual inspections shall be made:

- as *routine tests*, to check features such as adequacy of labelling, warnings and other safety aspects;
- as acceptance criteria of individual *type tests*, *sample tests* or *routine tests*, to verify that the requirements of this standard have been met.

Routine inspections may be part of the production or assembly process.

Before *type testing*, a check shall be made that the *PECS* delivered for the test is as expected with respect to supply voltage, input and output ranges, etc.

5.2.2 Mechanical tests

5.2.2.1 Clearances and creepage distances test (*type test*)

It shall be verified by measurement or visual inspection that the clearance and creepage distances comply with 4.4.7.4 and 4.4.7.5. See Annex D for measurement examples. Where this verification is impossible to perform, an impulse voltage test (see 5.2.3.2) shall be performed between the considered circuits.

5.2.2.2 Non-accessibility test (*type test*)

This test is intended to show that *live parts*, protected by means of *enclosures* or barriers in compliance with 4.4.3.3, are not accessible.

This test shall be performed as a *type test* of the *enclosure* of a *PECS* as specified in IEC 60529 for the *enclosure* classification for protection against access to hazardous parts. Except as noted below:

- the test probe for IP3X (2,5 mm Ø) shall not penetrate the top surface of the *enclosure* when probed from the vertical direction ±5 ° only.

The test probes are reproduced in Annex M for convenience.

5.2.2.3 Ingress protection test (IP rating) (*type test*)

The claimed IP rating of the *enclosure* shall be verified. This test shall be performed as a *type test* of the *enclosure* of a *PECS* as specified in IEC 60529 for the *enclosure* classification.

5.2.2.4 *Enclosure* integrity test (*type test*)

5.2.2.4.1 General

The integrity tests apply to *PECS*, and also where *PECS* are intended for operation without a further *enclosure* in *restricted access areas*. After completion of the integrity test, the *PECS* shall pass the tests of 5.2.3.2 and 5.2.3.4 and shall be inspected to confirm that:

- no degradation of any safety-relevant component of the *PECS* has occured;
- *hazardous live parts* have not become accessible (see 4.4.3.3);
- *enclosures* show no cracks or openings which could cause a hazard;
- clearances are not less than their minimum permitted values and other *insulation* is undamaged;
- barriers have not been damaged or loosened;
- no moving parts which could cause a hazard are exposed.

The integrity tests shall be performed at the worst case point on representative accessible face(s) of the *enclosure*.

The *PECS* is not required to be operational after testing and the *enclosure* may be deformed to such an extent that its original IP rating is not maintained.

5.2.2.4.2 Deflection test (*type test*)

5.2.2.4.2.1 General

If requested by 4.12.1 the test in 5.2.2.4.2.2 and 5.2.2.4.2.3 applies, for metallic *enclosure*, as applicable.

The *enclosure* shall be held firmly against a rigid support.

The tests are not applied to handles, levers, knobs or to transparent or translucent covers of indicating or measuring devices, unless parts at hazardous voltage are accessible by means of the test finger (Figure 2, test probe B of IEC 61032:1997) if the handle, lever, knob or cover is removed.

During the tests of 5.2.2.4.2.2 and 5.2.2.4.2.3, earthed or unearthed conductive *enclosures* shall not reduce clearance and creepage distances required for *basic insulation* or withstand the impulse voltage test in 5.2.3.2.

5.2.2.4.2.2 Steady force test, 30 N

Parts of an *enclosure* located in an *restricted access area*, which are protected by a cover or door meeting the requirements of 5.2.2.4.2.3, are subjected to a steady force of 30 N ± 3 N for a period of 5 s, applied by means of a straight unjointed version of the test finger (Figure 2, test probe B of IEC 61032:1997), to the part on or within the equipment.

5.2.2.4.2.3 Steady force test, 250 N

External *enclosures* are subjected to a steady force of 250 N ± 10 N for a period of 5 s, applied in turn to the top, bottom and sides of the *enclosure* fitted to the equipment, by means of a suitable test tool providing contact over a circular plane surface 30 mm in diameter. However, this test is not applied to the bottom of an *enclosure* of equipment having a mass of more than 18 kg or to surfaces that are mounted to a wall.

For surfaces neither horizontal nor vertical, test shall be performed by tilting the equipment in a suitable way so that the surface is either horizontal or vertical.

5.2.2.4.3 Impact test (*type test*)

External polymeric surfaces of *enclosures*, the failure of which would give access to hazardous parts, are tested as follows.

A sample consisting of the complete *enclosure*, or a portion thereof representing the largest unreinforced area, is supported in its normal position. A solid smooth steel ball, approximately 50 mm in diameter and with a mass of 500 g ± 25 g, is permitted to fall freely from rest through a vertical distance (H) of 1,3 m (see Figure 9) onto the sample. Vertical surfaces are exempt from this test.

In addition, the steel ball is suspended by a cord and swung as a pendulum in order to apply a horizontal impact, dropping through a vertical distance (H) of 1,3 m (see Figure 9) onto the sample. Horizontal surfaces are exempt from this test. Alternatively, the sample is rotated 90° about each of its horizontal axes and the ball dropped as in the vertical impact test.

The test is not applied to flat panel displays or to the platen glass of equipment.

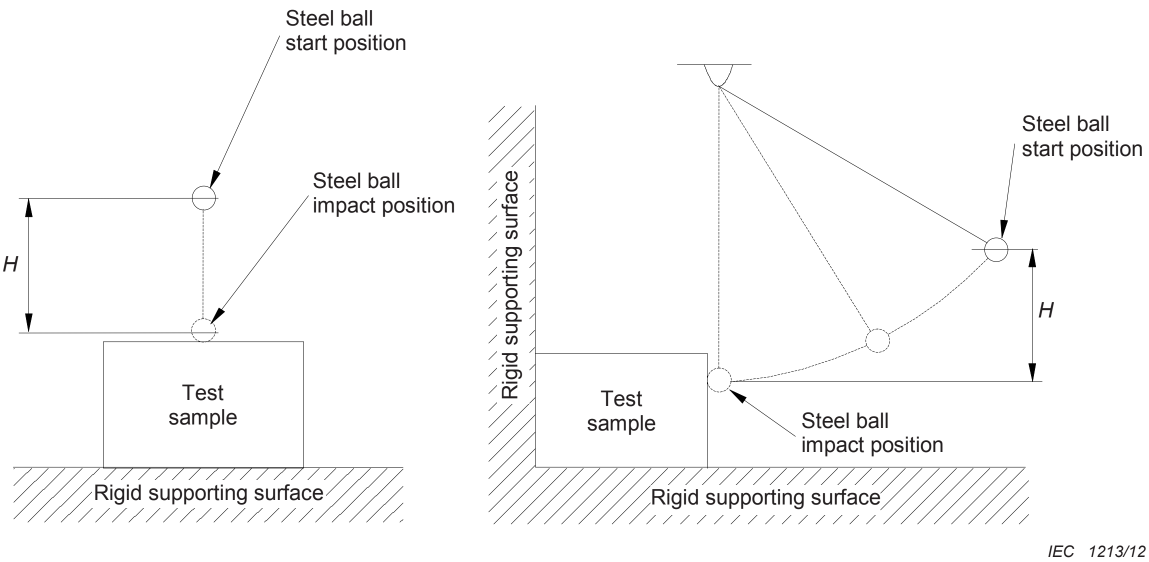


Figure 9 – Impact test using a steel ball

5.2.2.4.4 Drop test

Plugable hand-held, direct plug-in and transportable equipment with mass of 18 kg or less is subjected to the following test.

A sample of the complete equipment is subjected to three impacts that result from being dropped onto a sufficiently rigid horizontal surface in positions likely to produce the most adverse results.

The height of the drop shall be 1 000 mm.

5.2.2.4.5 Stress relief test

Enclosures of moulded or formed thermoplastic materials shall be so constructed that any shrinkage or distortion of the material due to release of internal stresses caused by the moulding or forming operation does not result in the exposure of hazardous parts or in the reduction of creepage distances or clearances below the minimum required.

Compliance shall be checked by the test procedure described below or by the inspection of the construction and the available data where appropriate.

One sample consisting of the complete equipment, or of the complete *enclosure* together with any supporting framework, is placed in a circulating air oven (according to IEC 60216-4-1) at a temperature 10 K higher than the maximum temperature of the *enclosure* during the test of 5.2.3.10, but not less than 70 °C, for a period of 7 h, then permitted to cool at room temperature.

With the concurrence of the manufacturer, it is permitted to increase the above time duration. For large equipment where it is impractical to condition a complete *enclosure*, it is permitted to use a portion of the *enclosure* representative of the complete assembly with regard to thickness and shape, including any mechanical support members.

5.2.2.5 Stability test

To prove the stability of the equipment the following tests shall be carried out, where relevant. Each test is carried out separately. During the tests, reservoirs are to contain the amount of liquid within their rated capacity producing the most disadvantageous condition. All castors and jacks, if used in normal operation, are placed in their most unfavourable position, with wheels and the like locked or blocked. However, if the castors are intended only to transport the unit, and if the installation instructions require jacks to be lowered after installation, then the jacks (and not the castors) are used in this test; the jacks are placed in their most unfavourable position, consistent with reasonable leveling of the unit.

A unit having a mass of 7 kg or more shall not fall over when tilted to an angle of 10° from its normal upright position. Doors, drawers, etc., are closed during this test. A unit provided with multi-positional features shall be tested in the least favourable position permitted by the construction.

A floor-standing unit having a mass of 25 kg or more shall not fall over when a force equal to 20 % of the weight of the unit, but not more than 250 N, is applied in any direction except upwards, at a height not exceeding 2 m from the floor. Doors, drawers, etc., which may be moved for servicing by the operator or by a service person, are placed in their most unfavourable position, consistent with the installation instructions.

A floor-standing unit shall not fall over when a constant downward force of 800 N is applied at the point of maximum moment to any horizontal surface of at least 12,5 cm by at least 20 cm, at a height up to 1 m from the floor. Doors, drawers, etc., are closed during this test. The 800 N force is applied by means of a suitable test tool having a flat surface of approximately 12,5 cm by 20 cm. The downward force is applied with the complete flat surface of the test tool in contact with the equipment under test; the test tool need not be in full contact with uneven surfaces (for example, corrugated or curved surfaces).

5.2.2.6 Wall or ceiling mounted equipment test

The equipment is mounted in accordance with the manufacturer's instructions. A force in addition to the weight of the equipment is applied downwards through the geometric centre of the equipment, for 1 min. The additional force shall be equal to three times the weight of the equipment but not less than 50 N. The equipment and its associated mounting means shall remain secure during the test.

5.2.2.7 Handles and manual controls securement test

Handles and manual controls shall be tested by manual test and by trying to remove the handle, knob, grip or lever by applying for 1 min an axial force as shown in Table 23.

Table 23 – Pull values for handles and manual control securement

	Axial pull unlikely N			Axial pull likely N		
Intented for operation by	Fingers	1 hand	2 hands	Fingers	1 hand	2 hands
Operating means of components[a]	15	100	200	30	150	300
Other	20	150	300	50	200	450

[a] Handles, knobs, grips levers and the like intented to operate components, such as valve controls, electrical switch handles etc.

Under the tests above the handles, knobs, grips levers and the like shall remain fixed to the equipment as intended.

5.2.3 Electrical tests

5.2.3.1 General

The electrical tests described in 5.2.3.2 to 5.2.3.5 are applicable to *basic*, *supplementary* and *reinforced insulation*. Before performing these tests, preconditioning according to 5.2.6.3.1 and 5.2.6.3.2 is required.

When performing electrical and preconditioning tests, the preferred procedure is to test the entire equipment; however it is acceptable to test the components or sub-assemblies providing the *basic* and *reinforced insulation*. When components or sub-assemblies are tested, test conditions shall simulate the least favourable conditions occurring inside the equipment at the place of *installation*.

5.2.3.2 Impulse voltage test (*type test* and *sample test*)

The impulse voltage test is performed with a voltage having a 1,2/50 μs waveform (see 6.1 and 6.2 of IEC 61180-1:1992) and is intended to simulate overvoltages of atmospheric origin. It also covers overvoltages due to switching of equipment. See Table 24 for conditions of the impulse voltage test.

Tests on clearances smaller than required by 4.4.7.4 and test on solid *insulation* required by 4.4.7.8 are performed as *type tests* using appropriate voltages from Table 25.

Tests on components and devices for *protective separation* are performed as a *type test* and a *sample test* before they are assembled into the *PECS*, using the impulse withstand voltages listed in column 3 or column 5 of Table 25.

To ensure that *surge protective devices* (see 4.4.7.2.2, 4.4.7.2.3, 4.4.7.3) are able to reduce the overvoltage, the values of column 2 or column 4 in Table 25, are applied to the *PECS* as a *type test*. The measured peak voltage shall not exceed the next lower voltage value of the same column of that table.

If it is necessary to test a clearance that has been designed according to 4.4.7.4.1 for altitudes between 2 000 m and 20 000 m (using Table A.2 of IEC 60664-1:2007, which is reproduced as Table E.1) or test a clearance designed according to 4.4.7.11 for frequencies above 30 kHz, the appropriate test voltage may be determined from the clearance distance, using Table 10 in reverse.

Table 24 – Impulse voltage test

Subject	**Test conditions**	
Test reference	IEC 61180-1:1992, 6.1. and 6.2; IEC 60664-1:2007: 6.1.3.3 1	
Requirement reference	According to 4.4.3.2, 4.4.5.4 and 4.4.7	
Preconditioning	*Precondition according to 5.2.3.1* *Live parts* belonging to the same circuit shall be connected together. *Protective impedances* may be disconnected unless required to be tested. Impulse voltage to be applied: 1) between circuit under test and the surroundings; and 2) between circuits to be tested. Power is not applied to circuits under test.	
Initial measurement	According to specification of *PECS*, component, or device.	
Test equipment	Impulse generator 1,2/50 µs with an output impedance not higher than: • 2 Ω for surge protective devices; • 2 Ω for testing clearances, *solid insulation* and components. A higher impedance, but not more than 500 Ω, may be chosen, if the impulse voltage is verified at the object under test.	
Measurement and verification	a) Clearances smaller than required by Table 10 Clearances reduced by *surge protective device* or by circuit characteristics Solid *basic* or *supplementary insulation*	b) Components and devices for *protective separation* Solid *reinforced insulation*
	Three pulses 1,2/50 µs of each polarity in ≥ 1 s interval, peak voltage (±5 %) according to:	
Test voltage	Column 2 or column 4 of Table 25	Column 3 or column 5 of Table 25
Altitude correction	When the test is carried out on a clearance at an altitude less than 2 000 m, the test voltage shall be increased according to Table F.5, 6.1.2.2.1.1, of IEC 60664-1:2007, which is reproduced as Table E.2 in this standard. The altitude correction factor does not apply to impulse voltage testing on solid *insulation* according to 6.1.3.3.1 of IEC 60664-1:2007.	

The impulse voltage test is successfully passed if no puncture of *insulation*, flashover, or sparkover occurs. In the case of components and devices which use solid *insulation* for *protective separation*, a subsequent partial discharge test (see 5.2.3.5) shall also be passed.

Table 25 – Impulse test voltage

Column 1	2	3	4	5
System voltage **(see 4.4.7.1.6)**	**Impulse withstand voltage for *insulation* between circuits connected to *non-mains supply* and their surroundings according to overvoltage category II**		**Impulse withstand voltage for *insulation* between circuits connected to *mains supply* and their surroundings according to overvoltage category III**	
	Basic or supplementary	**Reinforced**	**Basic or supplementary**	**Reinforced**
V	V	V	V	V
≤ 50	500	800	800	1 500
100	800	1 500	1 500	2 500
150	1 500	2 500	2 500	4 000
300	2 500	4 000	4 000	6 000
600	4 000	6 000	6 000	8 000
1 000	6 000	8 000	8 000	12 000
-	Interpolation is permitted		Interpolation is not permitted	
NOTE 1 Test voltages for overvoltage categories I and III can be derived in a similar way from Table 9.				
NOTE 2 Test voltages for overvoltage categories II and IV can be derived in a similar way from Table 9.				

5.2.3.3 Alternative to impulse voltage test (*type test* and *sample test*)

An a.c. or d.c. voltage test according to 5.2.3.4 may be used as an alternative method to the impulse voltage test of 5.2.3.2.

For an a.c. voltage test the peak value of the a.c. test voltage shall be equal to the impulse test voltage of Table 25 and applied for three cycles of the a.c. test voltage.

For a d.c. voltage test the average value of the d.c. test voltage shall be equal to the impulse test voltage of Table 25 and applied three times for 10 ms in each polarity.

See IEC 60664-1:2007, 6.1.2.2.2, for further information.

5.2.3.4 AC or d.c. voltage test (*type test* and *routine test*)

5.2.3.4.1 Purpose of test

The test is used to verify that the clearances and solid *insulation* of components and assembled *PECS* have adequate dielectric strength to resist *temporary overvoltage* conditions.

5.2.3.4.2 Value and type of test voltage

The values of the test voltage for circuits connected to *mains supply* are determined from column 2 or 3 of Table 26.

The test voltage from column 2 is used for testing circuits with *basic insulation*.

Between circuits with *protective separation* (*double* or *reinforced insulation*), the test voltage of column 3 shall be applied for *type tests*. For *routine tests* between circuits with *protective separation* the values from column 2 shall be applied to prevent damage to the *solid insulation* by partial discharge.

The values of column 3 shall apply to *PECS* with *enhanced protection* according to 4.4.3.

For circuits connected to *non-mains supply* the test voltage shall be:

- For *type testing* circuits with *simple separation*, and for all *routine testing*: the *temporary overvoltage* (a.c. r.m.s. or d.c.) as determined in 4.4.7.2.3.
- For *type testing* circuits with *protective separation*, and between circuits and accessible surfaces (non-conductive or conductive but not connected to protective earth, *protective class II* according to 4.4.6.3): twice the *temporary overvoltage* (a.c. r.m.s. or d.c.) as determined in 4.4.7.2.3.

For *non-mains* circuits, where *temporary overvoltages* are not present, the test voltages are determined from Table 27, based on the *working voltage*.

The test is performed between circuits and accessible surfaces of *PECS*, which are non-conductive or which are conductive but not connected to the *PE conductor*.

The voltage test shall be performed with a sinusoidal voltage at 50 Hz or 60 Hz. If the circuit contains capacitors the test may be performed with a d.c. voltage of a value equal to the peak value of the specified a.c. voltage.

Table 26 – AC or d.c. test voltage for circuits connected directly to *mains supply*

Column 1 ***System voltage*** **(see 4.4.7.1.6)**	**2** **Voltage for *type testing* circuits with *simple separation*, and for all *routine testing***		**3** [b] **Voltage for *type testing* circuits with *protective separation*, and between circuits and accessible surfaces (non-conductive or conductive but not connected to protective earth, *protective class II* according to 4.4.6.3)**	
	a.c. r.m.s. [a]	**d.c.**	**a.c. r.m.s.**	**d.c.**
V	V	V	V	V
≤ 50	1 250	1 770	2 500	3 540
100	1 300	1 840	2 600	3 680
150	1 350	1 910	2 700	3 820
300	1 500	2 120	3 000	4 240
600	1 800	2 550	3 600	5 090
1 000	2 200	3 110	4 400	6 220
Interpolation is permitted.				

[a] Corresponding to 1 200 V + *system voltage*.

[b] A voltage source with a short circuit current of at least 0,1 A according to 5.2.2.2 of IEC 61180-1:1992 is used for this test.

Table 27 – A.c. or d.c. test voltage for circuits connected to *non-mains supply* without *temporary overvoltage*s

Column 1 *Working voltage* (recurring peak) (see 4.4.7.1.6.2) V	2 [a] Voltage for *type testing* circuits with *simple separation*, and for all *routine testing*		3 [a] Voltage for *type testing* circuits with *protective separation,* and between circuits and accessible surfaces (non-conductive or conductive but not connected to protective earth, *protective class II* according to 4.4.6.3)	
	a.c. r.m.s. V	d.c. V	a.c. r.m.s. V	d.c. V
≤71	80	110	160	220
141	160	225	320	450
212	240	340	480	680
330	380	530	760	1 100
440	500	700	1 000	1 400
600	680	960	1 400	1 900
1 000	1 100	1 600	2 200	3 200
1 600	1 800	2 600	2 900	4 200
2 300	2 600	3 700	4 200	5 900
3 000	3 400	4 800	5 400	7 700
4 600	5 200	7 400	8 300	11 800
7 600	8 500	12 000	14 000	19 000
16 000	18 000	26 000	29 000	42 000
23 000	26 000	37 000	42 000	59 000
30 000	34 000	48 000	54 000	77 000
38 000	43 000	61 000	69 000	98 000
50 000	57 000	80 000	91 000	130 000
60 000	70 000	99 000	109 000	154 000

Interpolation is permitted.

NOTE Test voltages in this table are based upon 80 % of the withstand voltage for the corresponding clearance of Table 10 as provided by Table A.1 of IEC 60664-1:2007.

[a] A voltage source with a short circuit current of at least 0,1 A according to 5.2.2.2 of IEC 61180-1:1992 is used for this test.

Routine tests are performed to verify that clearances have not been reduced during the manufacturing operations. Protective devices designed to reduce impulse voltages on the circuits under test (see 4.4.7.2.2 and 4.4.7.2.3), and circuits belonging to monitoring or protection circuits, not designed to sustain the test overvoltage for the duration of the test, shall be disconnected in order to avoid damage and to ensure that the test voltage can be applied without a false indication of failure.

5.2.3.4.3 Performing the voltage test

The test shall be applied as follows, according to Figure 10:

a) Test (1) between accessible conductive part (connected to earth) and each circuit sequentially (except *DVC As* circuits). Test voltage according to Table 26, or Table 27, column 2, corresponding to voltage of considered circuit under test.

   Test (2) between accessible surface (non conductive or conductive but not connected to earth) and each circuit sequentially (except *DVC As* circuits). Test voltage according to Table 26 or Table 27, column 3 (for *type test*) or column 2 (for *routine test*), corresponding to voltage of considered circuit under test.

b) Test between each considered circuit sequentially and the other *adjacent circuits* connected together. Test voltage according to Table 26 or Table 27, column 2, corresponding to voltage of considered circuit under test.

c) Test between *DVC As* circuit and each *adjacent circuit* sequentially. Test voltage according to Table 26 or Table 27, column 3 (for *type test*) or column 2 (for *routine test*), corresponding to the circuit with the higher voltage. Either the *adjacent circuit* or the *DVC As* circuit may be earthed for this test. It is necessary to test *basic insulation* between *PELV* and *SELV circuits*, but it is not necessary to test *functional insulation* between *adjacent PELV* or *adjacent SELV circuits*.

   Because *PELV / SELV circuits* and circuits of *DVC C* are typically separated from chassis (earth) by *basic insulation*, it is typically impossible to test *double* or *reinforced insulation* separating low-voltage circuits from high-voltage circuits in a fully-assembled *PECS* without overstressing the *basic insulation*. Because of this, it may be necessary to disassemble the *PECS*, or it may not be possible to perform *type tests* of protective *insulation* at voltages according to column 3 of Table 26 to Table 27. In these cases the *type test* of *insulation* used for *protective separation* shall be performed at voltages according to column 2 of the appropriate table.

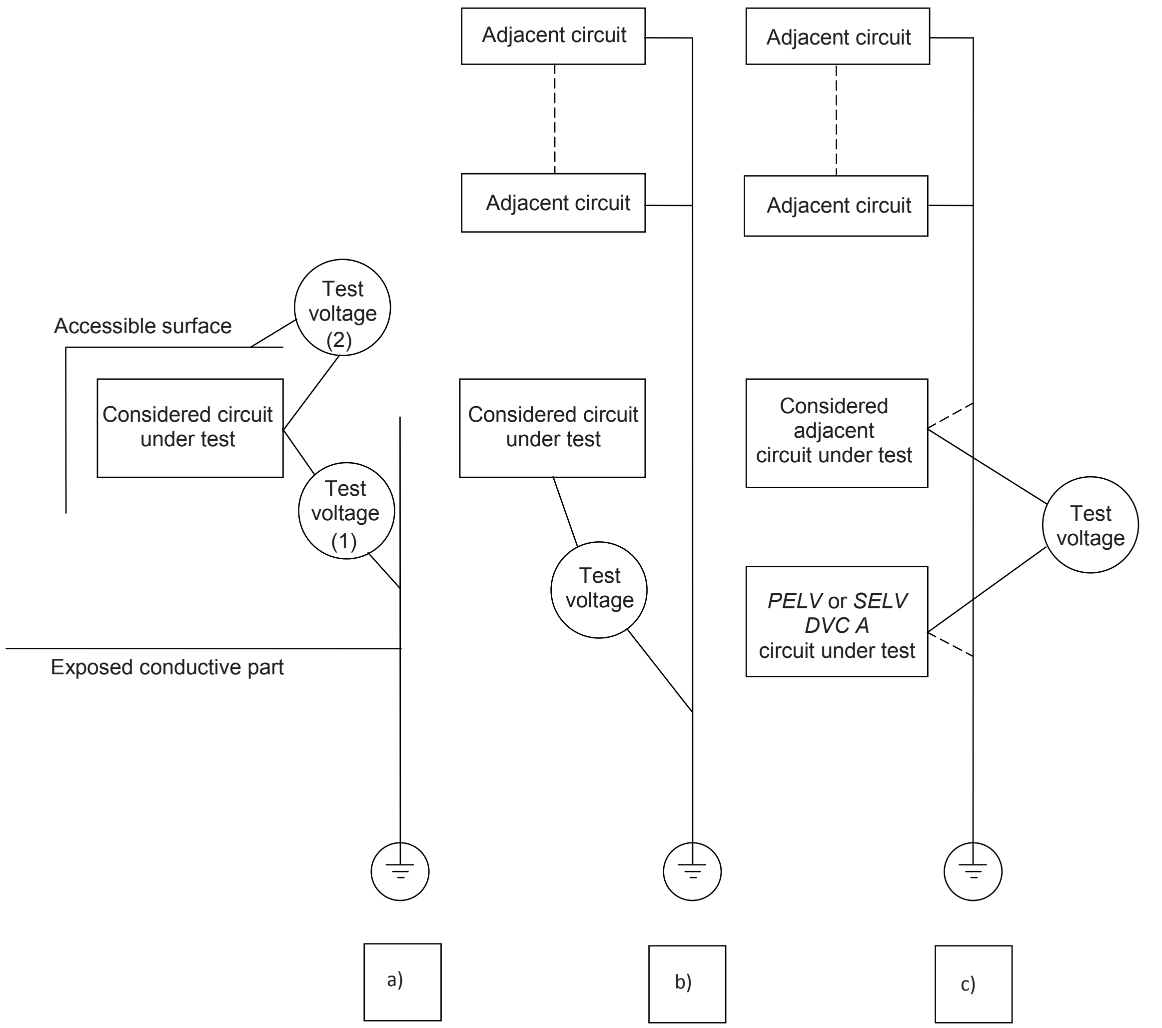


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Figure 10 – Voltage test procedures

The tests shall be performed with the doors of the *enclosure* closed.

When the circuit is electrically connected to accessible conductive parts, the voltage test is not relevant, and may be omitted.

To create a continuous circuit for the voltage test on the *PECS*, terminals, open contacts on switches and semiconductor devices, etc. shall be bridged where necessary. Before testing, semiconductor devices and other vulnerable components within a circuit may be disconnected and/or their terminals bridged to avoid damage occurring to them during the test.

Wherever practicable, individual components forming part of the *insulation* under test, for example interference suppression capacitors, should not be disconnected or bridged before the test. In this case, it is recommended to use the d.c. test voltage according to 5.2.3.4.2.

Where the *PECS* is covered totally or partly by a non-conductive accessible surface, a conductive foil to which the test voltage is applied shall be wrapped around this surface for testing. In this case, the *insulation* test between a circuit and non-conductive accessible surface may be performed as a *sample test* instead of a *routine test*.

Routine testing of the assembled *PECS* is not required if:

- *routine testing* of all sub-assemblies related to the *insulation system* of the *PECS* is performed; and
- it can be demonstrated that final assembly will not compromise the *insulation system*; and
- *type testing* of the fully-assembled *PECS* was performed successfully.

Protective impedances according to 4.4.5.4 shall either be included in the testing or the connection to the protectively separated part of the circuit shall be opened before testing. In the latter case, the connection shall be carefully restored after the voltage test in order to avoid any damage to the *insulation*. Protective screens according to 4.4.4.7 shall remain connected to accessible conductive parts during the voltage test.

5.2.3.4.4 Duration of the a.c. or d.c. voltage test

The duration of the test shall be at least 60 s for the *type test* and 1 s for the *routine test*. The test voltage may be applied with increasing and/or decreasing ramp voltage but the full voltage shall be maintained for 60 s and 1 s respectively for *type* and *routine tests*.

5.2.3.4.5 Verification of the a.c. or d.c. voltage test

The test is successfully passed if no *electrical breakdown* occurs during the test.

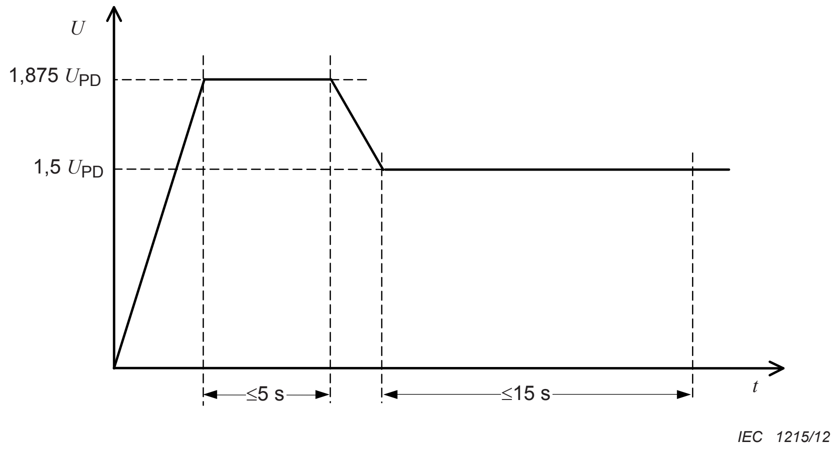
5.2.3.5 Partial discharge test (*type test*, *sample test*)

The partial discharge test shall confirm that the solid *insulation* (see 4.4.7.8) used in components and sub-assemblies for *protective separation* of electrical circuits remains partial-discharge-free within the specified voltage range (see Table 28).

This test shall be performed as a *type test* and a *sample test*. It may be omitted for insulating materials which are not degraded by partial discharge, for example ceramics.

The partial discharge inception and extinction voltage are influenced by climatic factors (e.g. temperature and moisture), equipment self heating, and manufacturing tolerance. These influencing variables can be significant under certain conditions and shall therefore be taken into account during *type testing*.

Table 28 – Partial discharge test

Subject	Test conditions
Test reference	6.1.3.5 of IEC 60664-1:2007
Requirement reference	4.4.7.8
Preconditioning	*Precondition according to 5.2.3.1* *Live parts* belonging to the same circuit shall be connected together. It is recommended that the partial discharge test is performed after the impulse voltage test (see 5.2.3.1) in order that any damage caused by the impulse voltage test is apparent. It is advisable that the partial discharge test is performed before inserting the components or devices into the equipment because partial discharge testing is not normally possible when the equipment is assembled.
Initial measurement	According to specification of component or device.
Test equipment	Calibrated charge measuring device or radio interference meter without weighting filters.
Test circuit	C.1 of IEC 60664-1:2007.
Test voltage	The peak value of a.c. 50 Hz or 60 Hz.
Test method	6.1.3.5 of IEC 60664-1:2007: F_1 = 1,2; F_2, F_3 = 1,25. Test procedure 6.1.3.5.3 of IEC 60664-1:2007.
Calibration of test equipment	C.4 of IEC 60664-1:2007.
Measurement	Starting from a voltage below the rated partial discharge test voltage U_{PD} [a], the voltage shall be linearly increased to 1,875 times U_{PD} and held for a maximum time of 5 s. The voltage shall then be linearly decreased to 1,5 times U_{PD} (± 5 %) and held for a maximum time of 15 s, during which the partial discharge is measured.
Verification	The test shall be considered to have been successfully passed if the partial discharge is less than 10 pC during the measurement period 
NOTE Partial discharge testing of *solid insulation* with a d.c. *working voltage* according to A.6.3 can be omitted	
[a] The rated partial discharge test voltage U_{PD} is the recurring peak voltage measured across the *insulation*.	

5.2.3.6 *Protective impedance* test (*type test* and *routine test*)

A *type test* shall be performed to verify that the current through a *protective impedance* under normal operating or single-fault conditions does not exceed the values given in 4.4.3.4. The test shall be performed using the circuit of IEC 60990:1999, Figure 4.

The test circuit of IEC 60990:1999, Figure 4, is reproduced in Annex L.

NOTE IEC 60990 states that the use of a single network for the measurement of a.c. combined with d.c. has not been investigated, but no suggestion is made for measurement in such cases.

The value of the *protective impedance* shall be verified as a *routine test*.

5.2.3.7 *Touch current* measurement test (*type test*)

The *touch current* shall be measured to determine if the measures of protection need not be taken (see 4.4.4.3.3). The *PECS* shall be set up in an insulated state without any connection to the earth and shall be operated at rated voltage. Under these conditions, the *touch current* shall be measured between the means of connection for the *PE conductor* and the *PE conductor* itself with the test circuit of Figure 4 of IEC 60990:1999.

- For a *PECS* to be connected to an earthed neutral *system*, the neutral of the mains of the test site shall be directly connected to the *PE conductor*.
- For a *PECS* to be connected to an isolated *system* or impedance *system*, the neutral shall be connected through a resistance of 1 kΩ to the *PE conductor* which shall be connected to each input phase in turn. The highest value will be taken as the definitive result.
- For a *PECS* to be connected to a corner earthed *system*, the *PE conductor* shall be connected to each input phase in turn. The highest value will be taken as the definitive result.
- For a *PECS* with a particular system earthing, this system shall operate as intended during the test.
- If a *PECS* is intended to be connected to more than one system network, each of these different system networks (or the worst-case, if that can be determined) shall be used to make the *touch current* measurement.

This is performed as a *type test*.

Product standard committees should consider the applicable effects of potential hazards as a result of high frequency touch current, and consider appropriate test requirements.

5.2.3.8 Capacitor discharge test (*type test*)

The capacitor discharge time as required by 4.4.3.4 may be verified by a *type test* and/or by calculation taking into account the relevant tolerances.

5.2.3.9 Limited power source test (*type test*)

When required by 4.6.5 a limited power circuit shall be tested as below, with the equipment operating under normal operating conditions.

In case the limited power source requirement depends on overcurrent protective device(s), the device(s) shall be short-circuited.

With the equipment operating under normal operating conditions, a variable resistive load is connected to the parts under consideration and adjusted to obtain a level of required limited VA power. Further adjustment is made, if necessary, to maintain the limited VA power for a period specified by 4.6.5.

A variable resistive load is connected to the circuit under consideration and adjusted to obtain the limit of apparent power as indicated in Table 16 or Table 17, as applicable. Further adjustment is made, if necessary, to maintain the limit of apparent power for the time period indicated in Table 16 or Table 17, as applicable.

The test is passed, if after the test period the available apparent power does not exceed the limits indicated in Table 16 or Table 17, as applicable.

In case the limited power source requirement depends on overcurrent protective device(s), the current rating of at least one of the protective device(s) in the current path shall not exceed the limit in Table 17.

5.2.3.10 Temperature rise test (*type test*)

The test is intended to ensure that parts and accessible surfaces of the *PECS* do not exceed the temperature limits specified in 4.6.4 and the manufacturer's temperature limits of safety-relevant parts.

Where possible, the *PECS* shall be tested at worst-case conditions of rated power and *PECS* output current, taking derating and cooling control characteristic into account.

For equipment where the amount of heating or cooling is designed to be dependent on temperature (for example, the equipment contains a fan that has a higher speed at a higher temperature), the temperature measurement shall be performed at the worst case ambient temperature condition within the manufacturer's specified operating range.

If this is not possible, it is permitted to simulate the temperature rise, if the validity of the simulation can be demonstrated by tests at lower power levels.

The *PECS* shall be tested with at least 1,2 m of wire attached to each *field wiring terminal*. The wire shall be of the smallest size intended to be connected to the *PECS* as specified by the manufacturer for installation. When there is only provision for the connection of bus-bars to the *PECS*, they shall be of the minimum size intended to be connected to the *PECS* as specified by the manufacturer, and they shall be at least 1,2 m in length.

The test shall be maintained until thermal stabilization has been reached. That is, when three successive readings, taken at intervals of 10 % of the previously elapsed duration of the test and not less than 10 min intervals, indicate no change in temperature, defined as ±1 °C between any of the three successive readings, with respect to the ambient temperature.

The temperature of an electrical *insulation* (other than that of windings) is measured on the surface of the *insulation* at a point close to the heat source, if a failure of this *insulation* could cause a hazard. If temperatures of windings are measured by the thermocouple method, the thermocouple shall be located on the surface of the winding assuming the hottest part due to surrounding heat emitting components. See also notes in Table 14.

The maximum temperature attained shall be corrected to the rated ambient temperature of the *PECS* by adding the difference between the ambient temperature during the test and the equipment's maximum rated ambient temperature.

No corrected temperature shall exceed the rated temperature of the material or component measured.

During the test, thermal cutout, overload detection functions and devices shall not operate.

5.2.3.11 *Protective equipotential bonding* tests (*type test*s and *routine test*)

5.2.3.11.1 General

Each conductive accessible part under consideration shall be tested separately, to determine if the *protective equipotential bonding* path for that part is adequate to withstand the test current that the bonding path may be subjected to under fault conditions.

The circuit under consideration shall be selected from amongst those circuits adjacent to the accessible part under consideration and separated from it by only *basic* or *functional insulation*.

All of these selected circuits have to be analyzed regarding *prospective short circuit current* and the associated protective element(s):

- If the circuit under consideration exceeds the 5 s disconnection time requirement of IEC 60364-4-41, the *protective equipotential bonding* impedance test of 5.2.3.11.2 and the *protective equipotential bonding* short circuit test of 5.2.3.11.3 have to be performed.

  NOTE 1 Examples for circuits with disconnection times of more than 5 s: non mains circuits where the short circuit current is limited by internal impedances or current limiters or by the load characteristics like solar panels.

- If the circuit under consideration meets the 5 s disconnection time requirement of IEC 60364-4-41, the *protective equipotential bonding* short circuit test of 5.2.3.11.3 has to be performed.

  NOTE 2 Examples for circuits with disconnection times of not exceeding 5 s: mains circuits where the *prospective short circuit current* is limited by the impedance of the main.

- If the circuit under consideration meets the disconnection time requirement of IEC 60364-4-41:2005, Table 41.1, as applicable, depending on the earthing system of the *installation*, no *type test* is required.

For *pluggable equipment type A only the* the *protective equipotential bonding* impedance test of 5.2.3.11.2 have to be performed.

The testing shall include an individual test of the *protective equipotential bonding* path for each conductive accessible part unless analysis shows that the short circuit withstand capability of the path is adequate, or that the results of one combination are representative of the anticipated results of another combination.

5.2.3.11.2 *Protective equipotential bonding* impedance test

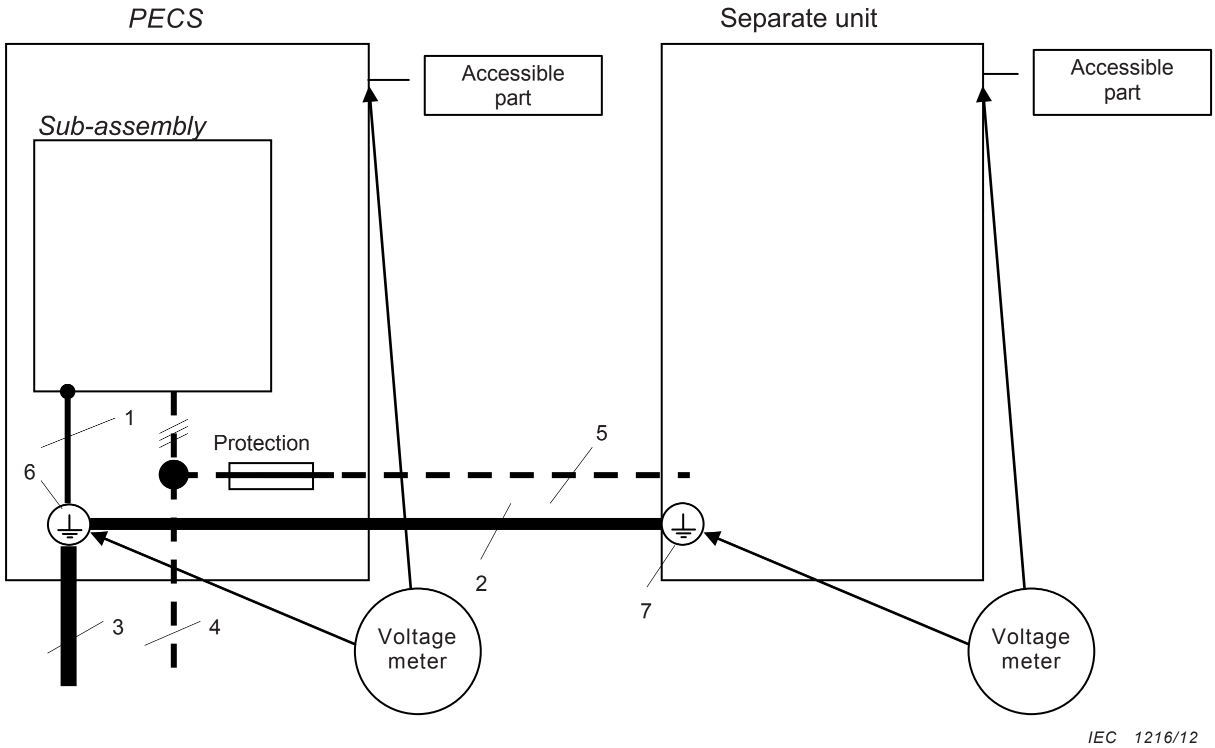
5.2.3.11.2.1 Test conditions

Where required by 4.4.4.2.2 and 5.2.3.11.2.1, the impedance of *protective equipotential bonding* means shall be checked by passing a test current through the bond for a period of time. The test current is based on the rating of the overcurrent protection for the equipment or part of the equipment under consideration, as follows:

- for *pluggable equipment type A*, the overcurrent protective device is that provided external to the equipment (for example, in the building wiring, in the mains plug or in an equipment rack);
- for *pluggable equipment type B* and *permanently connected* equipment, the maximum rating of the overcurrent protective device specified in the equipment installation instructions to be provided external to the equipment;
- the rating of the provided overcurrent device for a circuit or part of the equipment for which an overcurrent protective device is provided as part of the equipment.

Voltages are measured from the *protective earthing* terminal to all the parts whose *protective equipotential bonding* means are being considered. The impedance of the *PE conductor* is not included in the measurement. However, if the *PE conductor* is supplied with the equipment, it is permitted to include the conductor in the test circuit, but the measurement of the voltage drop is made only from the main *protective earthing* terminal to the accessible part required to be earthed.

On equipment where the protective earth connection to a sub-assembly or to a separate unit is part of a cable that also supplies power to that sub-assembly or unit, the resistance of the *protective equipotential bonding* conductor in that cable is not included in the *protective equipotential bonding* impedance measurements for the sub-assembly or separate unit as in Figure 11. However, this option is only permitted if the cable is protected by a suitably rated protective device that takes into account the size of the conductor. Otherwise the impedance of the *protective equipotential bonding* conductor between the separate units is to be included, by measuring to the *protective earthing* terminal where the power source enters the first unit in the *system*, as in Figure 12.



Key

1 = *protective equipotential bonding*

2 = *PE conductor* for the separate unit

3 = *PE conductor* for the *PECS*

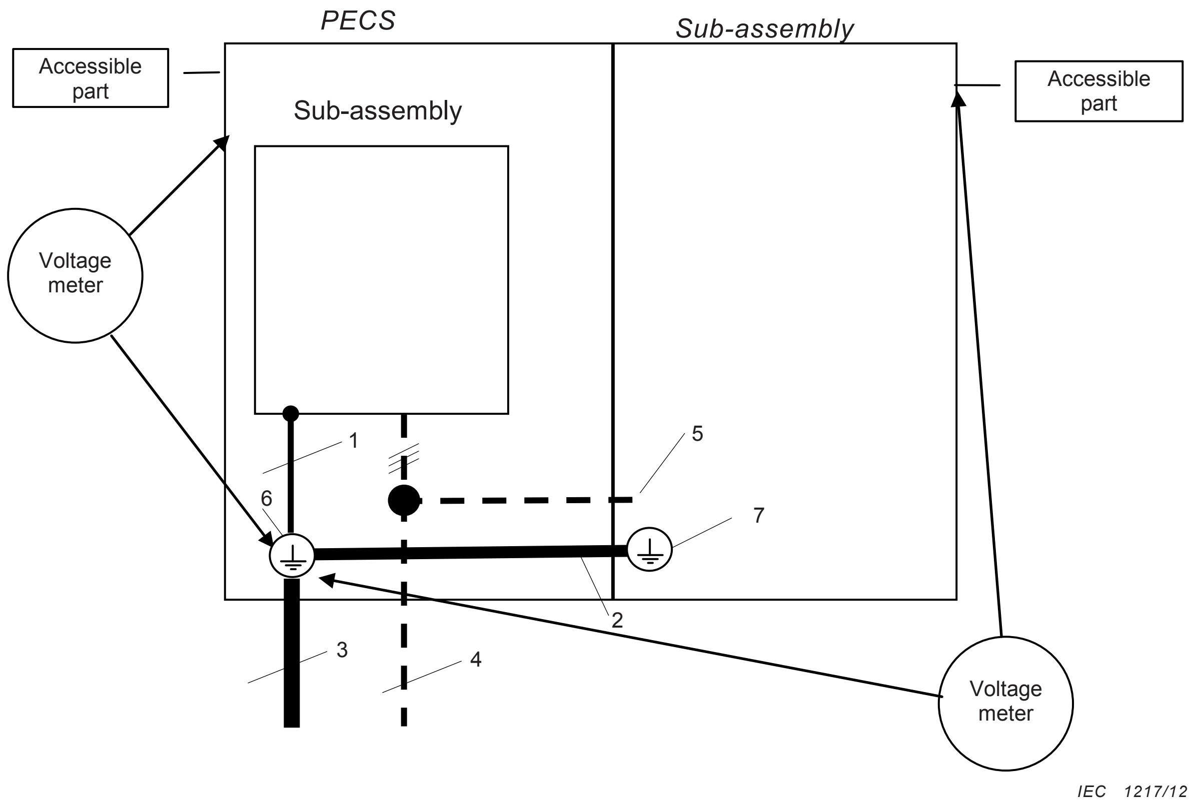
4 = energy supply from the mains

5 = energy supply from the *PECS* to the separate unit

6 = terminal point of the external *PE conductor*

7 = terminal point of the *PE conductor* for the separate unit

Figure 11 – Protective equipotential bonding impedance test for separate unit with power fed from the *PECS* with protection for the power cable



Key

1 = protective *equipotential* bonding

2 = protective *equipotential* bonding for the sub-assembly

3 = *PE conductor* for the *PECS*

4 = energy supply from the mains

5 = energy supply from the *PECS* to the sub-assembly

6 = terminal point of the external *PE conductor*

7 = connection point of the bonding to the sub-assembly (may be more than1)

Figure 12 – Protective equipotential bonding impedance test for sub-assembly with accessible parts and with power fed from the *PECS*

The test current is derived from an a.c or d.c supply source, the output of which is not earthed.

NOTE For protection of the person performing the test, the source should have a maximum no-load voltage below the limits for *DVC A*.

5.2.3.11.2.2 Test current, duration and acceptance criteria

The test current, duration of the test and acceptance criteria are as follows.

Table 29 – Test duration for *protective equipotential bonding* test

Overcurrent protective device rating A	Duration of the test min
up to 32	2
33 to 63	4
64 to 100	6
101 to 200	8
201 to 460	10

a) For *PECS* with an overcurrent protective device rating of 16 A or less, this test may be omitted, if an impedance not exceeding 0,1 Ω can be demonstrated.

b) As an alternative to Table 29, where the time-current characteristic of the overcurrent protective device that limits the fault current in the *protective equipotential bonding* means is known because the device is either provided in the equipment or fully specified in the installation instructions, the test duration may be based on that specific device's time-current characteristic. The tests are conducted for a duration corresponding to the 200 % current value on the time-current characteristic.

c) For *PECS* with an overcurrent protective device rating of more than 460 A, calculations or simulations according to IEC 60949 shall be used to show the ability of the prospective short circuit current to fulfill the requirements. The *protective equipotential bonding* continuity *routine test* of 5.2.3.11.4 shall be performed to show that the impedance of the *protective equipotential bonding* means during and at the end of the test shall not exceed the expected value.

Acceptance criteria:

The test current is 200 % of the overcurrent protective device rating and the duration of the test is as shown in Table 29. The voltage drop in the *protective equipotential bonding* means, during and at the end of the test, shall not exceed *DVC As*, as determined from Table 2 and Table 5 with respect to the accessible surface of the *enclosure*.

After the tests, visual inspection shall show no damage to the *protective equipotential bonding* means.

5.2.3.11.3 ***Protective equipotential bonding* short circuit withstand test (*type test*)**

As required by 5.2.3.11.2.1 the short circuit test in 5.2.4.3 shall be performed to ensure that *protective equipotential bonding* has the ability to withstand the *prospective short circuit current* that it may be subjected to under fault conditions.

The testing shall include an individual test of the *protective equipotential bonding* path for each conductive accessible part unless analysis shows that the short circuit withstand capability of the path is adequate, or that the results of one combination are representative of the anticipated results of another combination.

5.2.3.11.4 ***Protective equipotential bonding* continuity test (*routine test*)**

The *protective equipotential bonding* continuity *routine test* shall be conducted when:

- the continuity of the *protective equipotential bonding* is achieved by a single means only (for example a single conductor or a single fastener); or
- the *PECS* is assembled at the *installation* location; or
- if required by 5.2.3.11.2.2 c).

The test current may be any convenient value sufficient to allow measurement or calculation of the resistance of the *protective equipotential bonding* means.

NOTE Larger currents used for the continuity test increases the accuracy of the test result, especially with low impedance values, i.e. larger cross sectional areas and/or lower conductor length. In general 25 A is considered sufficient for most products.

The expected value of the resistance is the result of calculation or simulation according to 5.2.3.11.2.2 considering the length, the cross sectional area and the material of the related protective bonding conductor(s).

Acceptance criteria: the resistance measured shall be within 90 % upto 110 % of the expected value.

5.2.4 Abnormal operation and simulated faults tests

5.2.4.1 General

Protection against risk of thermal, electric shock and energy hazards in case of abnormal operating condition of a *PECS* in combination with its *installation* shall be evaluated by:

a) tests defined in this section; or
b) calculation or simulation based on tests as defined in 5.2.4.4 and 5.2.4.6 on a representative model of *PECS*, where no damage other than opening of overcurrent protective devices has occurred to the test sample.

NOTE A representative model means a *PECS* with similar power elements (for example, *power semiconductor devices*, fuses, circuit breakers, capacitors, overcurrent detection and output inductances) and circuit topologies as the *PECS* under consideration.

Before all abnormal tests, the test sample shall be mounted, connected, and operated as described in the temperature rise test.

Simulated faults or abnormal operating conditions shall be applied one at a time. Faults that are the direct consequence of a simulated fault or abnormal operating conditions are considered to be part of that simulated fault or abnormal operating condition.

In the case of a *PECS* supplied without an *enclosure*, a wire mesh cage which is 1,5 times the individual linear dimensions of the *PECS* part under study shall be used to simulate the intended *enclosure*.

The *PECS*, and the wire mesh cage (if used), shall be earthed according to the requirements of 4.4.4.2.2.

Cheese cloth or surgical cotton shall be placed at all openings, handles, flanges, joints and similar locations on the outside of the *enclosure* and the wire mesh cage (if used), in a manner which will not significantly affect the cooling.

Where the *PECS* under test is specified in its installation manual to require external means of protection against faults, these specific means shall be provided for the test.

The voltages of accessible *SELV*, *PELV* and *DVC As* circuits as well as accessible earthed and unearthed conductive parts shall be monitored.

The supply shall be capable of delivering the specified *prospective short circuit current* (see 4.3.1) at the connection to the *PECS*, unless the circuit analysis of 4.2 demonstrates that a lesser value may be used.

The individual tests shall be performed until terminated by activation of a protective device or mechanism (internal or external), a component failure occurs that interrupts the fault condition, or the temperatures stabilize.

5.2.4.2 Pass criteria

As a result of the abnormal operation tests, the *PECS* shall comply with the following:

- there shall be no emission of flame, burning particles or molten metal;
- the cheese cloth or surgical cotton indicator shall not have ignited;
- the earth connection and *protective equipotential bonding* of the *PECS* shall not have opened;
- doors and covers shall remain in place;
- during and after the test, accessible *DVC As*, *SELV* and *PELV circuits* and accessible conductive parts shall not exhibit voltages greater than the time dependent voltages of Figure 1, Figure 2 or Figure 3, as appropriate and shall be separated from *live parts* at voltages greater than *DVC As* with at least *basic insulation*. Compliance shall be checked by the a.c. or d.c. *insulation* test of 5.2.3.4 for *basic insulation*;
- during and after the test, *live parts* at voltages greater than *DVC As* shall not become accessible.

The *PECS* is not required to be operational after testing and it is possible that the *enclosure* can become deformed. Overcurrent protection integral to the *PECS*, or required to be used with the *PECS*, is allowed to open.

5.2.4.3 *Protective equipotential bonding* short circuit withstand test (*type test*)

5.2.4.3.1 General

When required by 5.2.3.11.2.1, a *protective equipotential bonding* path shall be subjected to the following short circuit withstand test.

5.2.4.3.2 Test conditions

The equipment under test shall be supplied with power and the output *port* shall be operating as intended in 5.2.4.1 prior to closing the switching means that applies the short circuit, unless energizing the equipment with the short circuit already applied will be more severe.

The *protective equipotential bonding* short circuit test shall be performed with the *PECS* working with light load, unless analysis shows that higher short circuit currents are available under higher loading conditions.

A new sample may be used for each short circuit test.

5.2.4.3.3 *Protective equipotential bonding* short circuit test method

The test current is applied by connecting the accessible part under consideration to one of the conductors of the the test source circuit through a switching means that will not limit the short circuit current. The switch shall be located such that the source is short circuited through the accessible part and its *protective equipotential bonding* path back to the *protective earthing* terminal for the source circuit under consideration. The connections to the shorting switch shall be through cables having the same cross-section as specified for the *PE conductor* in the *installation* and the length of the cables shall be limited to 2 m. If the size of the *PECS* requires a greater length, the length shall be as short as practical to perform the test and the short circuit current shall be calibrated at the entrance of the product.

5.2.4.3.4 Pass criteria

During and after the test, accessible *DVC As*, *SELV* and *PELV circuits* and accessible conductive parts shall not exhibit voltages greater than the time dependent voltages of Figure 1, Figure 2 or Figure 3 of 4.4.2.2.3, and shall remain separated from *live parts* at voltages greater than *DVC As* by at least *basic insulation*. Compliance shall be checked by the a.c.or d.c. voltage test of 5.2.3.4 for *basic insulation.*

At the conclusion of the test, there shall be no damage to the *protective equipotential bonding* means under test. Compliance shall be checked by inspection, and if necessary, by the *protective equipotential bonding* continuity test (*routine test*) of 5.2.3.11.4.

5.2.4.4 Output short-circuit test (*type test*)

5.2.4.4.1 Load conditions

The short-circuit test shall be performed with the *PECS* at full load or light load whichever creates the more severe condition.

5.2.4.4.2 Short-circuit test method

Power output *port* terminals shall be provided with cable of a cross-section as specified for the *installation* connected to an appropriate switching means that will not limit the short circuit current. The complete length of the cable (forth and back) shall be approximately 2 m, unless the size of the *PECS* requires a greater length, in which case the length shall be as short as practical to perform the test.

The equipment under test shall be supplied with power and the output *port* shall be operating as intended prior to closing the switching means that applies to the short circuit, unless energizing the equipment with the short circuit already applied will be more severe.

The testing shall include individual tests of each output *port* where combinations of two or more terminals, including earth, on each individual *port* are subjected to short circuit tests on those terminals. Analysis may be used to reduce the number of tests if it is shown that the results of one combination are representative of the anticipated results of another combination.

A new sample may be used for each short circuit test.

In addition to determining compliance with the criteria of 5.2.4.2, this test is used to determine the *output short circuit current* rating of the *port* under consideration, in accordance with 4.3.2.3. An oscilloscope or other suitable instrument shall be used to measure the peak current during the test, and to measure or calculate the r.m.s. value of the current.

The value(s) to be recorded and to be provided with the *PECS* instructions, in accordance with 6.2, are the peak current, and the highest of the r.m.s. current values measured or calculated over a time period as follows:

a) for a.c. signals, three cycles of the nominal a.c. frequency for the *port* under consideration, in which case the value is to be stated as the 3-cycle r.m.s. value;
b) for all signals, the duration of the short circuit from the time the short circuit is applied, until the time the short circuit current is interrupted by a protective device or other mechanism, in which case the value stated is to include the r.m.s. value and the time period in seconds;
c) for short circuit tests that result in a continuous non-zero value, the steady-state r.m.s. value, in which case the value is to be stated as a continuous r.m.s value.

For *PECS* with internal short circuit protection according to 4.3.2.3, which protects the output *port* within some few μs, the requirements in a), b) and c) are not applicable.

5.2.4.5 Output overload test (*type test*)

The overload test shall be performed after operating the *PECS* at full load until normal operating temperatures are attained. Each output of the *PECS*, and each section of a tapped output, shall be overloaded in turn, one at a time. The other outputs and windings are loaded or not loaded whichever load condition of normal use is less favorable.

Overloading is carried out by connecting a variable load across the output or winding. The load is adjusted as quickly as possible and readjusted, if necessary, after 1 min to maintain the applicable overload. No further readjustments are then permitted.

If overcurrent protection is provided by a current-sensitive device or circuit, the overload test current is the maximum current which the overcurrent protection device is just capable of passing for 1 h. Before the test, the overcurrent protection device is made inoperative or replaced by a link with negligible impedance.

For equipment in which the output voltage is designed to collapse when a specified overload current is reached, the overload is slowly increased to the point of maximum output power before the point which causes the output voltage to collapse.

In all other cases, the loading is the maximum power output obtainable from the output.

5.2.4.6 Breakdown of components test (*type test*)

5.2.4.6.1 Load conditions

The breakdown of a component, identified as a result of the circuit analysis of 4.2, shall be tested with the *PECS* at full load or light load whichever creates the more severe condition.

5.2.4.6.2 Application of short circuit or open-circuit

The short circuit shall be applied with cable of a cross-section appropriate for the current that normally flows through the component, but not less than 2,5 mm^2. The length of the loop shall be as short as practical to perform the test. Short circuits and open circuits are applied using an appropriate switching device.

Each identified component shall be subjected to only one breakdown of components test unless both open- and short circuit failure modes are likely in that component.

5.2.4.6.3 Test sequence

For the breakdown of components test, identified components shall be short circuited or open-circuited, whichever creates the worst hazard, one at a time.

5.2.4.7 PWB short circuit test (*type test*)

On PWBs, *functional insulation* provided by spacings which are less than those specified in Table 10 and Table 11 (see 4.4.7.7) shall be *type tested* as described below.

The decreased spacings shall be short circuited one at a time, on representative samples, and the short circuit shall be maintained until no further damage occurs.

5.2.4.8 Loss of phase test (*type test*)

A multi-phase *PECS* shall be operated with each line (including neutral, if used) disconnected in turn at the input. The test shall be performed by disconnecting one line with the *power conversion* equipment operating at its maximum normal load and shall be repeated by initially energizing the *PECS* with one lead disconnected.

The test shall continue until terminated by a protective mechanism, a component failure occurs, or the temperature stabilizes.

For *PECS* with rated input current greater than 500 A, compliance can be shown through simulation.

5.2.4.9 Cooling failure tests (*type tests*)

5.2.4.9.1 General and pass criteria

For *PECS* having a combination of cooling mechanisms, all relevant tests shall be performed. It is not necessary to perform the tests simultaneously.

The test shall continue:

- until the temperature stabilizes, in which case the temperature limits of 4.6.4.2 apply;

  or

- until terminated by a protective mechanism or a component failure occurs, in which case the temperature limits of accessible parts in 4.6.4.2 may be exceeded by not more than 5 °C. If this is not possible a warning statement shall be provided in the user documentation.

NOTE The temperature increase of 5 °C with regard to the steady state limits reflect the spread of the burn threshold given in IEC Guide 117.

5.2.4.9.2 Inoperative blower motor test

A *PECS* having forced ventilation shall be operated at rated load with fan or blower motor or motors made inoperative, single or in combination from a single fault, by physically preventing their rotation.

5.2.4.9.3 Clogged filter test

Enclosed *PECS* having filtered ventilation openings shall be operated at rated load with the openings blocked to represent clogged filters. The test shall be performed initially with 50 % of the ventilation openings surface blocked. The test shall be repeated under a full blocked condition.

5.2.4.9.4 Loss of coolant test

A liquid cooled *PECS* shall be operated at rated load. Loss of coolant shall be simulated by draining the coolant, blocking the flow or disabling the *system* coolant pump.

If the *PECS* is shut down due to the operation of a thermal device located inside the coolant, then the test shall be repeated with the coolant drained out of the *system*.

NOTE It is presumed that the thermal device will be inoperative if not surrounded by coolant liquid.

5.2.5 Material tests

5.2.5.1 General

When requested by 4.4.7.8.2, the manufacturer shall test the flammability properties of the materials used for insulating purposes, as defined in 5.2.5.2, 5.2.5.3 and 5.2.5.4.

When requested by 4.6.3.2 the manufacturer shall test the flammability properties of the materials used for *fire enclosure*, as defined in 5.2.5.5.

5.2.5.2 High current arcing ignition test (*type test*)

Five samples of each insulating material (Figure 13) to be tested are used. The samples shall have minimum 130 mm length and 13 mm width and of uniform thickness representing the thinnest section of the part. Edges shall be free from burrs, fins, etc.

Each test is made with a pair of test electrodes and a variable inductive impedance load connected in series to a source of 220 V to 240 V a.c, 50 Hz or 60 Hz (see Figure 13).

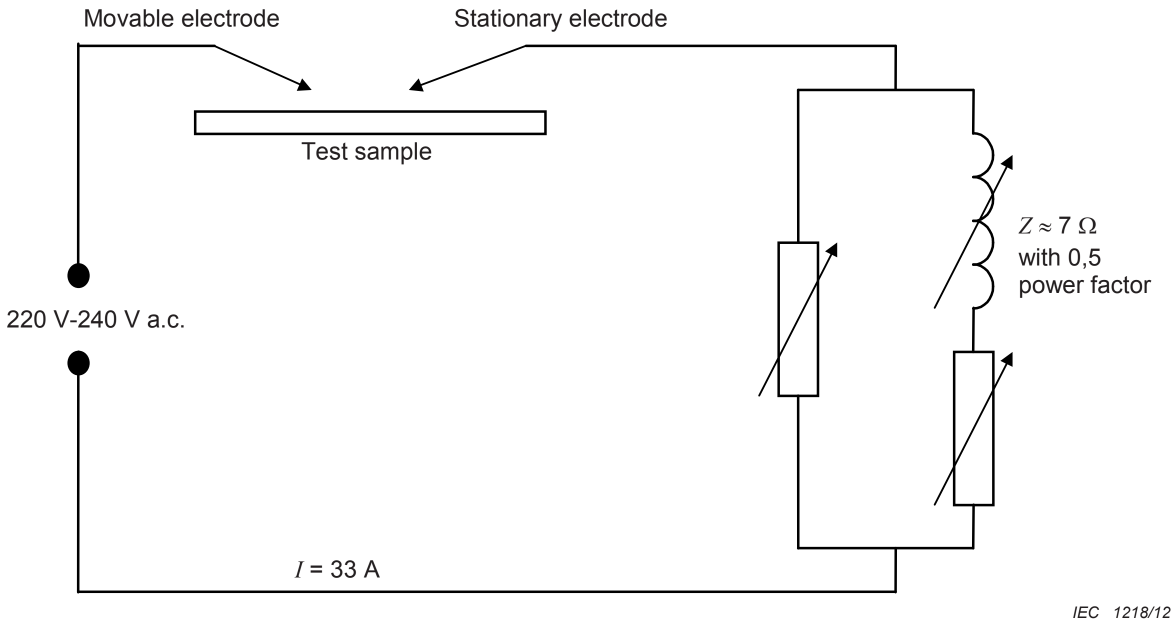


Figure 13 – Circuit for high-current arcing test

It is permitted to use an equivalent circuit.

One electrode is stationary and the second movable. The stationary electrode consists of a 3,5 mm diameter solid copper conductor having a 30° chisel point. The movable electrode is a 3 mm diameter stainless steel rod with a symmetrical conical point having a total angle of 60° and is capable of being moved along its own axis. The radius of curvature for the electrode tips does not exceed 0,1 mm at the start of a given test. The electrodes are located opposing each other, in the same plane, at an angle of 45° to the horizontal. With the electrodes short circuited, the variable inductive impedance load is adjusted until the current is 33 A at a power factor of 0,5.

The sample under test is supported horizontally in air or on a non-conductive surface so that the electrodes, when touching each other, are in contact with the surface of the sample. The movable electrode is manually or otherwise controlled so that it can be withdrawn from contact with the stationary electrode to break the circuit and lowered to remake the circuit, so as to produce a series of arcs at a rate of approximately 40 arcs/min, with a separation speed of 250 mm/s ± 25 mm/s.

The test is continued until ignition of the sample occurs, a hole is burned through the sample or a total of 200 arcs have elapsed.

The average number of arcs to ignition of the specimens tested shall be not less than 15 for V-0 class materials and not less than 30 for other materials.

5.2.5.3 Glow-wire test (*type test*)

The glow-wire test shall be made under the conditions specified in 4.4.7.8.2 according to IEC 60695-2-10 and IEC 60695-2-13.

5.2.5.4 Hot wire ignition test (*type test* – alternative to glow-wire test)

Five samples of each insulating material (see Figure 14) are tested. The samples shall have minimum 130 mm length and 13 mm width and of a uniform thickness representing the thinnest section of the part. Edges shall be free from burrs, fins, etc.

A 250 mm ± 5 mm length of nichrome wire (nominal composition 80 % nickel, 20 % chromium, iron-free) approximately 0,5 mm diameter and having a cold resistance of approximately 5 Ω/m is used. The wire is connected in a straight length to a variable source of power which is adjusted to generate 0,25 W/mm ± 0,01 W/mm in the wire for a period of 8 s to 12 s. After cooling, the wire is wrapped around a sample to form five complete turns spaced 6 mm apart.

The wrapped sample is supported in a horizontal position (see Figure 14) and the ends of the wire connected to the variable power source, which is again adjusted to generate 0,25 W/mm ± 0,01 W/mm in the wire.

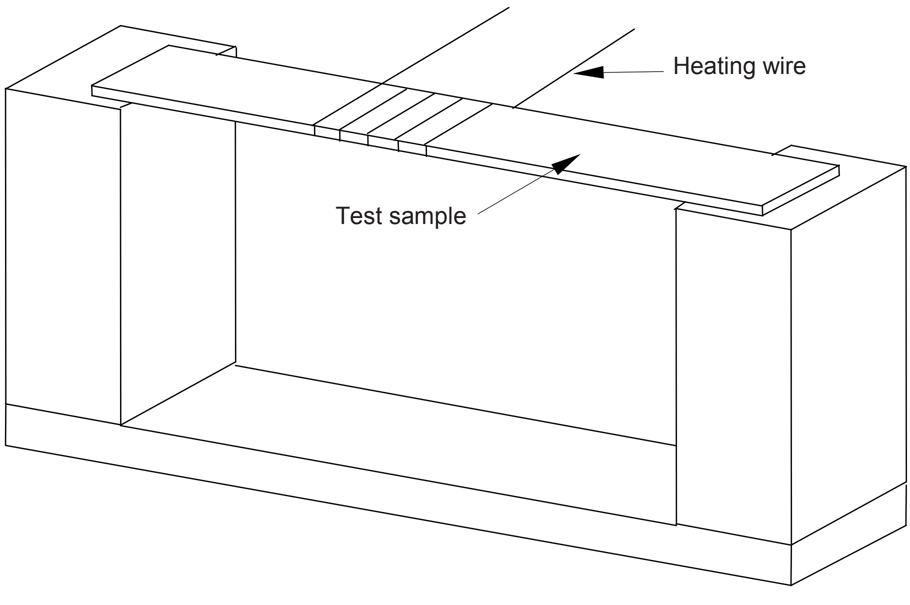


Figure 14 – Test fixture for hot-wire ignition test

The test is continued until the test specimen ignites or until 120 s have passed. When ignition occurs or 120 s have passed, the test is discontinued and the test time recorded. For specimens which melt through the wire without ignition, the test is discontinued when the specimen is no longer in intimate contact with all five turns of the heater wire.

The test is repeated on the remaining samples.

The average ignition time of the specimens tested shall not be less than 15 s.

5.2.5.5 Flammability test (*type test*)

Three samples of the complete equipment or three test specimens of the *enclosure* thereof (see 4.6.3) shall be subjected to this test. Consideration shall be given to leaving in place components and other parts that might influence the performance. The test samples shall be conditioned in a full draft circulating air oven for seven days at 10 °C greater than the maximum use temperature, as determined by the temperature rise test 5.2.3.10, but not less than 70 °C in any case. Prior to testing, the samples shall be conditioned for a minimum of 4 h at 23 °C ± 2 °C and 50 % ± 5 % relative humidity. The flame shall be applied to an inside surface of the sample at a location judged to be likely to become ignited because of its proximity to a source of ignition including surfaces provided with ventilation holes. If more than one part is near a source of ignition, each sample shall be tested with the flame applied to a different location.

The three test samples shall result in the acceptable performance described below. If one sample does not comply, the test shall be repeated on a set of three new samples with the flame applied under the same conditions as for the unsuccessful sample. If all the new specimens comply with the requirements described below the material is acceptable.

The laboratory burner, adjustment and calibration shall be identical to that described in IEC 60695-11-20.

When a complete *enclosure* is used to conduct the flame test, the sample shall be mounted as intended in service, if it does not impair the flame testing, in a draft-free test chamber, *enclosure*, or laboratory hood. A layer of absorbent 100 % cotton shall be located 305 mm below the point of application of the test flame. The 127 mm flame shall be applied to any portion of the interior of the part judged as likely to be ignited (by its proximity to live or arcing parts, coils, wiring, and the like) at an angle of approximately 20 ° insofar as possible from the vertical so that the tip of the blue cone touches the specimen. The test flame shall be applied to three different locations on each of the three samples tested. A supply of technical-grade methane gas shall be used with a regulator and meter for uniform gas flow. Natural gas having a heat content of approximately 37 MJ/m^3 at 23 °C has been found to provide similar results and may be used.

The flame shall be applied for 5 s and removed for 5 s. The operation shall be repeated until the specimen has been subjected to five applications of the test flame.

The following conditions shall be met as a result of this test:

- the material shall not continue to burn for more than 1 min after the fifth 5 s application of the test flame, with an interval of 5 s between applications of the flame;

and

- flaming drops or flaming or glowing particles that ignite surgical cotton 305 mm below the test specimen shall not be emitted by the test sample at any time during the test.

After the test, equipment shall meet the requirements for *basic protection* by means of *enclosures* or barriers in 4.4.3.3.

5.2.5.6 Flaming oil test (*type test*)

When required by 4.6.3.3.3 compliance is shown by the flame oil test as follows.

A sample of the complete finished bottom of the *fire enclosure* is securely supported in a horizontal position. Bleached cheesecloth of approximately 40 g/m2 is placed in one layer over a shallow, flat-bottomed pan approximately 50 mm below the sample, and is of sufficient size to cover completely the pattern of openings in the sample, but not large enough to catch any of the oil that runs over the edge of the sample or otherwise does not pass through the openings.

NOTE Use of a metal screen or a wired-glass partition surrounding the test area is recommended.

A small metal ladle (preferably no more than 65 mm in diameter), with a pouring lip and a long handle whose longitudinal axis remains horizontal during pouring, is partially filled with 10 ml of a distillate fuel oil that is a medium volatile distillate having a mass per unit volume between 0,845 g/ml and 0,865 g/ml, a flash point between 43,5 °C and 93,5 °C and an average calorific value of 38 MJ/l. The ladle containing the oil is heated and the oil ignited and permitted to burn for 1 min, at which time all of the hot flaming oil is poured at the rate of approximately 1 ml/s in a steady stream onto the centre of the pattern of openings, from a position approximately 100 mm above the openings.

The test is repeated twice at 5 min intervals, using clean cheesecloth.

During the test the cheesecloth shall not ignite.

5.2.5.7 Cemented joints test (*type test*)

When required by 4.4.7.9 representative samples of cemented joints providing protection of type 1 or type 2 as defined in IEC 60664-3:2003 shall be tested as a *type test* as follows.

The samples shall be subjected to the conditioning procedure specified in 5.7 of IEC 60664-3:2003, using the following parameters: for the cold test (5.7.1), a temperature of -25 °C shall be used, and for the rapid change of temperature test (5.7.3): –25 °C to +125 °C.

After the conditioning the samples shall pass the following tests in the prescribed order:

a) The mechanical strength of the joint shall be evaluated by loading the joint using the forces anticipated to be present under normal conditions. There shall be no separation of the parts.
b) The *insulation* resistance between the conductive parts separated by the joint shall be measured according to 5.8.3 of IEC 60664-3:2003.
c) Cemented joints shall be treated as to be thin sheet material and shall be tested according 4.4.7.8.3.
d) The sectioning of the joint shall not show any cracks, voids or separation.

5.2.6 Environmental tests (*type tests*)

5.2.6.1 General

Environmental testing is required to establish the safety of the *PECS* at the extremes of the environmental classification to which it will be subjected.

If size or power considerations prevent the performance of these tests on the complete *PECS*, it is permitted to test individual parts that are considered to be relevant to the safety of the *PECS*.

When testing components or sub-assemblies separately, the temperature during the dry-heat test shall be chosen as to simulate actual use in the end-product. The component or sub-assembly shall be energized simulating the same conditions as in the end-product.

Table 30 shows the standard tests to be performed for the different environmental conditions.

Compliance is shown by conducting test of 5.2.6.3, 5.2.6.4, 5.2.6.5 and 5.2.6.6 according to Table 30 as applicable for the environmental conditions specified by the manufacture.

Where the *PECS* is required to operate in conditions outside the range of values given in this standard, then the test conditions shall be agreed on between the supplier and the customer, as defined in the particular individual enquiry or purchasing specification. In any case the test requirements shall not be less demanding than the operating conditions specified.

Table 30 – Environmental tests

Test condition	Indoor conditioned IEC 60721-3-3	Indoor unconditioned IEC 60721-3-3	Outdoor unconditioned IEC 60721-3-4
Climatic	Dry heat (see 5.2.6.3.1) Damp heat (see 5.2.6.3.2)	Dry heat (see 5.2.6.3.1) Damp heat (see 5.2.6.3.2)	Dry heat (see 5.2.6.3.1) Damp heat (see 5.2.6.3.2)
Chemically active substances	**No test requirement**	**No test requirement**	**Test Kb of IEC 60068-2-52** Salt mist [a] (see 5.2.6.5)
Mechanically active substances	**No test requirement**	**No test requirement**	**Test Lc of IEC 60068-2-68** Dust and sand (see 5.2.6.6)
Mechanical	**Test Fc of IEC 60068-2-6** Vibration (see 5.2.6.4)	**Test Fc of IEC 60068-2-6** Vibration (see 5.2.6.4)	**Test Fc of IEC 60068-2-6** Vibration (see 5.2.6.4)
Biological	**No test requirement**	**No test requirement**	**No test requirement**

[a] Refer to Footnote [a] in Table 18.

When special environmental conditions are specified, additional tests (e.g. for chemically active substances) shall be considered.

5.2.6.2 Acceptance criteria

The following acceptance criteria shall be satisfied:

- no degradation of any safety-relevant component of the *PECS;*
- no potentially hazardous behaviour of the *PECS* during the test;
- no sign of component overheating;
- no *hazardous live part* greater than *As* shall become accessible;
- no cracks in the *enclosure* and no damaged or loose insulators;
- pass routine a.c. or d.c. voltage test 5.2.3.4;
- pass *protective equipotential bonding* impedance test 5.2.3.11.2;
- no potentially hazardous behaviour when the *PECS* is operated following the test.

5.2.6.3 Climatic tests

5.2.6.3.1 Dry heat test (steady state)

To prove the ability of components and equipment to be operated, transported or stored at high temperatures the dry heat (steady state) test shall be performed according to the conditions specified in Table 31.

Table 31 – Dry heat test (steady state)

Subject	Test conditions
Test reference	Test Bd of IEC 60068-2-2
Requirement reference	4.9
Preconditioning	According to 5.1.2 and 5.2.1
Operating conditions	Operating at rated conditions
Temperature	Temperature classification according to Table 18 or, for separate testing of components and sub-assemblies, according to 5.2.3.1 or manufacturer's specified maximum temperature, whichever is higher
Accuracy	± 2 °C (see IEC 60068-2-2)
Humidity	According to IEC 60068-2-2, Test Bd
Duration of exposure	(16 ± 1) h
Recovery procedure	
– Time	1 h minimum
– Climatic conditions	
– Temperature	15 °C to 35 °C
– Relative humidity	25 % to 75 %
– Barometric pressure	86 kPa to 106 kPa
– Power supply	Power supply unconnected

5.2.6.3.2 Damp heat test (steady state)

To prove the resistance to humidity, the *PECS* shall be subjected to a damp heat test (steady state) according to the conditions specified in Table 32.

Table 32 – Damp heat test (steady state)

Subject	Test conditions
Test reference	Test Cab of IEC 60068-2-78:2001
Requirement reference	4.9
Preconditioning	According to 5.1.2 and 5.2.1
Operating conditions	Power supply disconnected
Special precautions	Internal voltage sources may remain connected if the heat produced by them in the specimen is negligible
Temperature	Manufacturer's specified maximum temperature or, for separate testing of components and sub-assemblies, according to 5.2.3.1 , whichever is higher
Accuracy	± 2 °C (see Clause 5 of IEC 60068-2-78:2001)
Humidity	Manufacturer's specified maximum humidity
Accuracy	± 3 % (see Clause 5 of IEC 60068-2-78:2001)
Duration of exposure	4 days
Recovery procedure	
– Time	1 h minimum
– Climatic conditions	
– Temperature	15 °C to 35 °C
– Relative humidity	25 % to 75 %
– Barometric pressure	86 kPa to 106 kPa
– Power supply	Power supply disconnected
– Condensation	All external and internal condensation shall be removed by air flow prior to performing the a.c. or d.c. voltage test or re-connecting the *PEC* to a power supply

5.2.6.4 Vibration test (*type test*)

To verify the mechanical vibration strength the *PECS* in combination with its *installation* shall be evaluated by:

a) tests defined in this section according to the conditions specified in Table 33; or
b) calculation or simulation based on tests, as defined in this section, on a representative model of *PECS*.

For *PECS* with a mass more than 100 kg, this test may be performed on sub-assemblies.

NOTE For large equipment, the possibility of using a shock test as an alternative to a vibration test is under consideration.

Table 33 – Vibration test

Subject	Test conditions
Test reference	Test Fc of IEC 60068-2-6
Requirement reference	4.9
Preconditioning	According to 5.1.2 and 5.2.1
Conditions Motion Vibration amplitude/acceleration 10 Hz ≤ f ≤ 57 Hz 57 Hz < f ≤ 150 Hz Vibration duration Detail of mounting	Power supply unconnected Sinusoidal 0,075 mm amplitude 10 m/s^2 (1 g) 10 sweep cycles per axis on each of three mutually perpendicular axes According to manufacturer's specification
Where the manufacturer specifies vibration levels that are greater than those above, the higher levels shall be used for the test. The acceptance criteria shall not be changed. Where the environmental conditions are known to be lower product committees using this standard as a reference document might specify lower level or no vibration test according to this table. The acceptance criteria shall not be changed. NOTE Ths test is an accelerated test which means that the level is higher than indicated in Table 18.	

5.2.6.5 Salt mist test (*type test*)

To verify the resistance against salt mist, the *PECS* in combination with its *installation* shall be evaluated by tests defined in this section according to the conditions specified in Table 34.

For *PECS* with a mass more than 100 kg, this test may be performed on sub-assemblies.

Table 34 – Salt mist test

Subject	Test conditions
Test reference	Test Kb of IEC 60068-2-52
Requirement reference	Table 18
Preconditioning	According to 5.1.2 and 5.2.1
Conditions Severity level	Power supply unconnected Severity level 2
Where the manufacturer specifies salt mist levels that are greater than those above, the higher levels shall be used for the test. The acceptance criteria shall not be changed. Where the environmental conditions are known to be lower product committees using this standard as a reference document might specify lower level or no salt mist test according to this table. The acceptance criteria shall not be changed.	

5.2.6.6 Dust and sand test (*type test*)

To verify the mechanical strength against dust and sand the *PECS* in combination with its *installation* shall be evaluated by tests defined in this section under the conditions specified in Table 35.

For *PECS* with a mass more than 100 kg, this test may be performed on sub-assemblies.

Table 35 – Dust and sand test

Subject	Test conditions
Test reference	Test Lc1 of IEC 60068-2-68
Requirement reference	Table 18
Preconditioning	According to 5.1.2 and 5.2.1
Conditions Particle size Dust concentration Air velocity Air pressure in the specimen Test duration	Power supply unconnected Fine dust 2 g/m^3 5 m/s Air pressure in the specimen is that of the ambient air pressure 24 h
Where the manufacturer specifies dust and sand levels that are greater than those above, the higher levels shall be used for the test. The acceptance criteria shall not be changed. Where the environmental conditions are known to be lower product committees using this standard as a reference document might specify lower level or no dust and sand test according to this table. The acceptance criteria shall not be changed.	

5.2.7 Hydrostatic pressure test (*type test* and *routine test*)

For *type tests*, the pressure inside the cooling *system* of a liquid cooled *PECS* (see 4.7.2.3.3) shall be increased at a gradual rate until a pressure relief mechanism (if provided) operates, or until a pressure of twice the operating value or 1,5 times the maximum pressure rating of the *system* is achieved, whichever is the greater.

NOTE For the purpose of this test the coolant pump may be disabled.

For *routine tests*, the pressure shall be increased to the maximum pressure rating of the *system*.

The pressure shall be maintained for at least one minute.

There shall be no thermal, shock, or other hazard resulting from the test. There shall be no leakage of coolant or loss of pressure during the test, other than from a pressure relief mechanism during a *type test*.

After the hydrostatic pressure *type test* the *PECS* shall pass the a.c. or d.c. voltage test in 5.2.3.4.

6 Information and marking requirements

6.1 General

The purpose of this Clause 6 is to define the information necessary for the safe selection, installation and commissioning, operation, and maintenance of *PECS*. It is presented as Table 36, showing where the information shall be provided, followed by explanatory subclauses.

The requirements of Clause 6 apply to all *PECS*, unless otherwise stated.

Since any electrical equipment can be installed or operated in such a manner that hazardous conditions can occur, compliance with the design requirements of this standard does not by itself assure a safe *installation*. However, when equipment complying with those requirements is properly selected and correctly installed and operated, the hazards will be minimized.

All information shall be in an appropriate language, and documents shall have identification references. Drawing symbols shall conform to IEC 60417 or IEC 60617 as appropriate. Symbols not shown in IEC 60417 or IEC 60617 shall be identified where used.

NOTE Further guidance for the preparation of documentation is provided in IEC 61082-1, and for the preparation of instructions and manuals in IEC 62079.

Table 36 – Information requirements

Information	Subclause reference	Location [a, b]					Technical subclause reference
		1	2	3	4	5	
For selection	**6.2**						
Manufacturer's name or trademark	6.2	X	X	X	X	X	
Catalogue number	6.2	X	X	X	X	X	
Voltage rating	6.2	X		X	X	X	
Current / Power rating	6.2	X		X		X	
Power rating	6.2	X		X		X	
Frequency and numbers of phases	6.2	X		X		X	
Protective class (I, II or III)	6.2, 6.3.7.3	X		X		X	4.4.6, 4.4.4.3.2, 4.4.6.3
Type of electrical supply *system*	6.2; 6.3.7.2			X			6.3.7.2
Short circuit ratings	6.2			X			4.3
IP rating of *enclosure*	6.2	X		X		X	4.4.3.3, 4.12.1
Reference to standards	6.2			X			
Supply requirements for the load	6.2			X			
Coolant type and design pressure	6.2			X		X	4.7.2
Reference to instructions	6.2			X	X	X	
For installation and commissioning	**6.3**						
Dimensions (SI units)	6.3.2			X		X	
Mass (SI units)	6.3.2		X	X		X	
Mounting details (SI units)	6.3.2			X		X	
Operating and storage environments	6.3.3			X		X	4.9
Handling requirements	6.3.4		X	X		X	
Enclosures temperature	6.3.5			X		X	4.6.4.2, 4.6.3.1
Interconnection and wiring diagrams	6.3.6.2			X		X	
Cable requirements	6.3.6.3			X		X	4.11
Terminal details	6.3.6.4			X		X	4.11.8
Protection requirements	6.3.7			X		X	4.3
Acessible parts and circuits	6.3.7.1			X		X	4.4.3.3; 4.4.6.4.2
Touch current	6.3.7.4	X		X		X	4.4.4.3.3
Compatibility with RCD	6.3.7.5	X		X		X	4.4.8
Special requirements	6.3.7.6			X		X	
External protective devices	6.3.7.7			X		X	4.3.2, 4.3.3, 5.2.4
Commissioning information	6.3.8			X			
For use	**6.4**						
General	6.4.1				X		
Adjustment	6.4.2			X	X	X	
Labels, signs and signals	6.4.3	X		X	X	X	

Information	Subclause reference	Location [a, b]					Technical subclause reference
		1	2	3	4	5	
For maintenance	**6.5**						
Date code or serial number	6.5.1	X					
Maintenance procedures	6.5.1					X	4.4.3.3
Maintenance schedules	6.5.1				X	X	
Sub-assembly and component locations	6.5.1					X	
Repair and replacement procedures	6.5.1					X	
Adjustment procedures	6.5.1			X	X	X	
Special tools list	6.5.1			X		X	
Capacitor discharge	6.5.2	X		X		X	4.4.3.4
Auto restart/bypass	6.5.3			X	X	X	
Other hazards	6.5.4	X		X		X	

[a] Location: 1. On product (see 6.4.3); 2. On packaging; 3. In installation manual; 4. In user's manual; 5. In maintenance manual.

[b] The installation, user's and maintenance manuals may be combined as appropriate and, if acceptable to the customer, may be supplied in electronic format. When more than one of any product is supplied to a single customer, it is not necessary to supply a manual with each unit, if acceptable to the customer.

6.2 Information for selection

Each part of a *PECS* that is supplied as a separate product shall be provided with information relating to its function, electrical characteristics, and intended environment, so that its fitness for purpose and compatibility with other parts of the *PECS* can be determined. This information includes, but is not limited to:

- the name or trademark of the manufacturer, supplier or importer;
- catalogue number or equivalent;
- electrical ratings for each power *port*:
  - maximum nominal input voltage;
  - maximum nominal output voltage;
  - maximum nominal output current or nominal output power rating;
  - maximum nominal input current rms for dimensioning overload protective elements and wiring;
  - number of phases (e.g. 3 a.c.);
  - nominal frequency range; (e.g. 50-60Hz) protective class (I, II, III);
- the type of electrical supply *system* (e.g. TN, IT, etc.) to which the *PECS* may be connected;
- *prospective short circuit current* rating(s) in accordance with 4.3.2.2 and 5.2.4.4;
- *output short circuit current* accordance with 4.3.2.3;
- protective device characteristics, in accordance with 4.3.2 and 5.2.4.4;
- supply requirements of the load (if applicable);
- liquid coolant type and design pressure for liquid cooled *PECS*;
- IP rating for *enclosure*;
- operating and storage environment;
- reference(s) to relevant standard(s) for manufacture, test, or use;
- reference to instructions for installation, use and maintenance.

The information shall be limited to that which is essential for correct selection to be made, and should relate to specific equipment. If information covers a number of product variants, it shall be readily possible to distinguish between them.

6.3 Information for installation and commissioning

6.3.1 General

Safe and reliable installation is the responsibility of the installer, machine builder, and/or user. The manufacturer of any part of the *PECS* shall provide information to support this task. This information shall be unambiguous, and may be in diagrammatic form.

6.3.2 Mechanical considerations

The following drawings shall be prepared by the manufacturer:

- dimensional drawing, including mass information;
- mounting drawing.

Dimensions, mass, etc., shall be in SI units.

6.3.3 Environment

In accordance with 4.9 the following environmental conditions shall be specified, for operation, transportation and storage:

- climatic (temperature, humidity, altitude, pollution, ultra-violet light, etc.);
- mechanical (vibration, shock, drop, topple, etc.);
- electrical (overvoltage category).

NOTE Environmental categories as specified in IEC 60721 may be used where appropriate.

6.3.4 Handling and mounting

In order to prevent injury or damage, the installation documents shall include warnings of any hazards which can be experienced during installation. Where necessary, instructions shall be provided for:

- packing and unpacking;
- moving;
- lifting;
- strength and rigidity of mounting surface;
- fastening;
- provision of adequate access for operation, adjustment and maintenance.

6.3.5 *Enclosure* temperature

When surface temperatures of the *PECS,* close to mounting surfaces, exceed the limit of 4.6.4.2 , the installation manual shall contain a warning to consider the combustibility of the mounting surface.

Where required by 4.6.3.1, the following marking shall appear on the *PECS* and in the installation instructions: “suitable for mounting on concrete or other non-combustible surfaces only”.

6.3.6 Connections

6.3.6.1 General

Information shall be provided to enable the installer to make safe electrical connection to the *PECS*. This shall include information for protection against hazards (for example, electric shock or availability of energy) that may be encountered during installation, operation or maintenance.

6.3.6.2 Interconnection and wiring diagrams

The installation and maintenance manuals shall include details of all necessary connections, together with a suggested interconnection diagram.

6.3.6.3 Conductor (cable) selection

The installation manual shall define the voltage and current levels for all connections to the *PECS*, together with cable *insulation* requirements. These shall be worst-case values, taking into account short circuit and overload conditions and the possible effects of non-sinusoidal currents.

6.3.6.4 Terminal capacity and identification

The installation and maintenance manuals shall indicate the range of acceptable conductor sizes and types (solid or stranded) for all terminals, and also the maximum number of conductors which can simultaneously be connected.

For *field wiring terminals*, the manuals shall specify the requirements for tightening torque values and also the *insulation* temperature rating requirements for the conductor or cable.

The identification of all *field wiring terminals* shall be marked on the *PECS*, either directly or by a label attached close to the terminals.

The installation and maintenance manuals shall identify all external terminals relating to circuits protected by one of the methods of 4.4.6.4.

6.3.7 Protection requirements

6.3.7.1 Accessible parts and circuits

The installation and maintenance manuals shall identify any accessible parts at voltages greater than *DVC As*, and shall describe the *insulation* and separation provisions required for protection.

The manuals shall also indicate the precautions to be taken to ensure that the safety of *DVC As* connections is maintained during installation.

Where a hazard is present after the removal of a cover, a warning label shall be placed on the equipment. The label shall be visible before the cover is removed.

The manual of a *PECS* shall state the maximum voltage allowed to be connected to each *port*.

The manuals shall provide instructions for the use of *PELV circuits* within a *zone of equipotential bonding*.

6.3.7.2 Type of electrical supply *system*

The installation manual of the *PECS* shall specify requirements for safe earthing including the permitted earthing *system* of the *installation* (see 4.4.7.1.4).

The unacceptable earthing *system*s shall be indicated as:

- not permitted; or
- with modification of values and/or safety levels which shall be quantified through *type test.*

6.3.7.3 Protective class

6.3.7.3.1 General

The installation manual of the *PECS* shall declare the protective class specified for the *PECS* and the product shall be marked according to the requirement of 6.3.7.3.2, 6.3.7.3.3, and 6.3.7.3.4.

6.3.7.3.2 *Protective class I* equipment

Terminals for connection of the *PE conductor* shall be clearly and indelibly marked with one or more of the following:

- the symbol IEC 60417-5019 (2011-01) (see Annex C); or
- with the letters PE; or
- the colour coding green or green-yellow.

6.3.7.3.3 *Protective class II* equipment

Equipment of *protective class II* shall be marked with symbol IEC 60417-5172 (2011-01) (see Annex C). Where such equipment has provision for the connection of an earthing conductor for functional reasons (see 4.4.6.3) it shall be marked with symbol IEC 60417-5018 (2011-01) (see Annex C).

6.3.7.3.4 *Protective class III* equipment

No marking is required on the product.

6.3.7.4 *Touch current* marking

Where the *touch current* in the *PE conductor* exceeds the limits given in 4.4.4.3.3., this shall be stated in the installation and maintenance manuals. In addition, a warning symbol ISO 7010-W001 (2011-06) (see Annex C) shall be placed on the product, and a notice shall be provided in the installation manual to instruct the user that the minimum size of the *PE conductor* shall comply with the local safety regulations for high *PE conductor* current equipment.

6.3.7.5 Compatibility with RCD marking

The installation and maintenance manuals shall indicate compatibility with RCDs (see 4.4.8). When 4.4.8 b) applies, a caution notice and the symbol ISO 7010-W001 (2011-06) (see Annex C) shall be provided in the user manual, and the symbol shall be placed on the product. The caution notice shall be the following or equivalent: *"This product can cause a d.c. current in the PE conductor. Where a residual current-operated protective device (RCD) is used for protection against electrical shock, only an RCD of Type B is allowed on the supply side of this product."* (See 6.4.3 for general requirements for labels, signs and signals.)

6.3.7.6 Cable and connection

Any particular cable and connection requirements shall be identified in the installation and maintenance manuals.

6.3.7.7 External protection devices

Where external protective devices are necessary to protect against hazards, the installation and maintenance manual shall specify the required characteristics (see also 5.2.4 and 4.3.2.1).

6.3.8 Commissioning

If *commissioning tests* are necessary to ensure the electrical and thermal safety of a *PECS*, information to support these tests shall be provided for each part of the *PECS*. This information can depend on the specific *installation*, and close cooperation between manufacturer, installer, and user can be required.

Commissioning information shall include references to hazards that might be encountered during commissioning, for example those mentioned in 6.4 and 6.5.

6.4 Information for use

6.4.1 General

The user's manual shall include all information regarding the safe operation of the *PECS*. In particular, it shall identify any hazardous materials and risks of electric shock, overheating, explosion, excessive acoustic noise, etc.

The manual should also indicate any hazards which can result from reasonably foreseeable misuse of the *PECS*.

6.4.2 Adjustment

The user's manual shall give details of all safety-relevant adjustments intended for the user. The identification or function of each control or indicating device and overcurrent protective devices shall be marked adjacent to the item. Where it is not possible to do this on the product, the information shall be provided pictorially in the manual.

Maintenance adjustments may also be described in this manual, but it shall be made clear that they should only be made by qualified personnel.

Clear warnings shall be provided where excessive adjustment could lead to a hazardous state of the *PECS*.

Any special equipment necessary for making adjustments shall be specified and described.

6.4.3 Labels, signs and signals

6.4.3.1 General

Labelling shall be in accordance with good ergonomic principles so that notices, controls, indications, test facilities, overcurrent protective devices, etc., are sensibly placed and logically grouped to facilitate correct and unambiguous identification.

All safety related equipment labels shall be located so as to be visible after installation or readily visible by opening a door or removing a cover.

Where a symbol is used, the information provided with the *PECS* shall contain an explanation of the symbol and its meaning.

Labels shall:

- wherever possible, use international symbols as given by ISO 3864-1, ISO 7000 or IEC 60417;
- if no international symbol is available, be worded in an appropriate language or in a language associated with a particular technical field;
- be conspicuous, legible and durable;
- be concise and unambiguous;
- state the hazards involved and give ways in which risks can be reduced.

When instructing the person(s) concerned as to

- what to avoid: the wording should include “no”, “do not”, or “prohibited”;
- what to do: the wording should include “shall”, or “must”;
- the nature of the hazard: the wording should include “caution”, “warning”, or “danger”, as appropriate;
- the nature of safe conditions: the wording should include the noun appropriate to the safety device.

Safety signs shall comply with ISO 3864-1.

The signal words indicated hereinafter shall be used and the following hierarchy respected:

- DANGER to call attention to a high risk, for example: “High voltage”.
- WARNING to call attention to a medium risk, for example: “This surface can be hot.”
- CAUTION to call attention to a low risk, for example: “Some of the tests specified in this standard involve the use of processes imposing risks on persons concerned.”

Danger, warning and caution markings on the *PECS* shall be prefixed with the word “DANGER”, “WARNING”, or “CAUTION” as appropriate in letters not less than 3,2 mm high. The remaining letters of such markings shall be not less than 1,6 mm high.

6.4.3.2 Isolators

Where an isolating device is not intended to interrupt load current, a warning shall state:

DO NOT OPEN UNDER LOAD.

The following requirements apply to any supply isolating device which does not disconnect all sources of power to the *PECS*.

- If the isolating device is mounted in an equipment *enclosure* with the operating handle externally operable, a warning label shall be provided adjacent to the operating handle stating that it does not disconnect all power to the *PECS*.
- Where a control circuit disconnector can be confused with power circuit disconnectors due to size or location, a warning label shall be provided adjacent to the operating handle of the control circuit disconnector stating that it does not disconnect all power to the *PECS*.

6.4.3.3 Visual and audible signals

Visual signals such as flashing lights, and audible signals such as sirens, may be used to warn of an impending hazardous event such as the driven equipment start-up and shall be identified.

It is essential that these signals:

- are unambiguous;
- can be clearly perceived and differentiated from all other signals used;
- can be clearly recognized by the user;
- are emitted before the occurrence of the hazardous event.

It is recommended that higher frequency flashing lights be used for higher priority information.

NOTE IEC 60073 provides guidance on recommended flashing rates and on/off ratios.

6.4.3.4 Hot surfaces

Where required by 4.6.4.2 the warning symbol ISO 7010-W017 (2011-06) (see Annex C) shall be marked on or adjacent to parts exceeding the touch temperature limits of Table 15.

6.4.3.5 Control and device marking

The identification of each control or indicating device and overcurrent protective devices shall be marked adjacent to the item. Replaceable overcurrent protective devices shall be marked with their rating and time characteristics. Where it is not possible to do this on the product, the information shall be provided pictorially in the manual.

Appropriate identification shall be marked on or adjacent to each movable connector.

Test points shall be individually marked with the circuit diagram reference.

The polarity of any polarized devices shall be marked adjacent to the device.

The diagram reference and if possible the function shall be marked adjacent to each pre-set control in a position where it is clearly visible while the adjustment is being made.

6.5 Information for maintenance

6.5.1 General

The *PECS* shall be marked with the date code, or serial number from which the date of manufacture can be determined.

Safety information shall be provided in the installation and maintenance manuals including, as appropriate, the following:

- preventive maintenance procedures and schedules;
- safety precautions during maintenance;
- location of *live parts* that can be accessible during maintenance (for example, when covers are removed);
- adjustment procedures;
- sub-assembly and component repair and replacement procedures;
- any other relevant information.

NOTE 1 These can best be presented as diagrams.

NOTE 2 A list of special tools can be provided, when appropriate.

6.5.2 Capacitor discharge

When the requirements in 4.4.3.4 are not met, the warning symbol ISO 7010-W012 (2011-06) (see Annex C) and an indication of the minimum discharge time required for discharge under worst conditions (for example, discharge time 5 min) shall be placed in a clearly visible position on the *enclosure*, the capacitor protective barrier, or at a point close to the capacitor(s) concerned (depending on the construction). The symbol shall be explained and the time required for the capacitors to discharge after the removal of power from the *PECS* shall be stated in the installation and maintenance manuals.

NOTE The value of the discharge time declared by the manufacturer may cover a range of *PECS* taking into account the relevant tolerances for the complete range of *PECS*.

6.5.3 Auto restart/bypass connection

If a *PECS* can be configured to provide automatic restart or bypass connection, the installation, user and maintenance manuals shall contain appropriate warning statements.

A *PECS* which is set to provide automatic restart or bypass connection, after the removal of power, shall be clearly identified at the *installation*.

6.5.4 Other hazards

The manufacturer shall identify, on the product, in the installation and maintenance manuals, as applicable, any components and materials of a *PECS* which require special procedures to prevent hazards on the product.

6.5.5 Equipment with multiple sources of supply

In accordance with 4.8, where there is more than one source of supply energizing the *PECS*, information shall be provided to indicate which disconnect device or devices are required to be operated in order to completely isolate the equipment.

Annex A
(normative)

Additional information for protection against electric shock

A.1 General

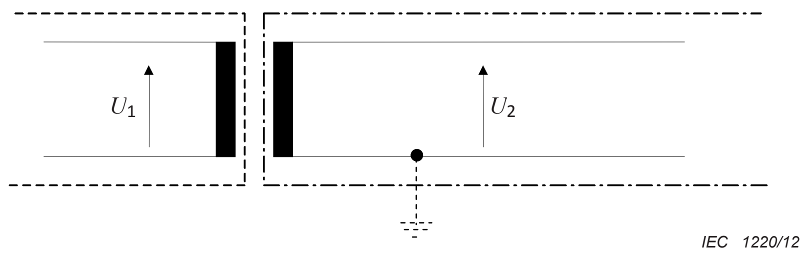
Figure A.1 to Figure A.3 show examples of the methods used for protection against electric shock in *protective class III* equipment and circuits (see 4.4.6.4).

- - - - - - - - - - - - - - - - - - - *Basic protection*

–·–·–·–·–·–·–·–·– *Protective separation* from circuits requiring *basic protection*

A.2 Protection by means of *DVC As*

(see 4.4.2.2)



Key

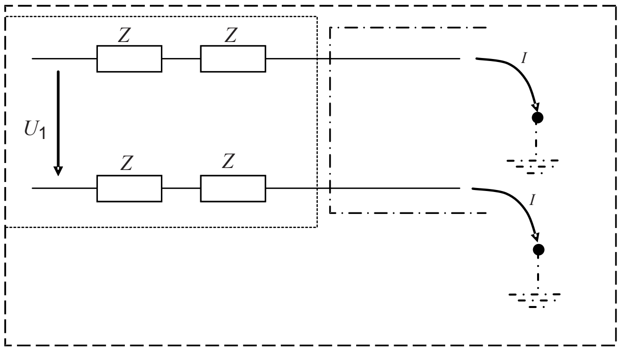
U_1: hazardous voltage, earthed or unearthed

U_2: ≤ *DVC As* from Table 5

Figure A.1 – Protection by *DVC As* with *protective separation*

A.3 Protection by means of *protective impedance*

(see 4.4.5.4)



Key

Z resistor

U_1 hazardous voltage, earthed or unearthed

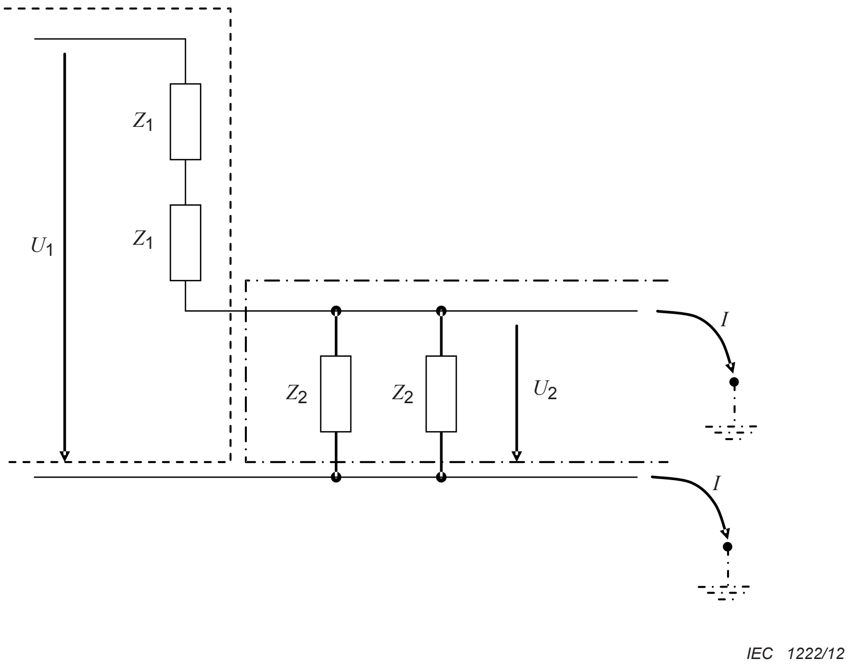
$I \leq$ 3,5 mA a.c., 10 mA d.c.

NOTE To provide protection in single-fault conditions, use the following equation $I = \frac{U_1}{Z}$

Figure A.2 – Protection by means of *protective impedance*

A.4 Protection by using limited voltages

(see 4.4.5.4)



Key

Z: resistor

U_1: hazardous voltage, earthed

$U_2 \leq$ *DVC As* from Table 5.

NOTE To provide protection in single-fault conditions, use equations: $U_2 = \frac{U_1 Z_2}{2Z_1 + Z_2}$ or. $U_2 = \frac{U_1 Z_2}{2(Z_1 + Z_2/2)}$

Figure A.3 – Protection by using limited voltages

A.5 Evaluation of *working voltage* and selection of *DVC* for touch voltage, *PELV* and *SELV* circuits

A.5.1 General

In A.4, the selection of *DVC* for touch voltage and for *PELV* and *SELV* circuit is possible depending on the different body reactions:

- *Ventricular fibrillation* (AC4 / DC4 ofIEC 60479-1)
- *Muscular reaction (inability to let go)* (AC3 / DC3 of IEC 60479-1)
- *Startle reaction* (AC2 / DC2 of IEC 60479-1)

NOTE Both “inability to let go reaction” or “muscular reaction” from IEC/TR 60479-5 are related to the same body reaction.

in combination with the following humidity body skin conditions:

- dry;
- water wet;
- saltwater wet;

and in combination with the following surface areas for contact of the touch voltages:

- part of the body (nearly 500 cm^2);
- hand (nearly 80 cm^2);
- finger tip (nearly 1 cm^2);

The *DVC* for touch voltage, as suggested in the Tables A.1, A.2 and A.3, depends on:

- the body reaction (one table for each body reaction);
- the body contact area;
- the skin condition.

Data are given for the design of equipment which possibly includes more than one circuit.

Conditions for selection of *DVC* for *PELV* & *SELV* circuits are given in 4.4.6.4.2.

For a dedicated body reaction, the *DVC* decreases:

- coming from a small contact area to a large contact area;
- coming from the dry skin condition to the saltwater wet skin condition.

Under a dedicated body contact area and a dedicated body skin humidity condition, the *DVC* decreases coming from a strong body reaction (*ventricular fibrillation*) to a light body reaction (*startle reaction*).

Some combinations of a body contact area and a body skin humidity condition do not allow defining any possible *DVC* for the prevention of a dedicated body reaction. For these combinations, *basic protection* is required.

A.5.2 Selection of DVC for touch voltage sets to protect against *ventricular fibrillation*

Table A.1 – Selection of touch voltage sets to protect against *ventricular fibrillation*

Body skin humidity condition	Body contact area		
	Part of the body	Hand	Finger tip
Dry	*DVC A2*	*DVC A*	*DVC B*
Water wet	*DVC A1*	*DVC A2*	*DVC A*
Saltwater wet	*Basic protection* against accessibility is required	*DVC A1*	*DVC A2*

NOTE Table A.1 is identical to Table 2.

A.5.3 Selection of DVC for touch voltage sets to protect against *muscular reaction*

Table A.2 – Selection of touch voltage sets to protect against *muscular reaction*

Body skin humidity condition	Body contact area		
	Part of the body	Hand	Finger tip
Dry	*Basic protection* against accessibility is required	*DVC A2*	*DVC A*
Water wet	*Basic protection* against accessibility is required	*DVC A1*	*DVC A2*
Saltwater wet	*Basic protection* against accessibility is required	*Basic protection* against accessibility is required	*DVC A1*

A.5.4 Selection of DVC for touch voltage sets to protect against *startle reaction*

Table A.3 – Selection of touch voltage sets to protect against *startle reaction*

Body skin humidity condition	Body contact area		
	Part of the body	Hand	Finger tip
Dry	*Basic protection* against accessibility is required	*Basic protection* against accessibility is required	*DVC A2*
Water wet	*Basic protection* against accessibility is required	*Basic protection* against accessibility is required	*DVC A1*
Saltwater wet	*Basic protection* against accessibility is required	*Basic protection* against accessibility is required	*Basic protection* against accessibility is required

A.5.5 Determination of voltage limits for touch voltage under fault condition depending on *protective equipotential bonding* impedance

The evaluation of the *protective equipotential bonding* impedance in 4.4.4.2.2 shall be done by using the following figures. The maximum touch voltages values under fault allowed are depending on reaction of the body, environmental condition and part of the body in contact.

The curves are provided with a current path way from hand to the contact area of the body with the person standing up.

The short-term non-recurring touch voltage limits are given in A.5.6 to A.5.8.

A.5.6 Touch time-d.c. voltage zones of *ventricular fibrillation*

Figures A.4, A.5 and A.6 provide information on the short term non-recurring d.c. touch voltage limits for protection against *ventricular fibrillation*.

The figures provide information for acceptable level for part of the body, hand and finger tip under dry, water-wet and salt water wet conditions.

For some combinations no information for time-voltage zone is given and *basic protection* against accessibility is required.

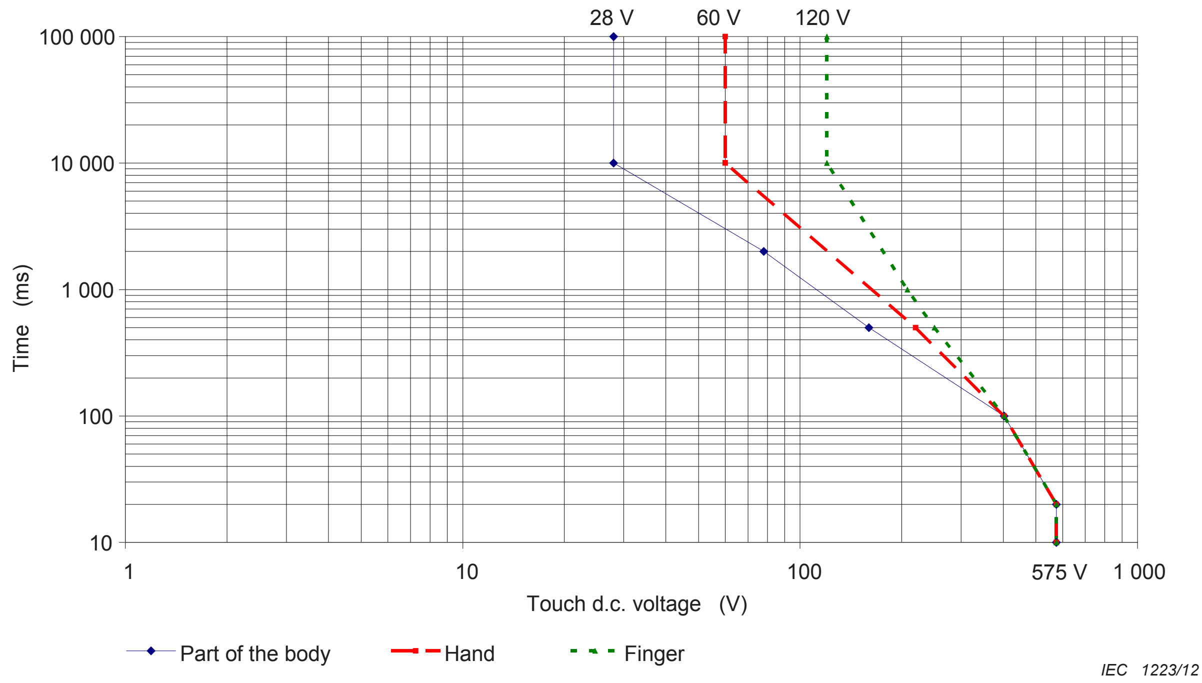


Figure A.4 – Touch time- d.c. voltage zones for dry skin condition

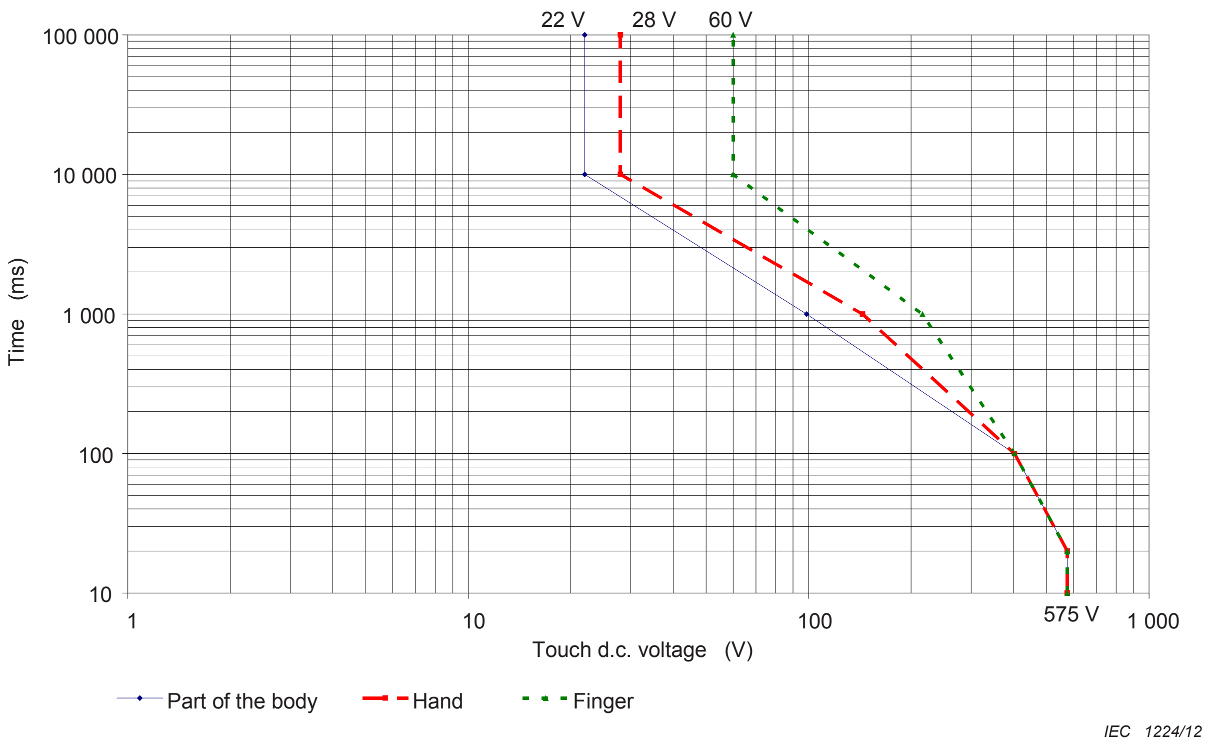


Figure A.5 – Touch time- d.c. voltage zones for water-wet skin condition

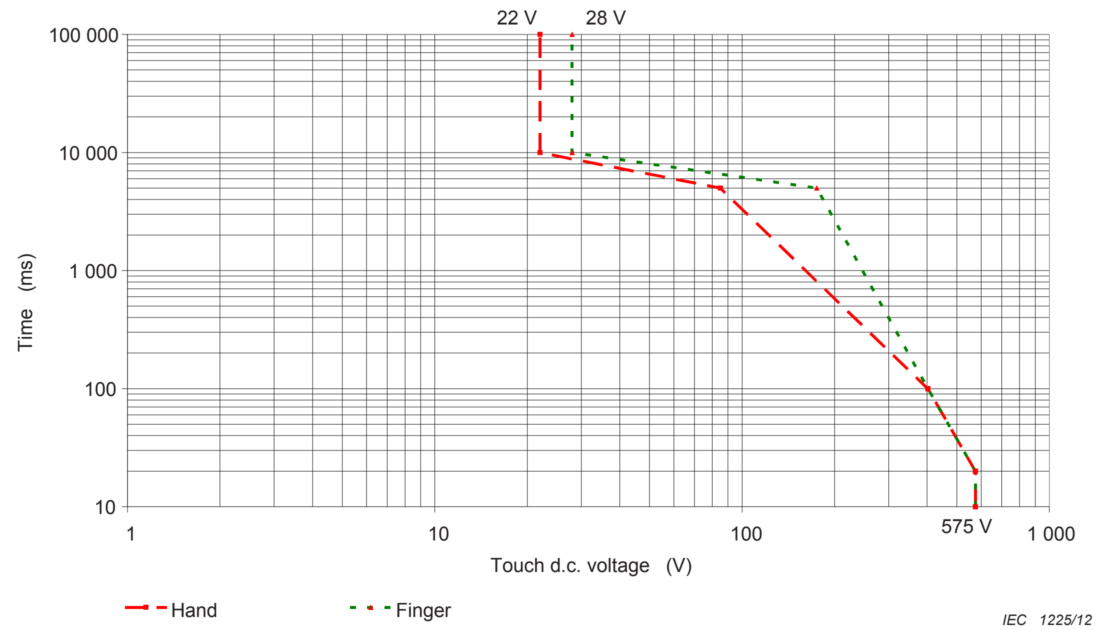


Figure A.6 – Touch time- d.c. voltage for saltwater-wet skin condition

NOTE Figures A.4 to A.6 are identical to Figures 1 to 3.

A.5.7 Touch time- d.c. voltage zones of *muscular reaction (inability to let go reaction)*

Figures A.7, A.8 and A.9 provide information on the short term non-recurring d.c. touch voltage limits for protection against *muscular reaction*.

The figures provide information for acceptable level for part of the body, hand and finger tip under dry, water-wet and salt water wet conditions.

For some combinations no information for time-voltage zone is given and *basic protection* against accessibility is required.

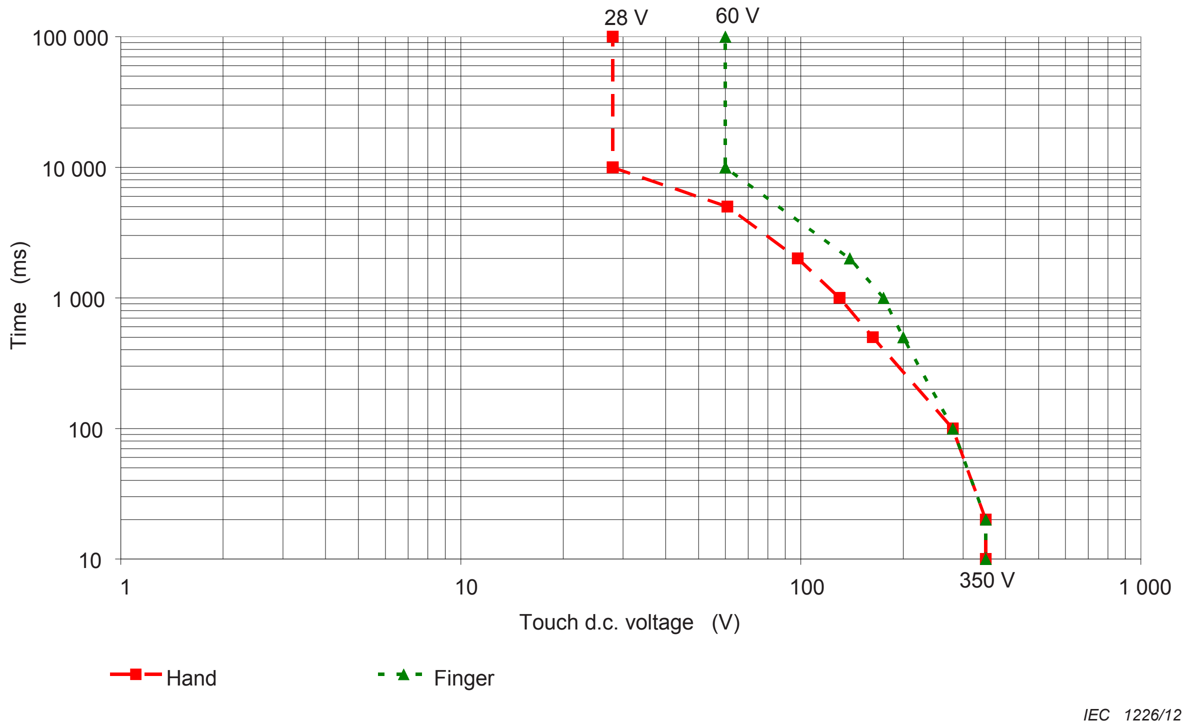


Figure A.7 – Touch time- d.c. voltage zones of dry skin condition

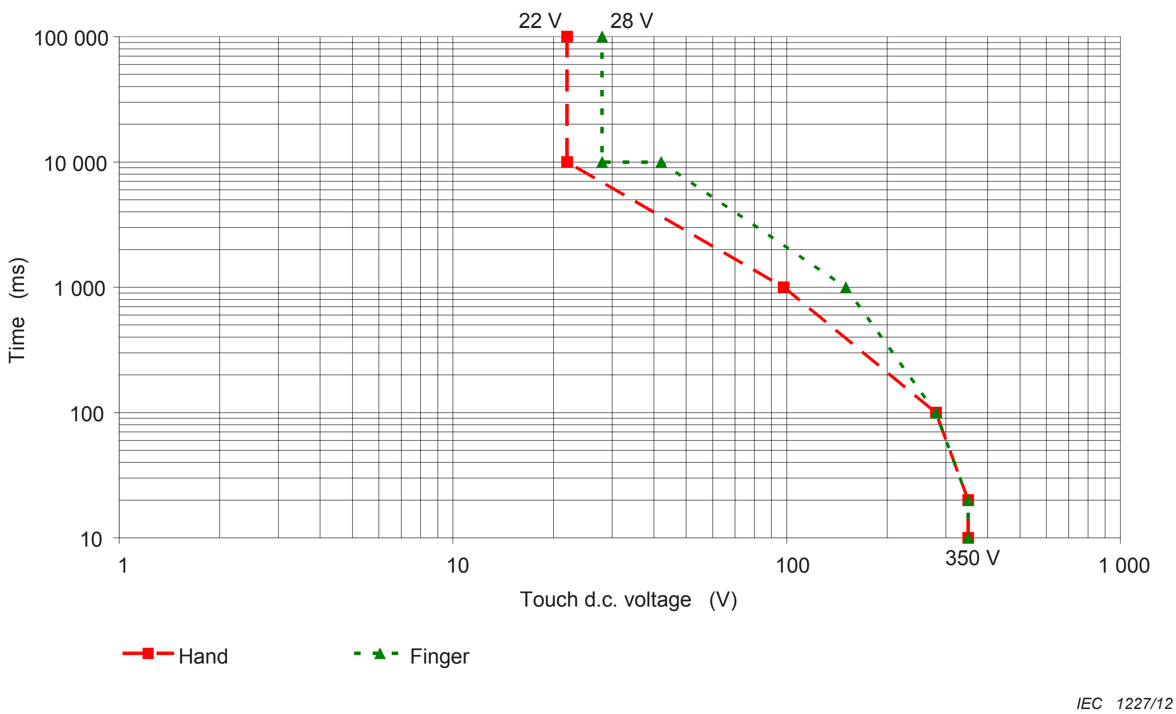


Figure A.8 – Touch time- d.c. voltage zones of water-wet skin condition

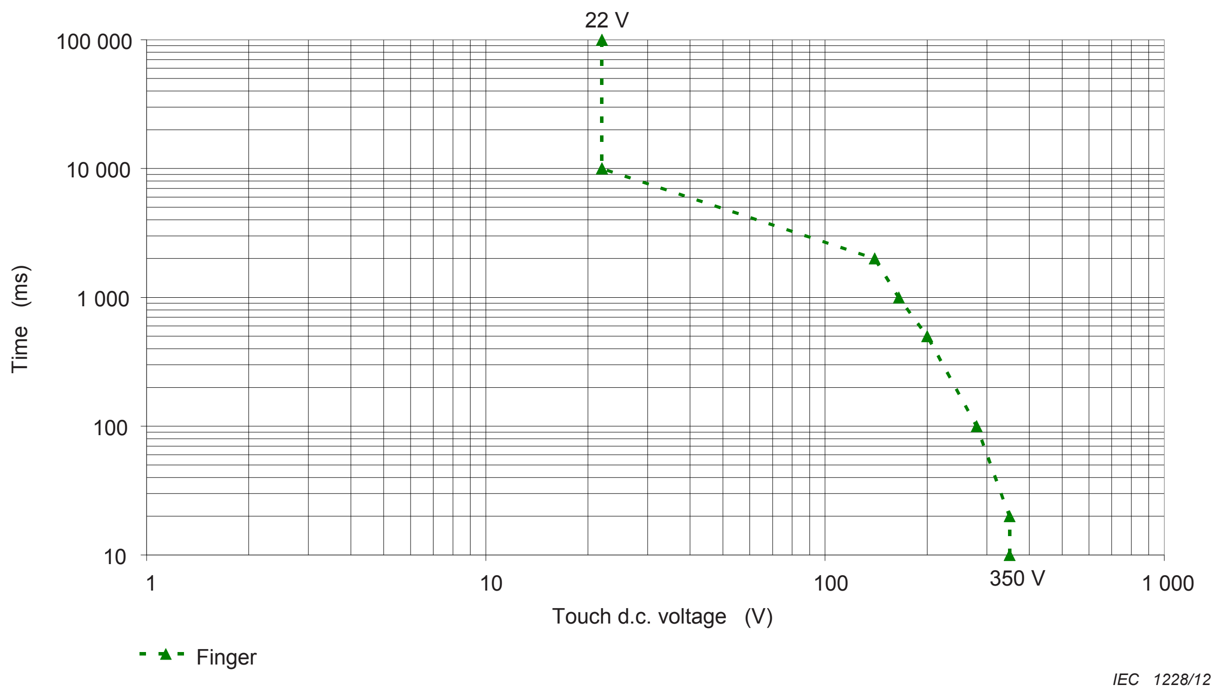


Figure A.9 – Touch time- d.c. voltage zones of saltwater-wet skin condition

A.5.8 Touch time- d.c. voltage zones for *startle reaction*

Figures A.10 and A.11 provide information on the short term non-recurring d.c. touch voltage limits for protection against *startle reaction*.

The figures provide information for acceptable level for part of the body, hand and finger tip under dry, water-wet and salt water wet conditions.

For some combinations no information for time-voltage zone is given and *basic protection* against accessibility is required.

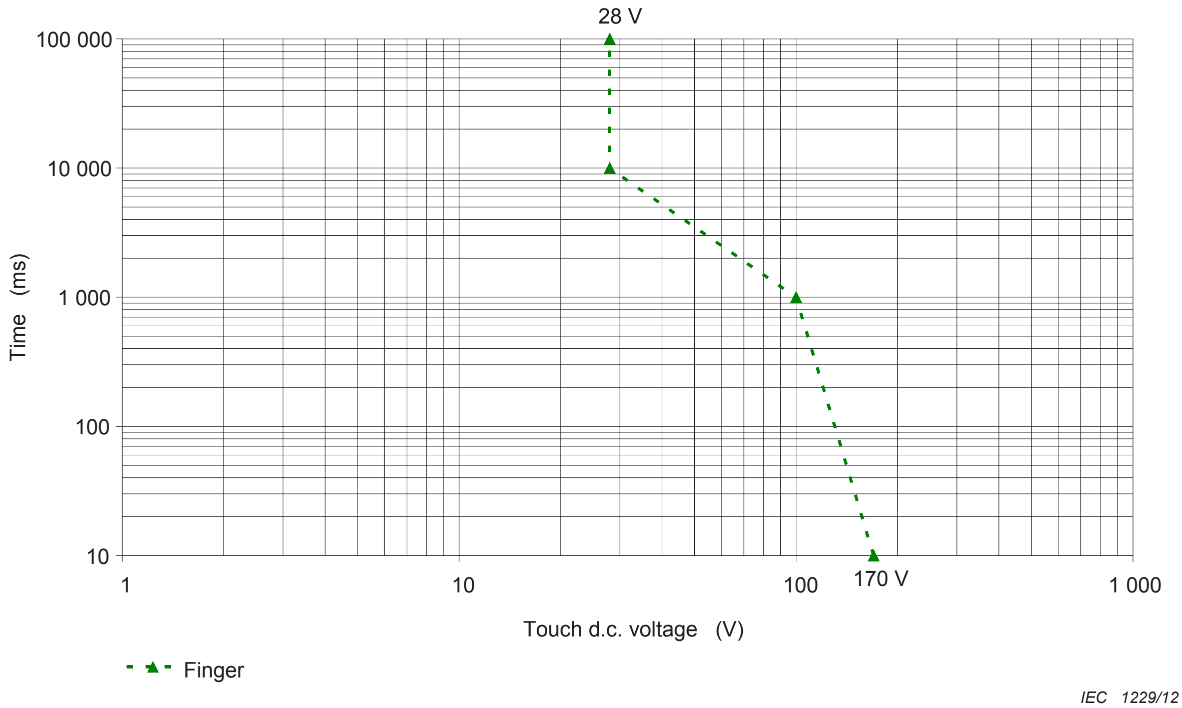


Figure A.10 – Touch time- d.c. voltage zones of dry skin condition

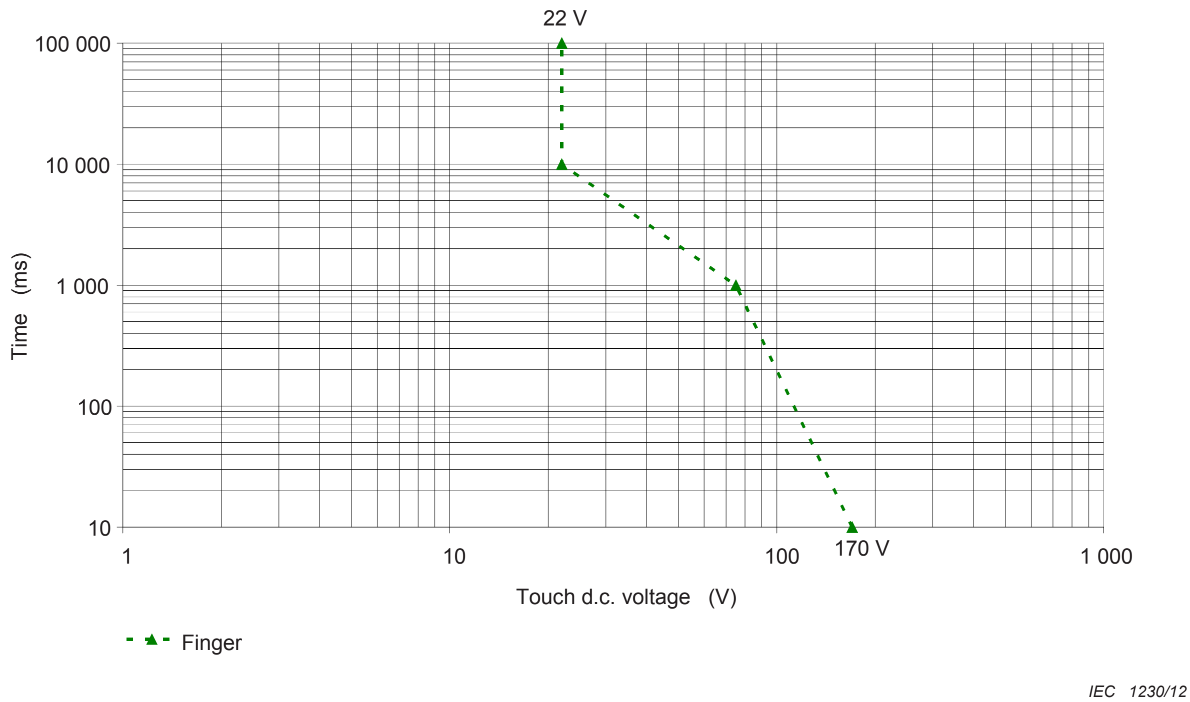


Figure A.11 – Touch time- d.c. voltage zones of water-wet skin condition

A.5.9 Touch time-a.c. voltage zones of *ventricular fibrillation*

Figures A.12, A.13 and A.14 provide information about the short term non-recurring a.c. touch voltage limits for protection against ventricular fibrilation.

The figures provide information for acceptable level for part of the body, hand and finger tip under dry, water-wet and salt water wet conditions.

For some combinations no information for time-voltage zone is given and *basic protection* against accessibility is required.

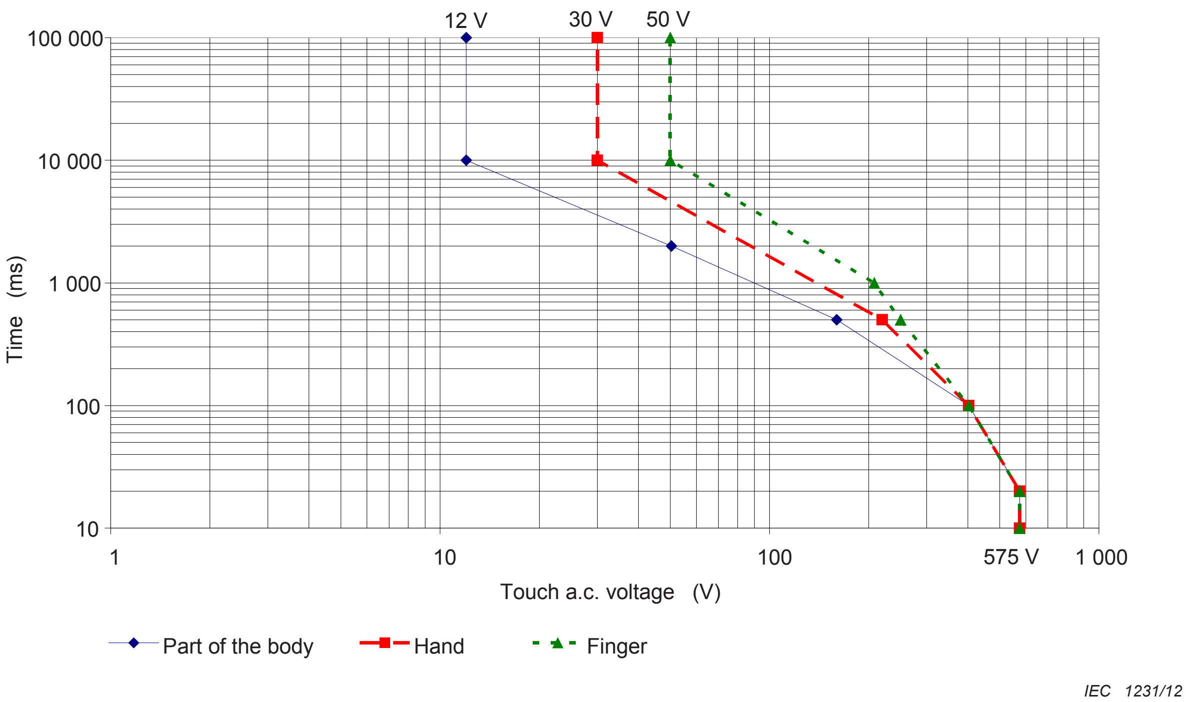


Figure A.12 – Touch time- a.c. voltage zones for dry skin condition

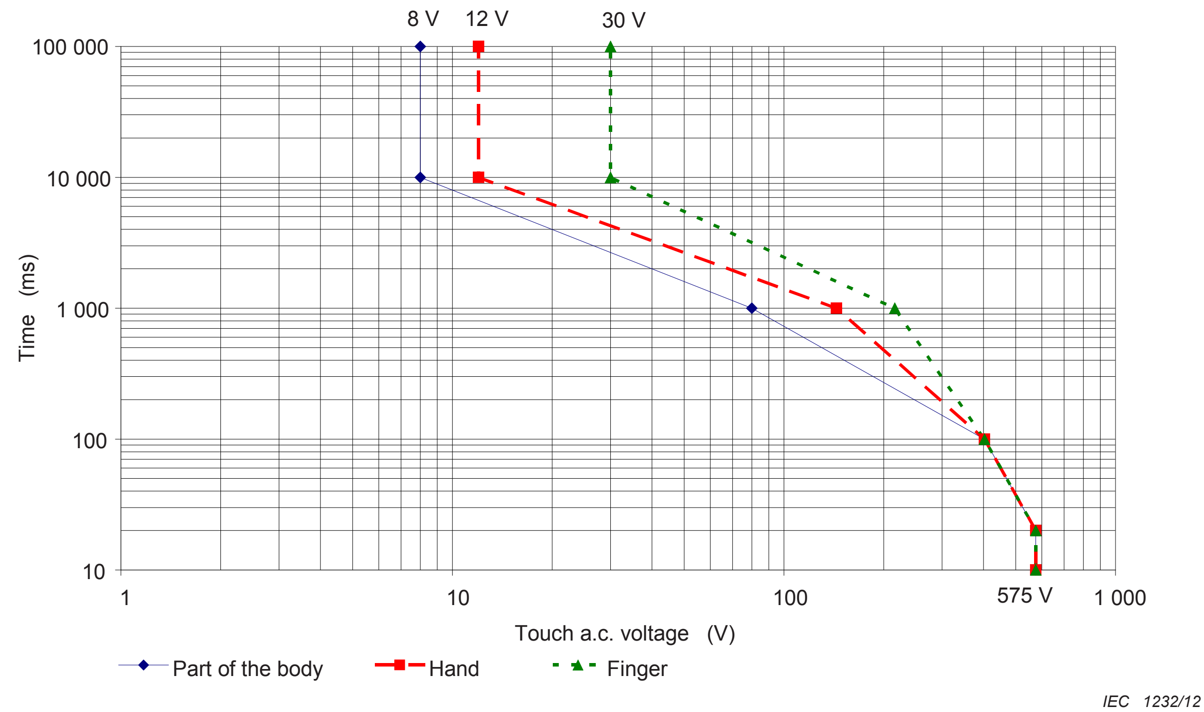


Figure A.13 – Touch time- a.c. voltage zones of water-wet skin condition

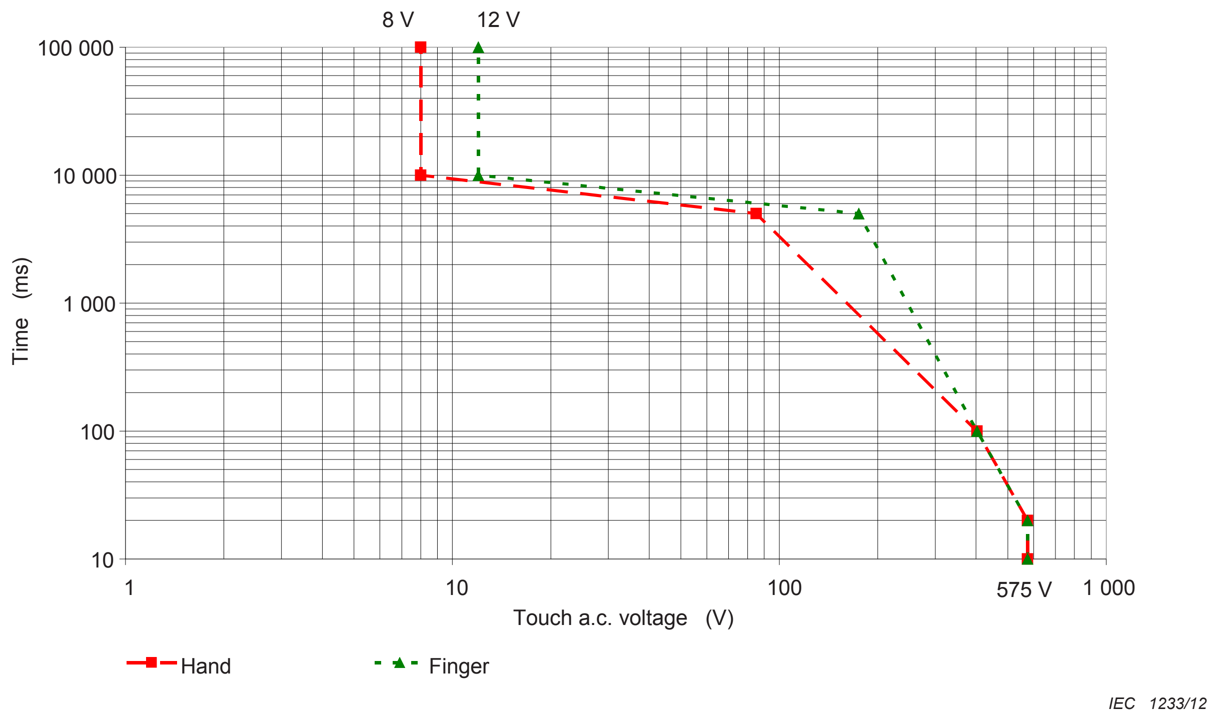


Figure A.14 – Touch time- a.c. voltage of saltwater-wet skin condition

A.5.10 Touch time- a.c. voltage zones of *muscular reaction (inability to let go reaction)*

Figures A.15, A.16 and A.17 provide information about the short term non-recurring a.c. touch voltage limits for protection against *muscular reaction*.

The figures provide information for acceptable level for part of the body, hand and finger tip under dry, water-wet and salt water wet conditions.

For some combinations no information for time-voltage zone is given and *basic protection* against accessibility is required.

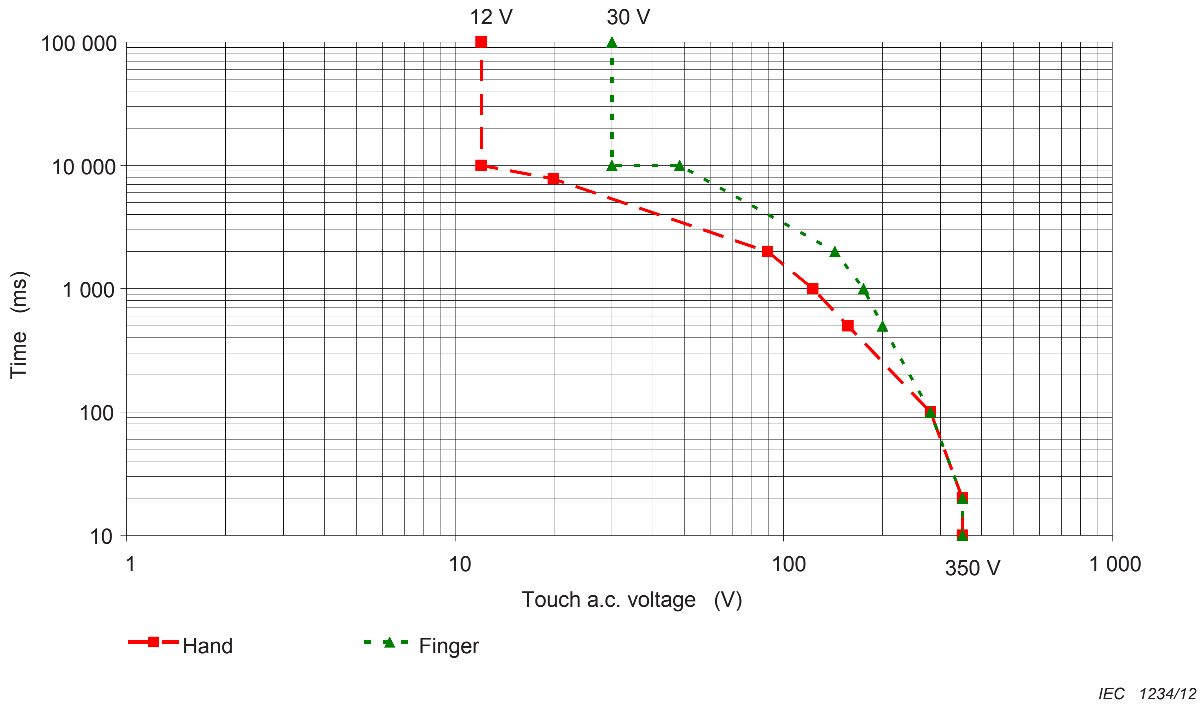


Figure A.15 – Touch time- a.c. voltage zones of dry skin condition

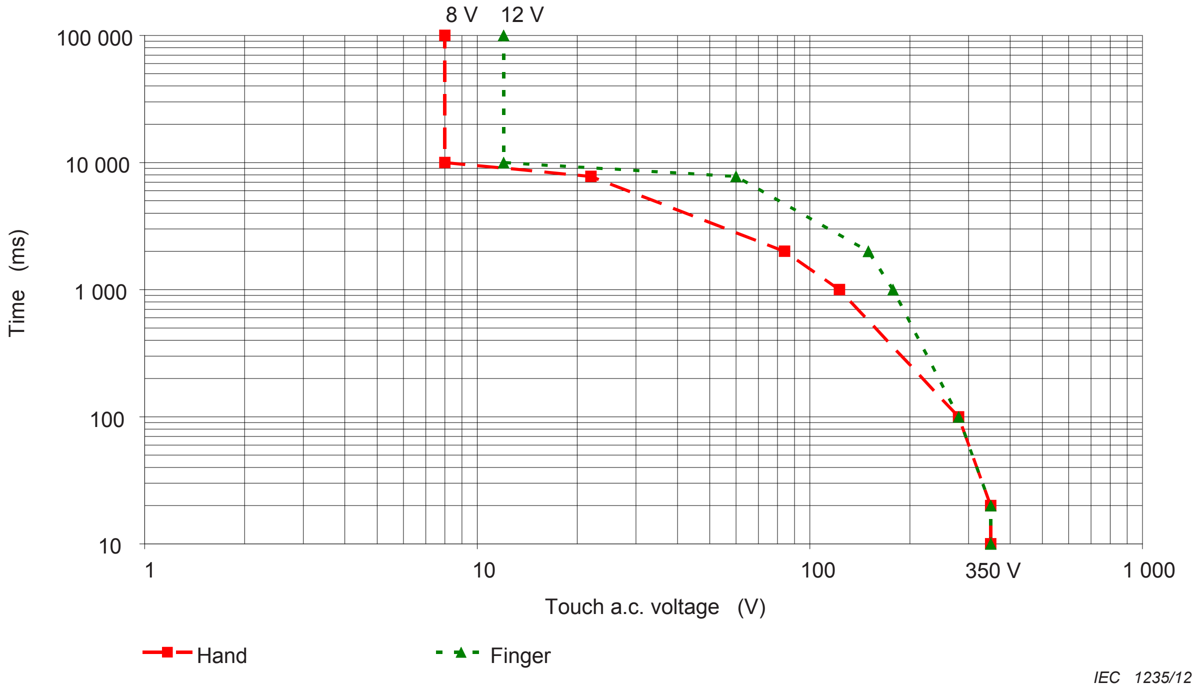


Figure A.16 – Touch time- a.c. voltage zones of water-wet skin condition

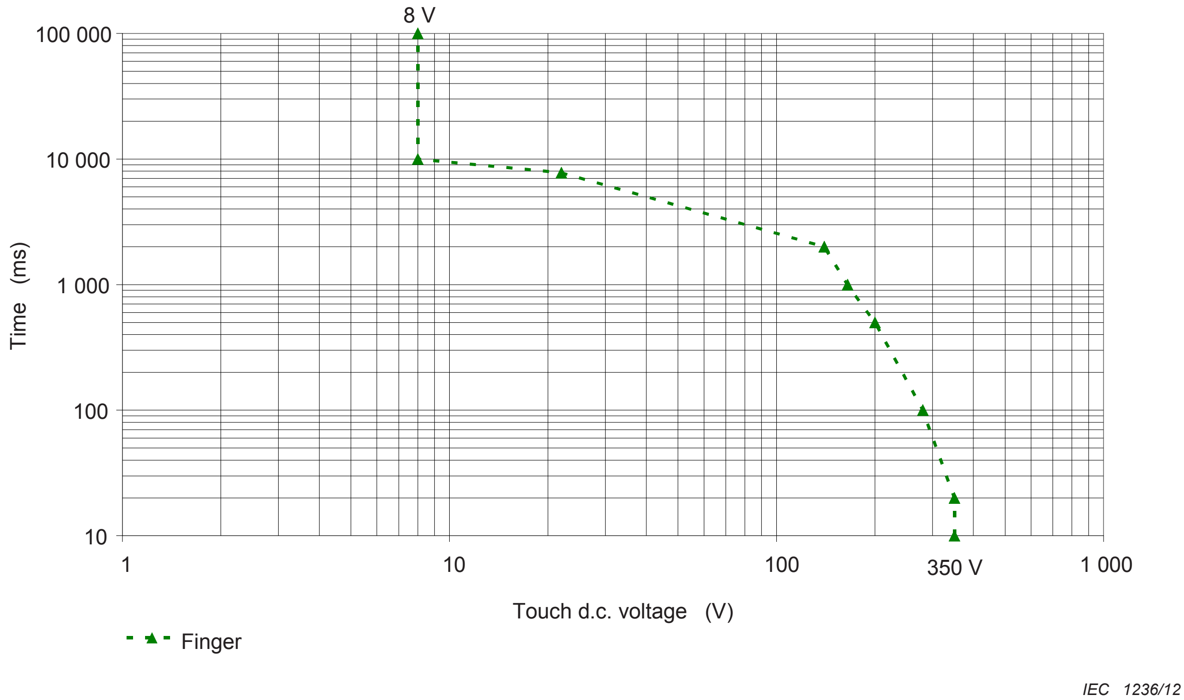


Figure A.17 – Touch time- a.c. voltage zones of saltwater-wet skin condition

A.5.11 Touch time- a.c.voltage zones for *startle reaction*

Figures A.18 and A.19 provide information about the short term non-recurring a.c. touch voltage limits for protection against *startle reaction*.

The figures provide information for acceptable level for part of the body, hand and finger tip under dry, water-wet and salt water wet conditions.

For some combinations no information for time-voltage zone is given and *basic protection* against accessibility is required.

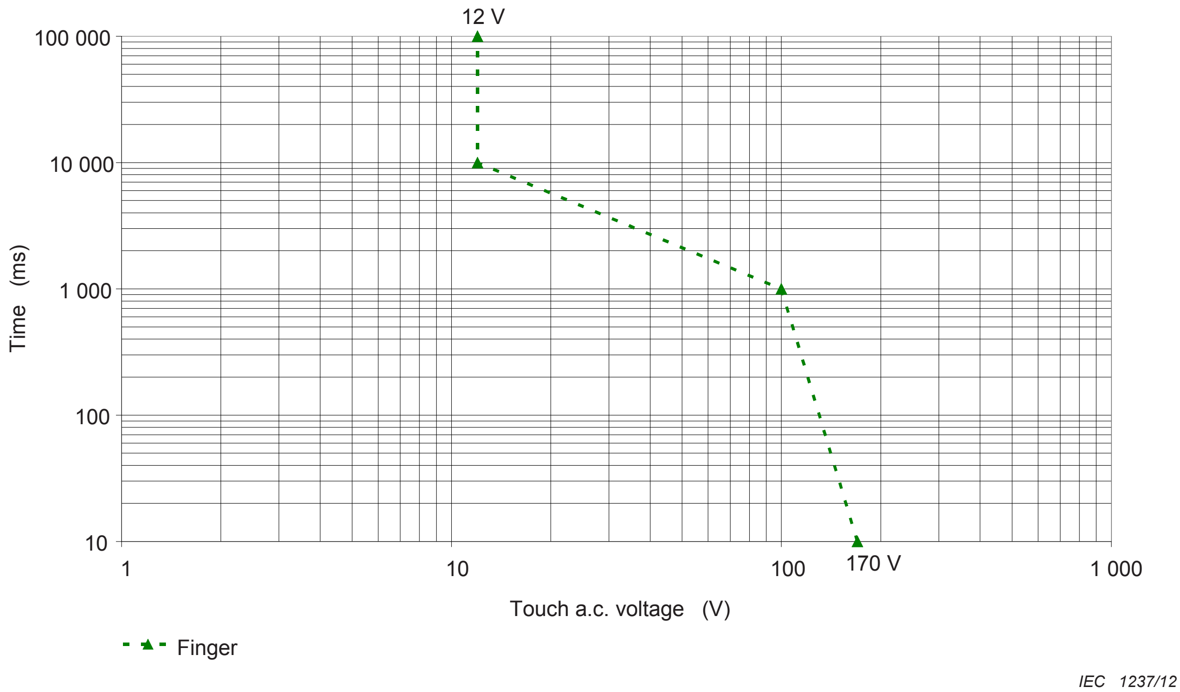


Figure A.18 – Touch time- a.c. voltage zones of dry skin condition

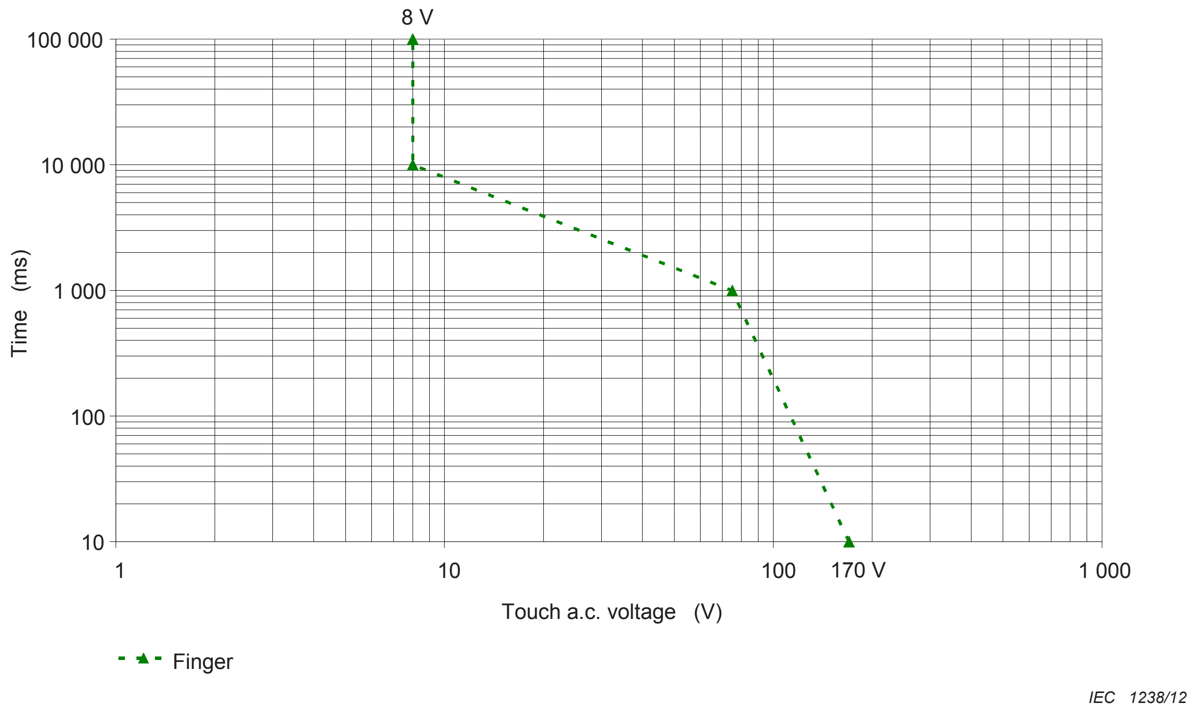


Figure A.19 – Touch time- a.c. voltage zones of water-wet skin condition

A.6 Evaluation of the *working voltage* of circuits

A.6.1 General

Determination of the *working voltage* for

- a.c. r.m.s. (U_{AC});
- a.c. recurring peak (U_{ACP}); and
- d.c. (average)

is done with the method set out below. Three cases of waveforms are considered as an example.

Figures A.20 to A.22 show typical waveforms for the evaluation of *working voltage*.

A.6.2 AC working voltage

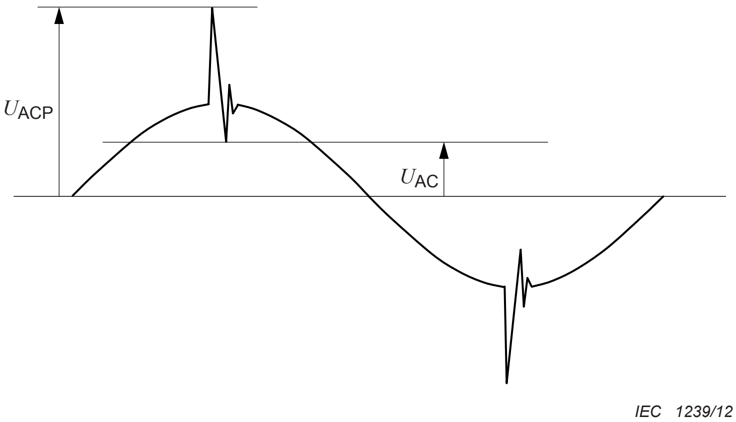


Figure A.20 – Typical waveform for a.c. *working voltage*

The *working voltage* has an r.m.s. value U_{AC} and a recurring peak value U_{ACP}.

The *DVC* is that of the lowest voltage row of Table 5 for which both of the following conditions are satisfied:

- $U_{AC} \leq U_{ACL}$
- $U_{ACP} \leq U_{ACPL}$

Example with values:

U_{AC} = 39 V --> is lower than U_{ACL} = 50 V --> *DVC B*
U_{ACP} = 91 V --> is higher than U_{ACPL} = 71 V --> *DVC C*

The rule for determination of *DVC* of the voltage is to select the highest *DVC*.

Result: --> this *working voltage* becomes *DVC C.*

A.6.3 DC *working voltage*

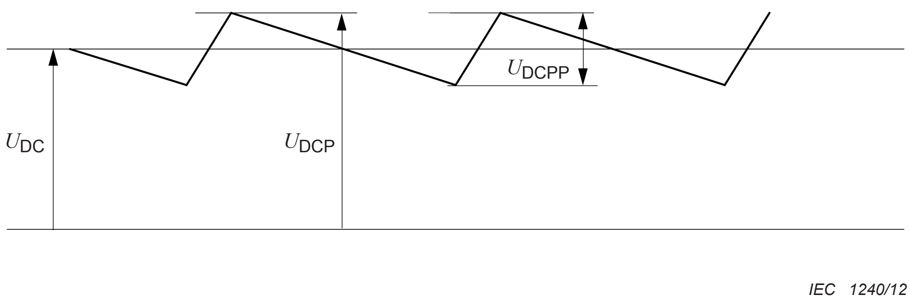


Figure A.21 – Typical waveform for d.c. *working voltage*

The *working voltage* has a mean value U_{DC} and a recurring peak value U_{DCP}, caused by a ripple voltage of r.m.s. value not greater than 10 % of U_{DC}.

The *DVC* is that of the lowest voltage row of Table 5 for which both of the following conditions are satisfied:

- $U_{DC} \leq U_{DCL}$

- $U_{DCP} \leq 1{,}17 \times U_{DCL}$

A.6.4 Pulsating *working voltage*

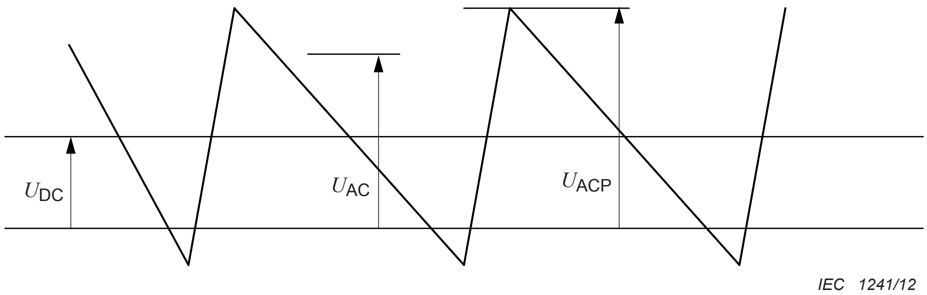


Figure A.22 – Typical waveform for pulsating *working voltage*

The *working voltage* has a mean value U_{DC} and a recurring peak value U_{ACP}, caused by a ripple voltage of r.m.s. value U_{AC} greater than 10 % of U_{DC}.

The *DVC* is that of the lowest voltage row of Table 5 for which both of the following conditions are satisfied:

$$\frac{U_{AC}}{U_{ACL}} + \frac{U_{DC}}{U_{DCL}} \leq 1$$

$$\frac{U_{ACP}}{U_{ACPL}} + \frac{U_{DC}}{1{,}17 \times U_{DCL}} \leq 1$$

A.7 Examples of the use of elements of protective measures

Protection against electric shock shall be achieved by means of:

- combination of *basic protection* according to 4.4.3 and *fault protection* according to 4.4.4; or
- *Enhanced protection* according to 4.4.5.

Table A.4 provides examples of typical combinations of those measures.

The grade of *insulation* depends on:

- the *DVC* of the *live parts* according *to* Table 5;
- the *insulation* requirement between *adjacent circuits* according to Table 6;
- the connection of accessible conductive parts to earth by *protective equipotential bonding* according to Table 6; and
- non conductive accessible parts.

As an alternative to solid *insulation*, a clearance according to 4.4.7.4, shown by L_1 and L_2 in Table A.4 may be provided.

In Table A.4, three cases are considered:

Case a):

Accessible parts are conductive and are connected to earth by *protective equipotential bonding*.

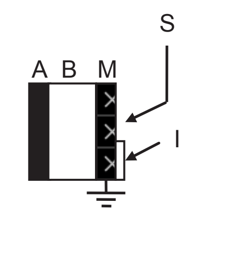
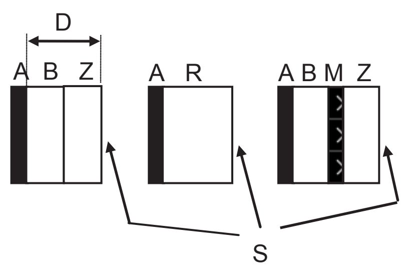
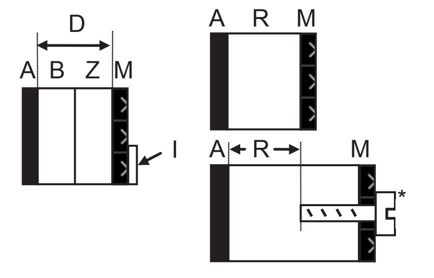
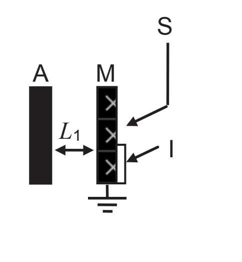
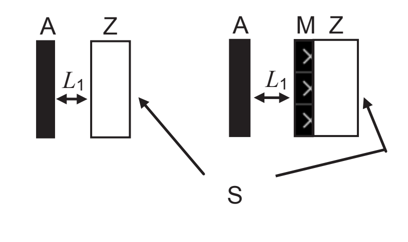
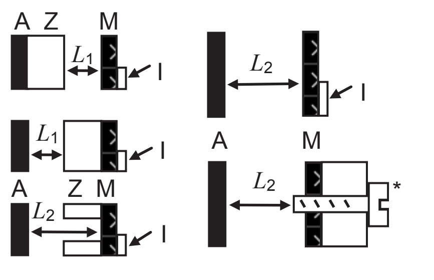
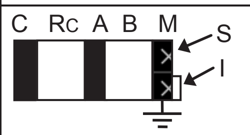
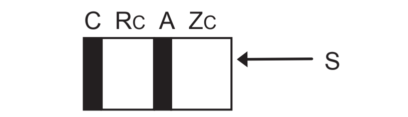
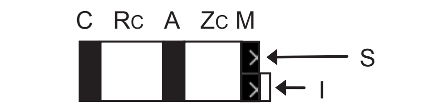
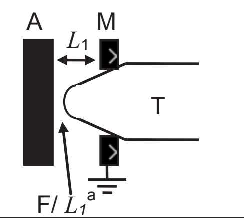
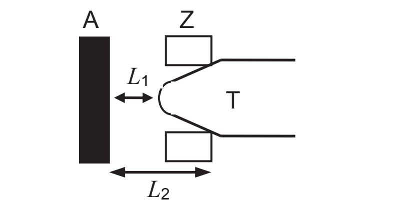
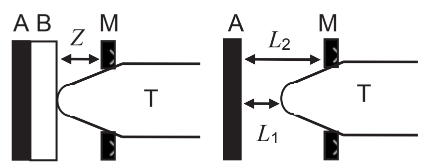
- *Basic insulation* is required between accessible parts and the *live parts*. The relevant voltage is that of the *live parts* (see Table A.4, cells 1a, 2a, 3a).

Cases b) and c):

Accessible parts are non-conductive (case b) or conductive but not connected to earth by *protective equipotential bonding* (case c). The required *insulation* is:

- Double or reinforced *insulation* between accessible parts and *live parts* of *DVC C*. The relevant voltage is that of the *live parts* (see Table A.4, cells 1b), 1c), 2b) and 2c)).
- Supplementary *insulation* between accessible parts and *live parts* of circuits of *DVC A* or B which are separated by *basic insulation* from *adjacent circuits* of *DVC C*. The relevant voltage is the highest voltage of the *adjacent circuits* (see Table A.4, upper cells 3b), 3c)).
- *Basic insulation* between accessible parts and *live parts* of circuits of *DVC B* which have protective *separation* from *adjacent circuits* of *DVC C*. The relevant voltage is that of the *live parts* (see Table A.4, lower cells 3b), 3c)).

Table A.4 – Examples for protection against electrical shock

Type of *insulation*	*Insulation* configuration		
	a **Accessible conductive parts connected to earth by *protective equipotential bonding***	**b** **Accessible parts not conductive**	**c** **Accessible parts conductive, but NOT connected to earth by *protective equipotential bonding***
1. Solid			
2. Totally or partially by air clearance			
3. *Insulation* for *adjacent circuits*: **Circuit A: lower voltage circuit** **Circuit C: higher voltage circuit; *DVC C***			
4. Requirements for apertures in *enclosures*			

A	*live part*	L_1	clearance for *basic insulation*	T	test finger (Clause 12 of IEC 60529:1989)
B	*basic insulation* for circuit A	L_2	clearance for *reinforced insulation*	Z	*supplementary insulation* for circuit A
BC	*basic insulation* for circuit C	M	conductive part	ZC	*supplementary insulation* for circuit C
C	*adjacent circuit*	R	*reinforced insulation* for circuit A	*	also applies to plastic screws
D	*double insulation* for circuit A	RC	*reinforced insulation* for circuit C	F	*functional insulation* for circuit A
I	*insulation* less than B	S	surface of equipment		

NOTE 1 In column c) a plastic screw is treated like a metal screw because a user could replace it with a metal screw during the life of the equipment.

NOTE 2 In row 4, the insertion of the test finger is considered to represent the first fault.

[a] *Functional insulation* is sufficient if the opening is covered during normal operation. It shall not be possible to remove the cover without the use of a tool or key. If the opening is not covered during normal operation, *basic insulation* is required.

Annex B
(informative)

Considerations for the reduction of the pollution degree

B.1 Introduction

The objective of this annex is to give an overview of what factors should be considered to reduce the pollution degree for electrical equipment in order to allow for a reduction of the clearance and creepage distances. As the measures to be taken depend heavily on the nature of pollution, no comprehensive guidance can be given on how to achieve the goal of a lower pollution degree for the equipment.

B.2 Factors influencing the pollution degree

The following factors influence the pollution degree:

- Pollution:
  - no pollution;
  - dry non-conductive pollution;
  - dry non-conductive pollution that can become conductive, when moist;
  - conductive pollution.

NOTE Pollution may be external or may be internally generated or present internally at the conclusion of manufacturing.

- Moisture:
  - no or low moisture without condensation;
  - temporary condensation;
  - permanent moisture;
  - rain or snow.

B.3 Reduction of influencing factors

Following are some measures that may be applied to reduce the influencing factors. The described measures to meet the requirements are only illustrative. There may be other possibilities.

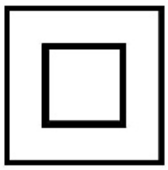
- Coating (see 4.4.7.6);
- IP5X (dust test according to IEC 60529);
- IPX4.. IPX8 depending on the environment.

When hermetically sealing an electrical equipment, it should be ensured that the moisture level will be at the required low level when resealing the equipment after opening the enclosure (e.g. for service).

Annex C
(informative)

Symbols referred to in IEC 62477-1

Table C.1 – Symbols used

Symbol	Standard reference	Description	Subclauses
	IEC 60417–5019 (2011-01)	*PE conductor* terminal	4.4.4.3.2, 6.3.7.2
	ISO 7010–W001 (2011-06)	Caution, refer to documentation	4.4.4.3.3, 4.4.8, 6.3.7.2
	IEC 60417-5018 (2011-01)	Functional earthing terminal	4.4.6.3
	IEC 60417–5172 (2011-01)	Class II (double insulated) equipment	4.4.6.3
	IEC 60417-6042 (2012-05)	Caution, risk of electric shock	4.4.9, 6.5.2
	IEC 60417-5041 (2012-05)	Caution, hot surface	4.6.4.2, 6.4.3.4

Annex D
(normative)

Evaluation of clearance and creepage distances

D.1 Measurement

Clearance and creepage distances shall be evaluated as illustrated in the examples contained in Examples D.1 to D.14.

For paths consisting of parts with different pollution degrees, as for example when including a cemented joint that provides protection type 1 (IEC 60664-3) in a pollution degree 2 environment, the clearance and creepage distances are determined according to Table 10 and Table 11, using the following rules:

- In general a creepage distance may be split in several portions of different materials and/or have different pollution degrees if one of the creepage distances is dimensioned to withstand the total voltage or if the total distance is dimensioned according to the material having the lowest CTI and the highest pollution degree.
- For creepage distances for *functional insulation* on PWB and components assembled on PWB, designed for pollution degree 1 and 2, the sum of the determining voltages of each part of the path shall not be less than the determining voltage of the circuits involved. The distances for each portion of the creepage distance under consideration shall comply with the minimum distances according to Table D.1.

D.2 Relationship of measurement to pollution degree

The "X" values are a function of pollution degree and shall be as specified in Table D.1. If the associated permitted clearance is less than 3 mm, the X value is one third of the clearance.

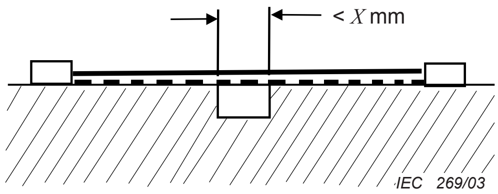
Table D.1 – Width of grooves by pollution degree

Pollution degree	X value mm
1	0,25
2	1,0
3	1,5

D.3 Examples

In the Examples D.1 to D.14 below, clearance and creepage distances are denoted as follows:

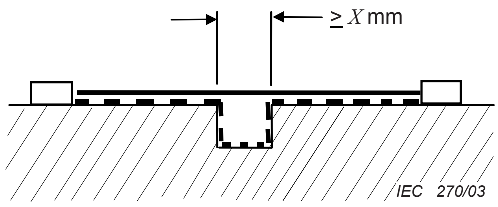
Clearance ——— Creepage distance – – –



Condition: The path under consideration includes a parallel, diverging or converging-sided groove of any depth with a width less than *X* mm.

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

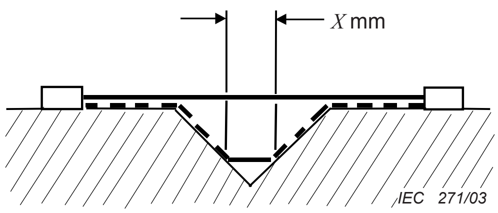
Example D.1



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

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

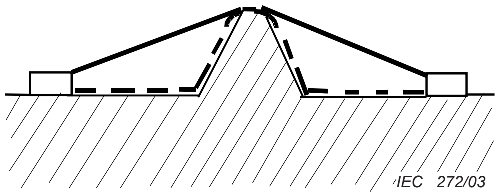
Example D.2



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

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

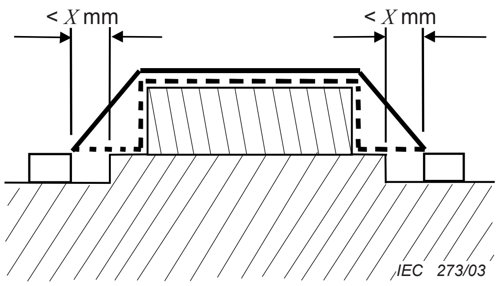
Example D.3



Condition: Path under consideration includes a rib.

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

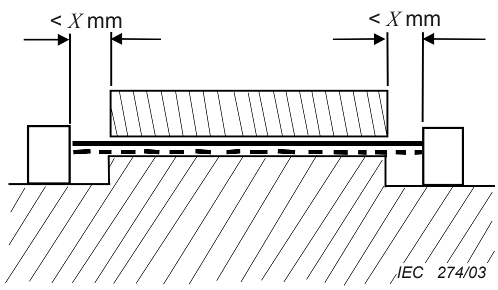
Example D.4



Condition: Path under consideration includes a cemented joint that provides protection of type 2 with grooves less than X mm wide on each side.

Rule: Clearance is the shortest air path over the top of the joint. Creepage distance is measured directly across the grooves and follows the contour of the joint.

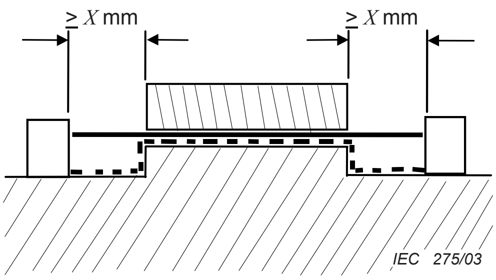
Example D.5



Condition: Path under consideration includes an uncemented joint or a cemented joint that provides protection of type 1 with grooves less than X mm wide on each side.

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

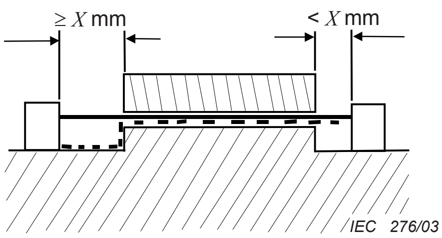
Example D.6



Condition: Path under consideration includes an uncemented joint or a cemented joint that provides protection of type 1 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.

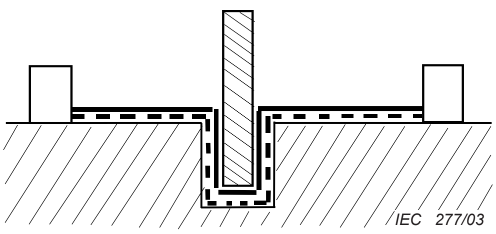
Example D.7



Condition: Path under consideration includes an uncemented joint or a cemented joint that provides protection of type 1 with a groove on one side less than X mm wide and the groove on the other side equal to or more than X mm wide.

Rule: Clearance and creepage paths are as shown.

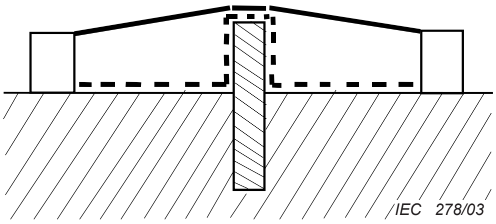
Example D.8



Condition: Path under consideration includes an uncemented barrier or a cemented joint that provides protection of type 1 when path under the barrier is less than the path over the barrier.

Rule: Clearance and creepage paths follow the contour under the barrier.

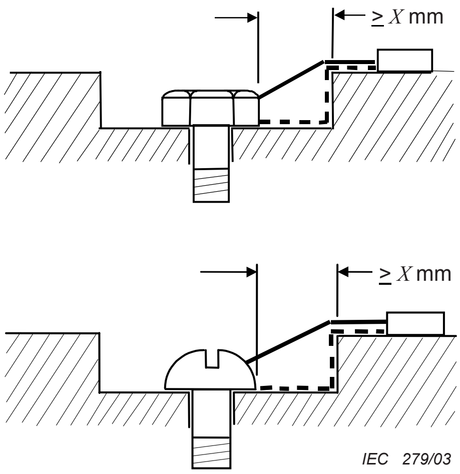
Example D.9



Condition: Path under consideration includes an uncemented or a cemented barrier when path over the barrier is less than the path under the barrier.

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

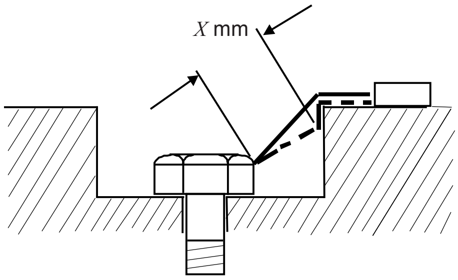
Example D.10

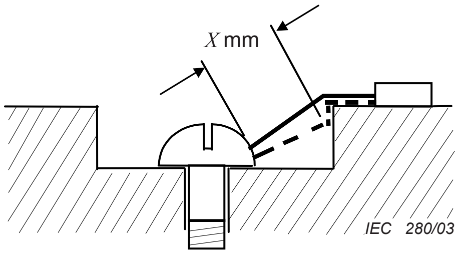


Condition: Path under consideration includes a gap between head of screw and wall of recess which is equal to or more than X mm wide.

Rule: Clearance is the shortest air path through the gap and over the top surface. Creepage path follows the contour of the surfaces.

Example D.11

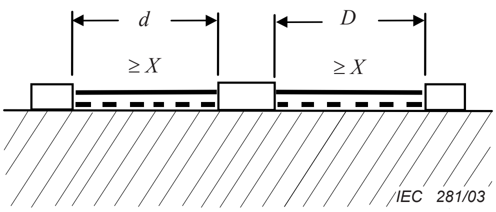




Condition: Path under consideration includes a gap between head of screw and wall of recess which is less than X mm wide.

Rule: Clearance is the shortest air path through the gap and over the top surface. Creepage path follows the contour of the surfaces but “short circuits” the bottom of the recess by X mm link.

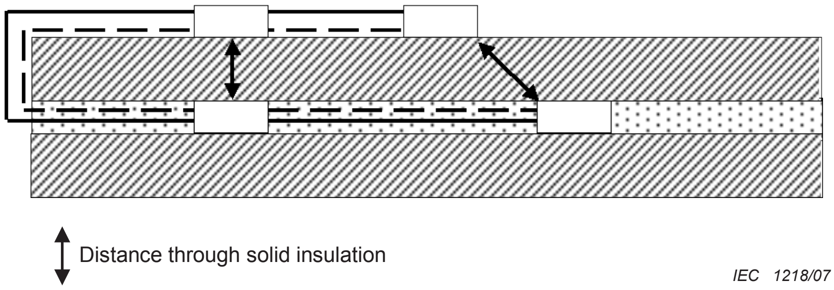
Example D.12



Condition: Path under consideration includes an isolated part of conductive material.

Rule: Clearance and creepage paths are the sum of d plus D.

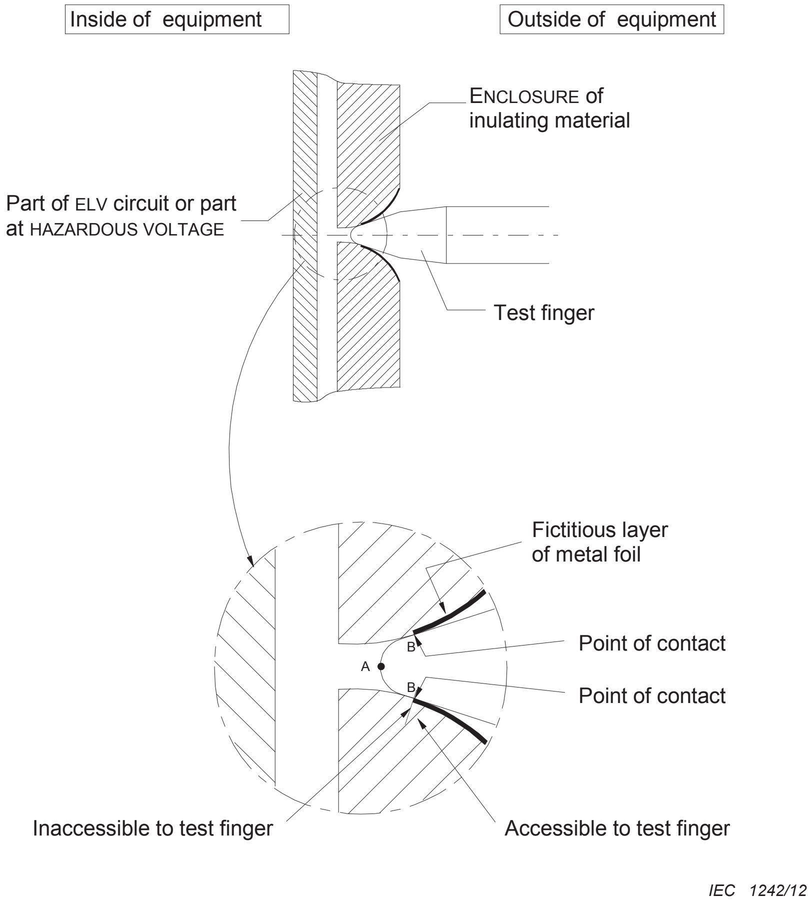
Example D.13



Condition: Path under consideration includes inner layer of PWB.

Rule: For the inner layer(s), the distance between adjacent tracks on the same layer is treated as creepage distance for pollution degree 1 and clearance as in air (see 4.4.7.8.4.1).

Example D.14



Point A is used for determining the air gap to a part inside the *enclosure*.

Point B is used for measurements of clearance and creepage distance from the outside of an *enclosure* of insulating material to a part inside the *enclosure*.

Example D.15 – Example of measurements in an *enclosure* of insulating material

Annex E
(informative)

Altitude correction for clearances

Refer to 4.4.7.4.1 in combination with the correction factor from Table E.1 for clearances at altitudes between 2 000 m and 20 000 m.

Table E.1 – Correction factor for clearances at altitudes between 2 000 m and 20 000 m

Altitude m	**Normal barometric pressure** kPa	**Multiplication factor for clearances**
2 000	80,0	1,00
3 000	70,0	1,14
4 000	62,0	1,29
5 000	54,0	1,48
6 000	47,0	1,70
7 000	41,0	1,95
8 000	35,5	2,25
9 000	30,5	2,62
10 000	26,5	3,02
15 000	12,0	6,67
20 000	5,5	14,50

Table E.2 – Test voltages for verifying clearances at different altitudes

Impulse voltage (from Table 9) kV	**Impulse test voltage at sea level** kV	**Impulse test voltage at 200 m altitude** kV	**Impulse test voltage at 500 m altitude** kV
0,33	0,36	0,36	0,35
0,50	0,54	0,54	0,53
0,80	0,93	0,92	0,90
1,50	1,8	1,7	1,7
2,50	2,9	2,9	2,8
4,00	4,9	4,8	4,7
6,00	7,4	7,2	7,0
8,00	9,8	9,6	9,4
12,00	15	14	14

NOTE 1 Explanations concerning the influencing factors (air pressure, altitude, temperature, humidity) with respect to electric strength of clearances are given in 6.1.2.2.1.3 of IEC 60664-1:2007.

NOTE 2 When testing clearances, associated solid *insulation* will be subjected to the test voltage. As the impulse test voltage is increased with respect to the rated impulse voltage, solid *insulation* will have to be designed accordingly. This results in an increased impulse withstand capability of the solid *insulation*.

NOTE 3 Values given above have been rounded from the calculation in 6.1.2.2.1.3 of IEC 60664-1:2007.

The voltage values of Table E.2 apply for the verification of clearances only.

Annex F
(normative)

Clearance and creepage distance determination for frequencies greater than 30 kHz

F.1 General influence of the frequency on the withstand characteristics

The *insulation* requirement for clearance, creepage and solid *insulation* as mentioned in 4.4.7 are given for frequencies up to and including 30 kHz. For higher frequencies, a reduction of the withstand capability of any type of *insulation* needs to be expected and taken into account for dimensioning.

For frequencies greater than 30 kHz and up to 10 MHz, IEC 60664-4 needs to be applied together with IEC 60664-1, for the design of clearance and creepage distances as well as solid *insulation*.

This annex provides detailed information for the design of clearance, creepage and solid *insulation* based on the requirement from IEC 60664-4.

The following situation needs to be considered for the design:

- clearance distance for inhomogenous fields (see F.2.2);
- clearance distance for approximately homogenous fields (see F.2.3);
- creepage distance (see F.3);
- solid *insulation* (see F.4).

The result of the investigation for frequencies above 30 kHz shall be compared to the investigation in 4.4.7 and the greater value of the two investigations shall be chosen.

F.2 Clearance

F.2.1 General

The withstand voltage capability within the scope of IEC 60664-4 will only be influenced by the frequency for periodic voltages. For transient overvoltages, dimensioning according to 4.4.7.4 shall be used.

For frequencies exceeding 30 kHz within the scope of IEC 60664-4, the withstand voltage capability of clearances with homogenous and approximately homogenous field distribution can be reduced by up to 25 %.

The requirement for clearance will depend on the field distribution of the *insulation* under investigation. F.2.2 will give the requirement for clearance distance for inhomogenous fields and F.2.3 provides design criteria for clearance distance for approximately homogenous fields.

For frequencies exceeding 30 kHz, an approximately homogeneous field is considered to exist when the radius of curvature r of the conductive parts is equal or greater than 20 % of the clearance. The necessary radius of curvature can only be specified at the end of the dimensioning procedure.

The result of the investigation of clearance for frequencies above 30 kHz shall be compared to the investigation in 4.4.7.4 and the greater value of the two investigations shall be chosen.

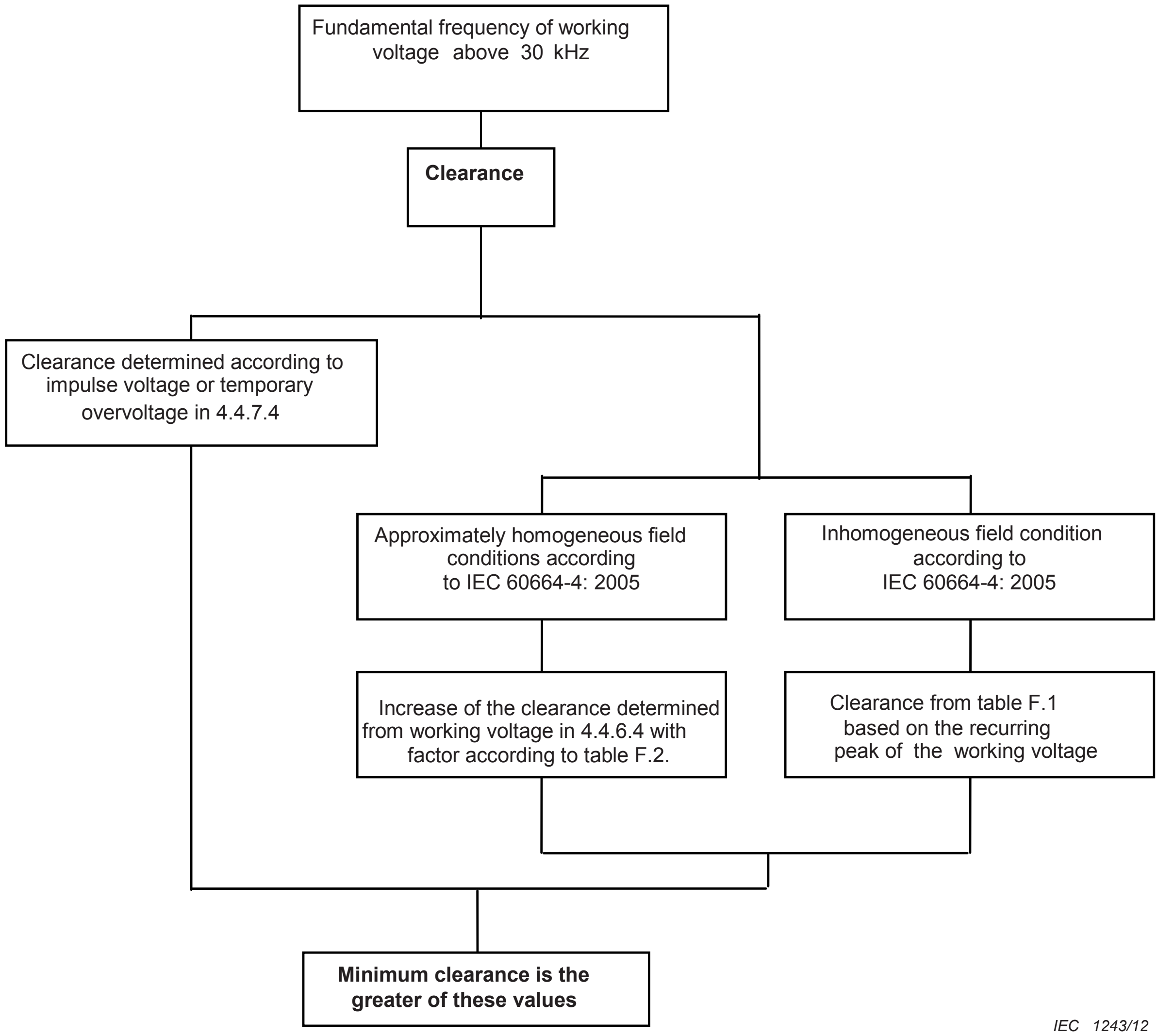


Figure F.1 – Diagram for dimensioning of clearances

F.2.2 Clearance for inhomogenous fields

For frequencies exceeding 30 kHz, an inhomogeneous field is considered to exist when the radius of curvature of the conductive parts is less than 20 % of the clearance. For inhomogeneous field distribution, the reduction of the withstand voltage capability of clearances can be much higher.

Dimensioning for inhomogeneous field distribution is done for the required withstand voltage of the clearance according to the values in Table F.1. No withstand voltage test other than the requirement in 4.4.7 is required.

Table F.1 – Minimum values of clearances in air at atmospheric pressure for inhomogeneous field conditions (Table 1 of IEC 60664-4:2005)

Peak voltage [a] kV	**Clearance** mm
≤ 0,6 [b]	0,065
0,8	0,18
1,0	0,5
1,2	1,4
1,4	2,35
1,6	4,0
1,8	6,7
2,0	11,0

[a] For voltages between the values stated in this table, interpolation is permitted.

[b] No data is available for peak voltages less than 0,6 kV.

The dimensioning for inhomogeneous field and high voltage stress (>1 kV condition) leads to impractical distances. It is therefore preferable to choose a design improving the field distribution (approximately homogeneous field distribution).

F.2.3 Clearance for approximately homogenous fields

For clearance with approximately homogenous fields conditions the clearance found in table Table 10, where the clearance is determined on the *working voltage* or recurring peak voltage (column 2 or 3), is increased by a multiplication factor depending on the fundamental frequency. The multiplication factors are indicated in Table F.2.

Table F.2 – Multiplication factors for clearances in air at atmospheric pressure for approximately homogeneous field conditions

Fundamental frequency kHz	**Multiplication factor**
$30 < f_{\text{fundamental}} \leq 500$	1,05
$500 < f_{\text{fundamental}} \leq 1\,000$	1,10
$1\,000 < f_{\text{fundamental}} \leq 2\,000$	1,20
$2\,000 < f_{\text{fundamental}} \leq 3\,000$	1,25

NOTE 1 The multiplication factors are determined based on calculations as per IEC 60664-4:2005, 4.3.3. More precise calculation can be determined using the equation in IEC 60664-4:2005, 4.3.3.

NOTE 2 Circuits where the clearance is designed based on the impulse withstand voltage (Table 10, column 1), will normally not be affected by these considerations.

The dimensioned clearance, for approximately homogenous field conditions, is applicable for frequencies above the critical frequency calculated by means of following equation taking into account the new distance from Table F.2:

$$f_{\text{crit}} \approx \frac{0{,}2}{d}\left(\frac{\text{MHz}}{\text{mm}}\right)$$

F.3 Creepage distance

For frequencies of the voltage greater than 30 kHz, in addition to tracking, thermal effects need to be taken into account with respect to the withstand capability of creepage distances. Dimensioning is performed both for the required r.m.s. withstand voltage of the creepage distance according to the values in Table 11 and for the required peak withstand voltage according to the values in Table F.3. This peak withstand voltage is the highest value of any periodic peak of the voltage across the creepage distance. The greater of the distances is applicable. The dimensioning according to Table F.3 is applicable for all insulating materials which can deteriorate due to thermal effects. This includes typical base materials for printed circuit boards made from epoxy resin. For materials which cannot deteriorate due to thermal effects and where no tracking needs to be expected, dimensioning according to the clearance requirements, as described in 4.4.7.5, is sufficient.

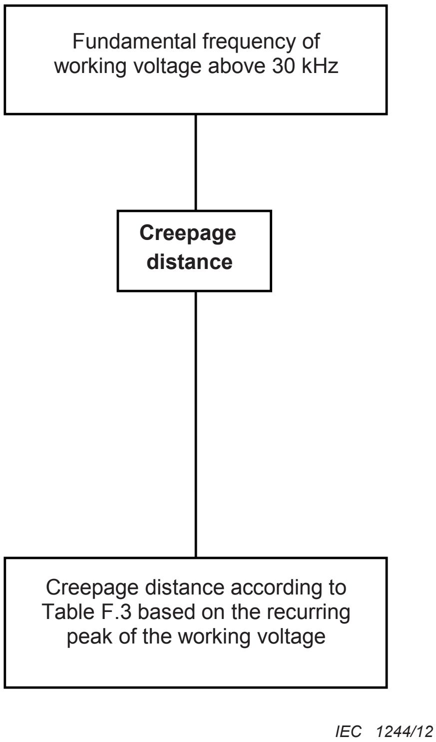


Figure F.2 – Diagram for dimensioning of creepage distances

Table F.3 – Minimum values of creepage distances for different frequency ranges (Table 2 of IEC 60664-4:2005)

Peak voltage kV	Creepage distance [a] [b] mm						
	30 kHz < f ≤ 100 kHz	**f ≤ 0,2 MHz**	**f ≤ 0,4 MHz**	**f ≤ 0,7 MHz**	**f ≤ 1 MHz**	**f ≤ 2 MHz**	**f ≤ 3 MHz**
0,1	0,0167						0,3
0,2	0,042					0,15	2,8
0,3	0,083	0,09	0,09	0,09	0,09	0,8	20
0,4	0,125	0,13	0,15	0,19	0,35	4,5	
0,5	0,183	0,19	0,25	0,4	1,5	20	
0,6	0,267	0,27	0,4	0,85	5		
0,7	0,358	0,38	0,68	1,9	20		
0,8	0,45	0,55	1,1	3,8			
0,9	0,525	0,82	1,9	8,7			
1	0,6	1,15	3	18			
1,1	0,683	1,7	5				
1,2	0,85	2,4	8,2				
1,3	1,2	3,5					
1,4	1,65	5					
1,5	2,3	7,3					
1,6	3,15						
1,7	4,4						
1,8	6,1						

[a] The values for the creepage distances in the table apply for pollution degree 1. For pollution degree 2, a multiplication factor of 1,2 and for pollution degree 3 a multiplication factor 1,4 should be used.

[b] Interpolation between columns is permitted.

F.4 Solid *insulation*

F.4.1 General

Due to increased heating effects and accelerated deterioration in solid *insulation* further consideration is needed, when using solid *insulation* across *insulation* affected by frequencies above 30 KHz.

F.4.2 Approximately uniform field distribution without air gaps or voids

For solid *insulation* where uniform field distribution is present and no air gaps or voids are present in the solid *insulation*, the maximum field distribution shall be calculated as following:

- For thick layers of solid *insulation* of $d_1 \geq 0{,}75$ mm the peak value of the field strength E needs to be equal or less than 2 kV/mm.
- For thin layers of solid *insulation* of $d_2 \leq 30$ µm the peak value of the field strength needs to be equal or less than 10 kV/mm.
- For $d_1 > d > d_2$ Equation (1) is used for interpolation for a certain thickness d (see also Figure F.3):

$$E = \left(\frac{0{,}25}{d} + 1{,}667\right)\left(\frac{\text{kV}}{\text{mm}}\right) \qquad (1)$$

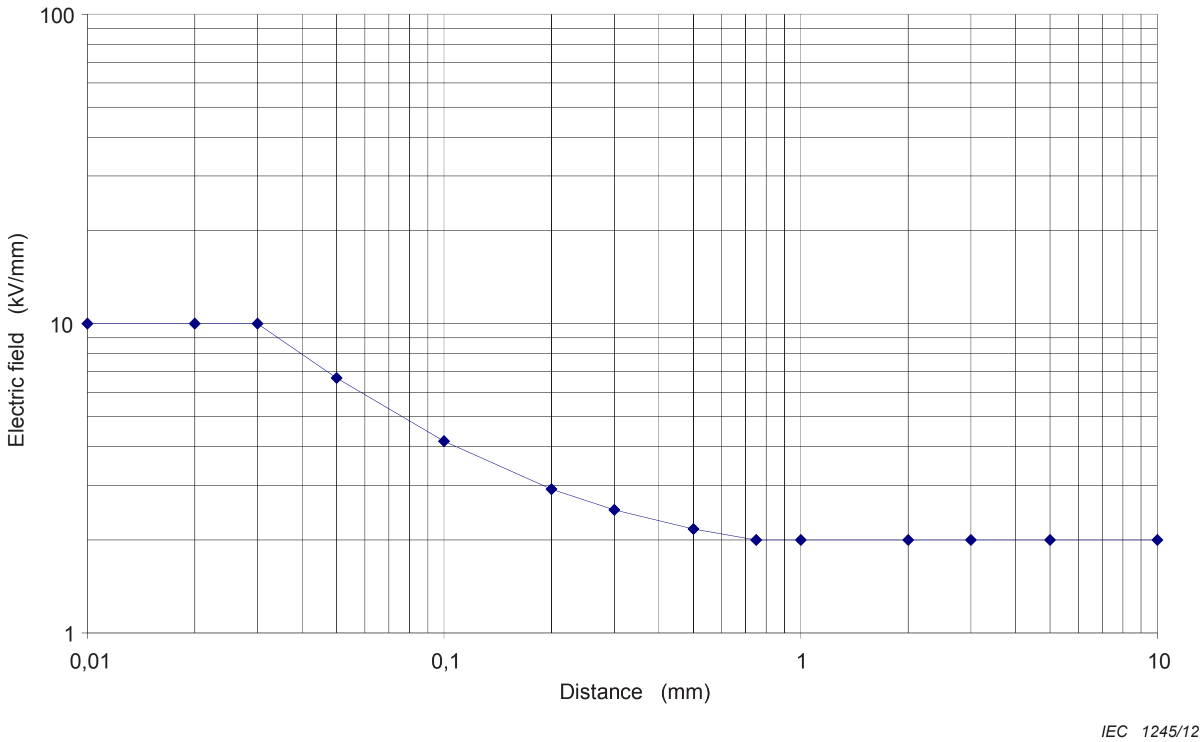


Figure F.3 – Permissible field strength for dimensioning of solid *insulation* according to Equation (1)

F.4.3 Other cases

For solid *insulation* where:

- uniform field distribution is not present; or
- air gaps or voids are to be expected; or
- the field strength is above the calculation in F.4.2.

In the solid *insulation*, the evaluation according to 4.4.7.8 for solid *insulation* shall be performed.

If possible the partial discharge test described in 5.2.3.5 should be performed with the frequency, which is present over the *insulation* under evaluation when evaluation is made according to this annex. At the time of writing such test equipment is not commonly available, and the standard allows test to be conducted at 50Hz. Product commitees using this standard as reference document should take this into consideration.

Annex G
(informative)

Cross-sections of round conductors

Standard values of cross-section of round copper conductors are shown in Table G.1, which also gives the approximate relationship between ISO metric and AWG/MCM sizes.

Table G.1 – Standard cross-sections of round conductors

	AWG/kcmil	
ISO cross-section mm^2	**Size**	**Equivalent cross-section** mm^2
0,2	24	0,205
–	22	0,324
0,5	20	0,519
0,75	18	0,82
1,0	–	–
1,5	16	1,3
2,5	14	2,1
4,0	12	3,3
6,0	10	5,3
10	8	8,4
16	6	13,3
25	4	21,2
35	2	33,6
50	0	53,5
70	00	67,4
95	000	85,0
–	0000	107,2
120	250 kcmil	127
150	300 kcmil	152
185	350 kcmil	177
240	500 kcmil	253
300	600 kcmil	304
–	700 kcmil	355
–	750 kcmil	380
400	800 kcmil	405
–	900 kcmil	456
500	1 000 kcmil	506
630	1 250 kcmil	633
–	1 500 kcmil	760
800	–	–
–	1 750 kcmil	887
1 000	2 000kcmil	1 013

NOTE The dash, when it appears, counts as a size when considering connecting capacity (see 4.11.8.2).

Annex H
(informative)

Guidelines for RCD compatibility

H.1 Selection of RCD type

Depending on the nature of the power supply, its installation and the type of RCD (type A, AC or B, – see IEC 61008 series, IEC 61009 series, IEC 62423, IEC 60364-4-44 and IEC 60364-5-53), *PECS* and RCD can be compatible or incompatible (see 4.4.8). If circuits which can cause current with a d.c. component to flow in the *PE conductor* during normal operation or during failure are not separated from the environment by *double* or *reinforced insulation*, it is considered that the *PECS* itself can cause smooth d.c. current and is therefore incompatible with RCDs of type A and AC.

The flow chart in Figure H.1 will help with the selection of the RCD type when using a *PECS* downstream of the RCD.

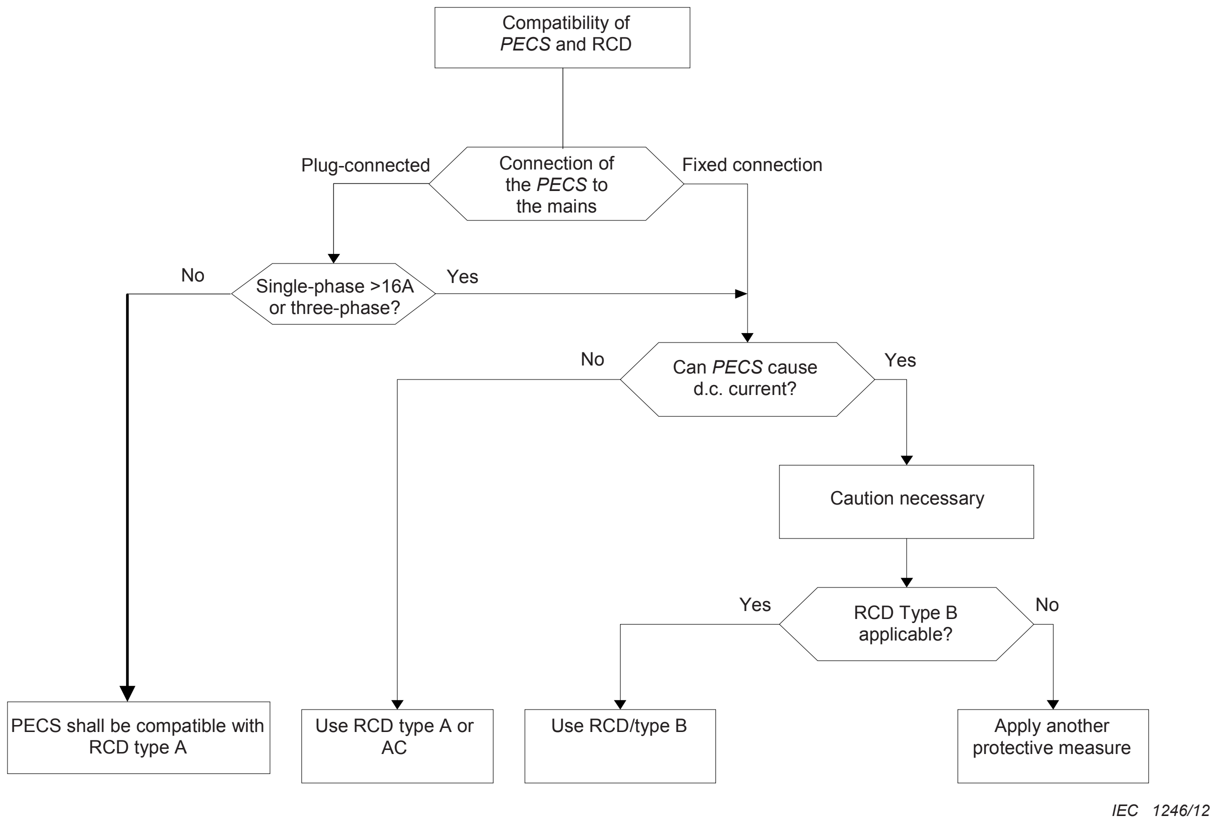
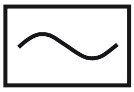
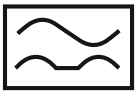
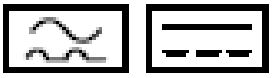
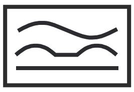


Figure H.1 – Flow chart leading to selection of the RCD type upstream of a *PECS*

RCDs suitable to be triggered by different waveforms of residual current are marked with the following symbols, as defined in IEC 60755.

	Type AC: – a.c. current sensitive (suitable for circuits 8 and 9 of Figure H.2)
	Type A: – a.c. current sensitive and pulse current sensitive (suitable for circuits 1, 4, 5, 8, 9 of Figure H.2)
 or 	Type B: – universal current sensitive (suitable for all circuits of Figure H.2)

H.2 Fault current waveforms

Figure H.2 shows typical fault current waveforms for different *PECS* circuit configurations, used to determine RCD compatibility.

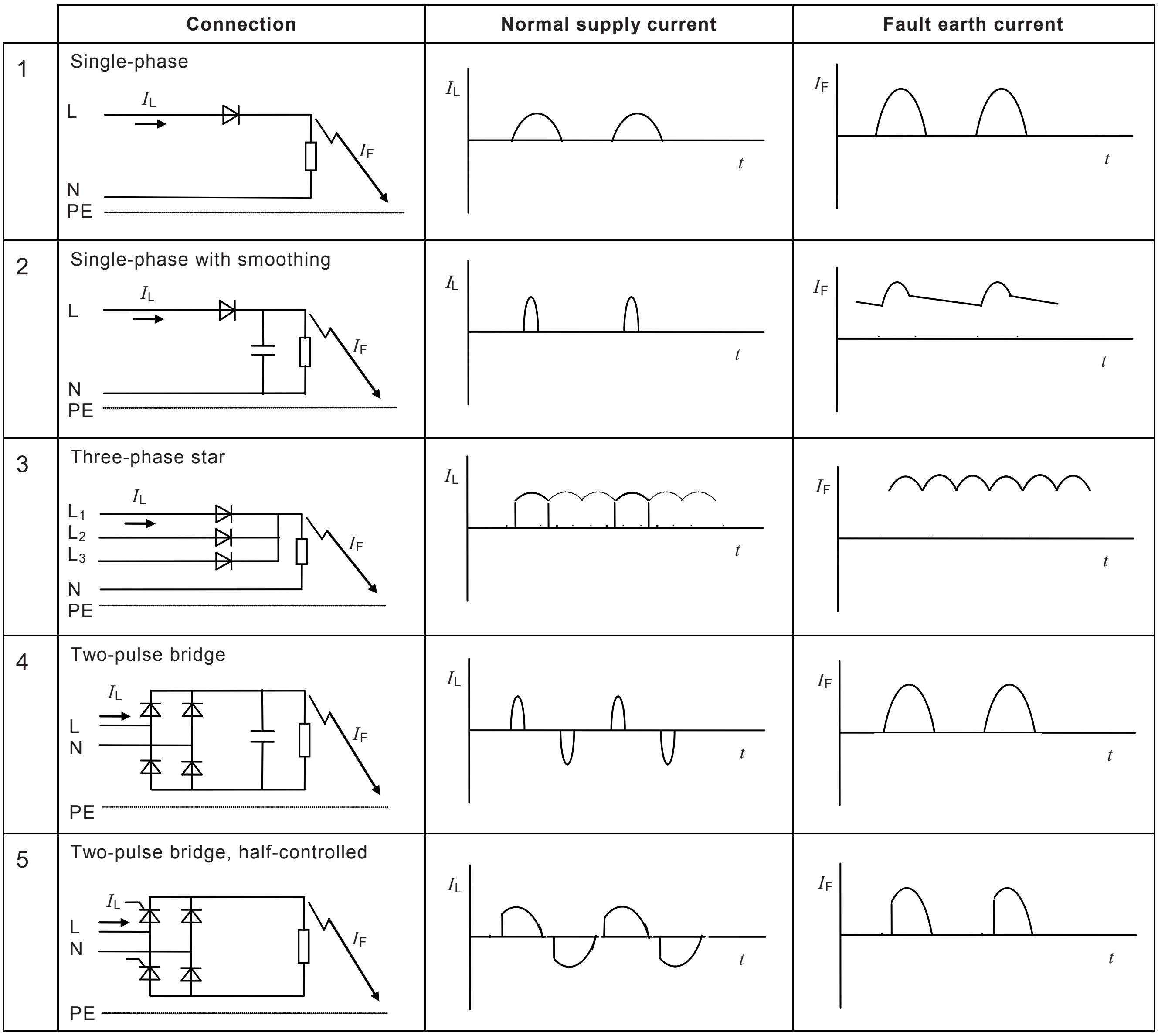


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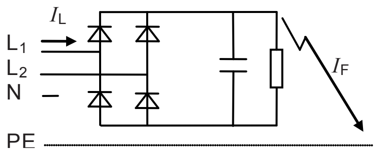
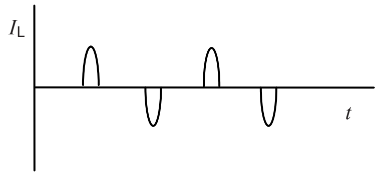
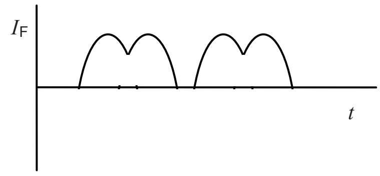
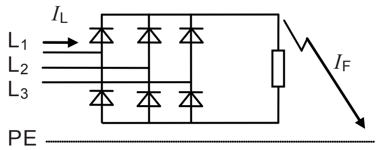
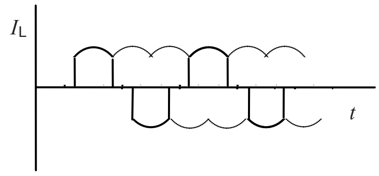
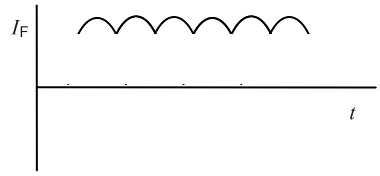
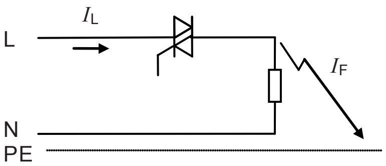
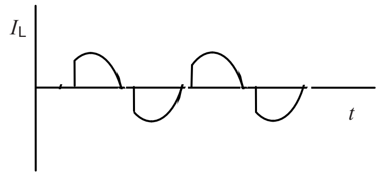
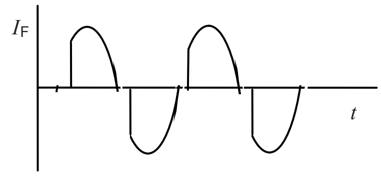
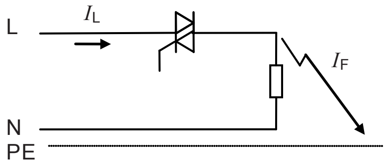
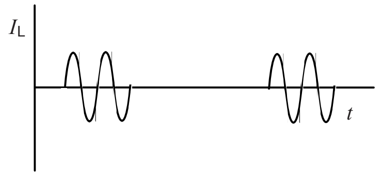
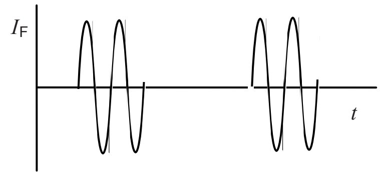
Figure H.2 – Fault current waveforms in connections with power electronic converter devices

	Connection	Normal supply current	Fault earth current
6	Two-pulse bridge between phases 		
7	Six-pulse bridge 		
8	Phase control 		
9	Burst control 		

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NOTE I_F symbolizes a fault current, not a short circuit current.

Figure H.2 – Fault current waveforms in connections with power electronic converter devices *(continued)*

Annex I
(informative)

Examples of overvoltage category reduction

I.1 General

Figures I.1 to I.15 are intended as illustrations of the requirements in Table 6, 4.4.7.2 and 4.4.7.3. They are not intended as indications of good design practice.

- - - - - - - - -	*Basic protection*
— — —	Conductive accessible parts
—·—·—·—·	*Protective separation*
SPD	Surge protection device (example of measure to reduce transient overvoltages)
OVC	Overvoltage category

I.2 *Insulation* to the surroundings (see 4.4.7.2)

I.2.1 Circuits connected to *mains supply* (see 4.4.7.2.2)

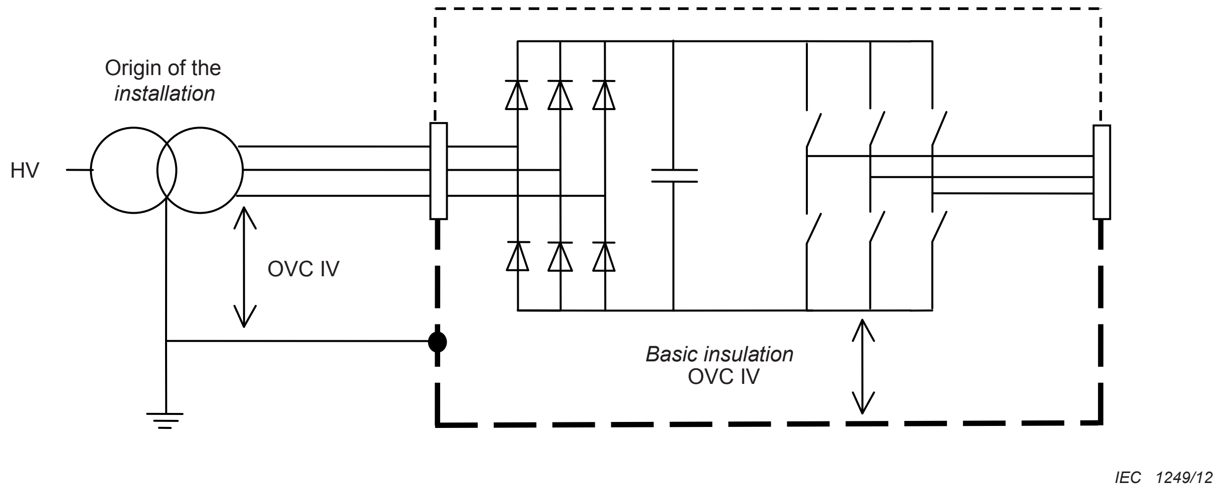


Figure I.1 – *Basic insulation* evaluation for circuits connected to the origin of the *installation mains supply*

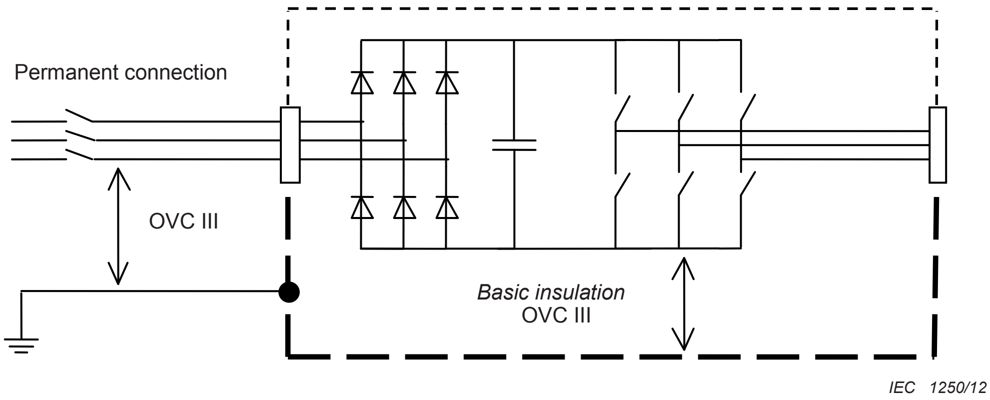


Figure I.2 – *Basic insulation* evaluation for circuits connected to the *mains supply*

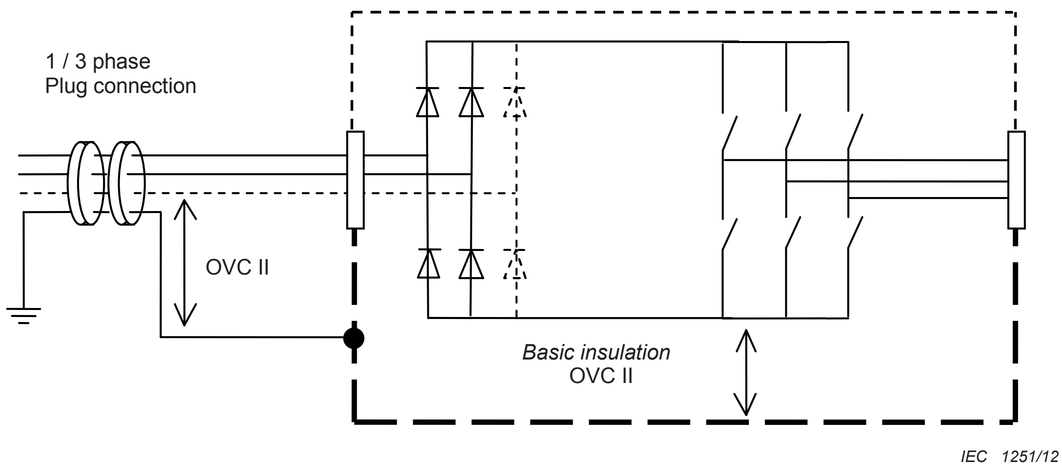


Figure I.3 – *Basic insulation* evaluation for single and three phase equipment not *permanently connected* to the *mains supply*

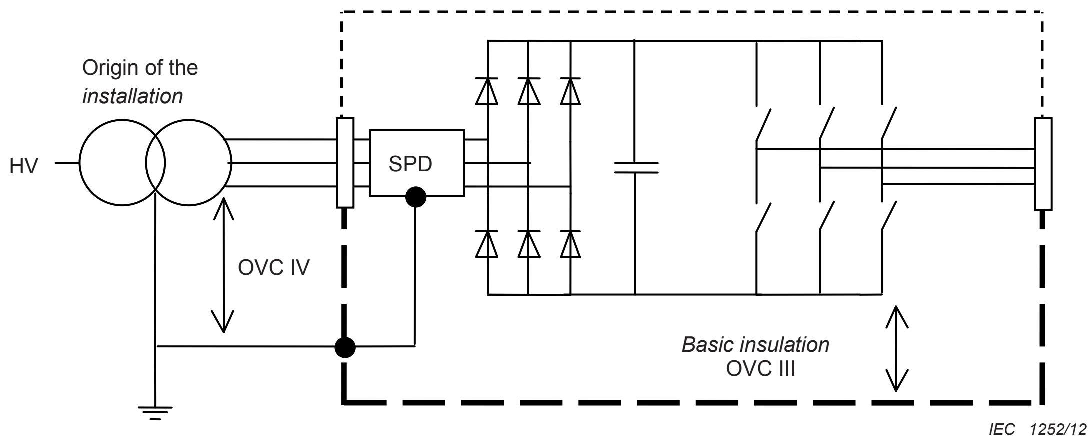


Figure I.4 – *Basic insulation* evaluation for circuits connected to the origin of the *installation mains supply* where internal *SPD*s are used

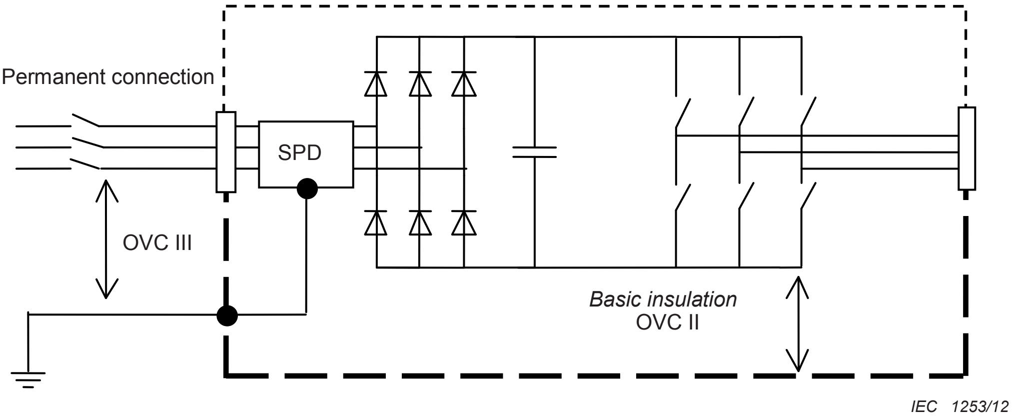


Figure I.5 – *Basic insulation* evaluation for circuits connected to the *mains supply* where internal *SPD*s are used

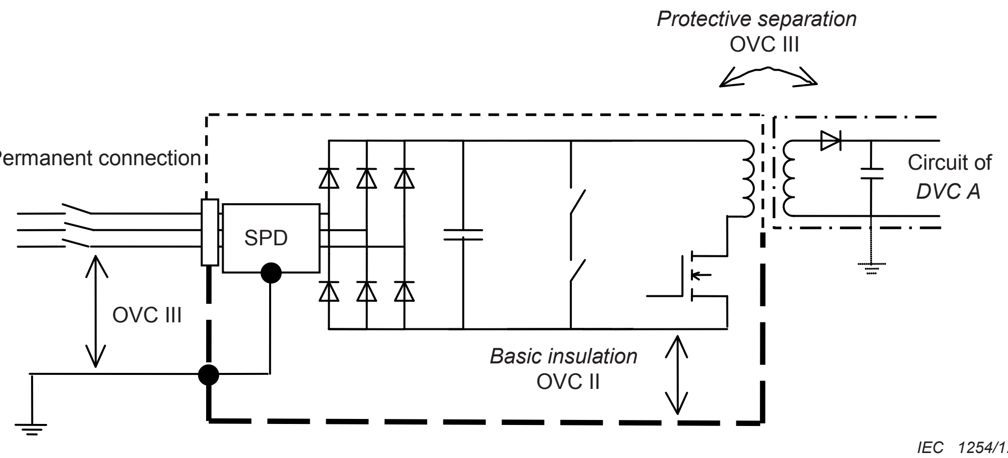


Figure I.6 – Example of *protective separation* evaluation for circuits connected to the *mains supply* where internal *SPD*s are used

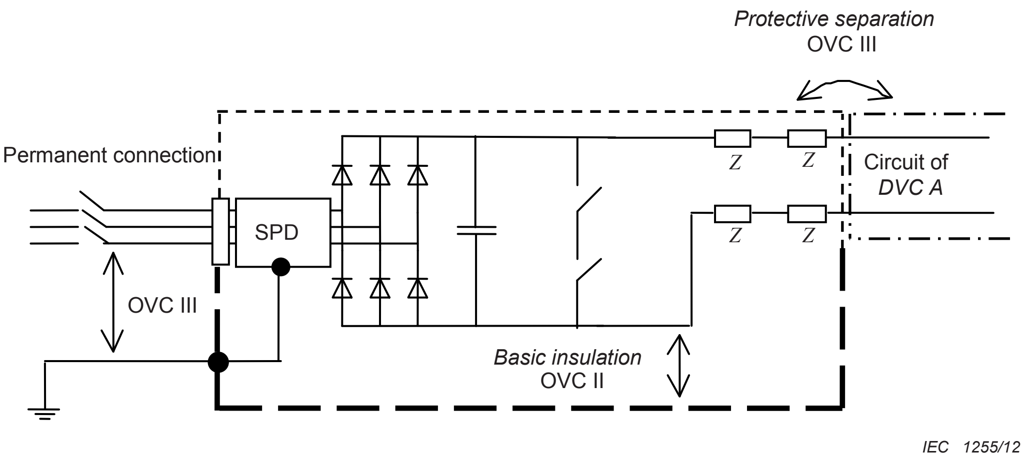


Figure I.7 – Example of *protective separation* evaluation for circuits connected to the *mains supply* where internal *SPD*s are used

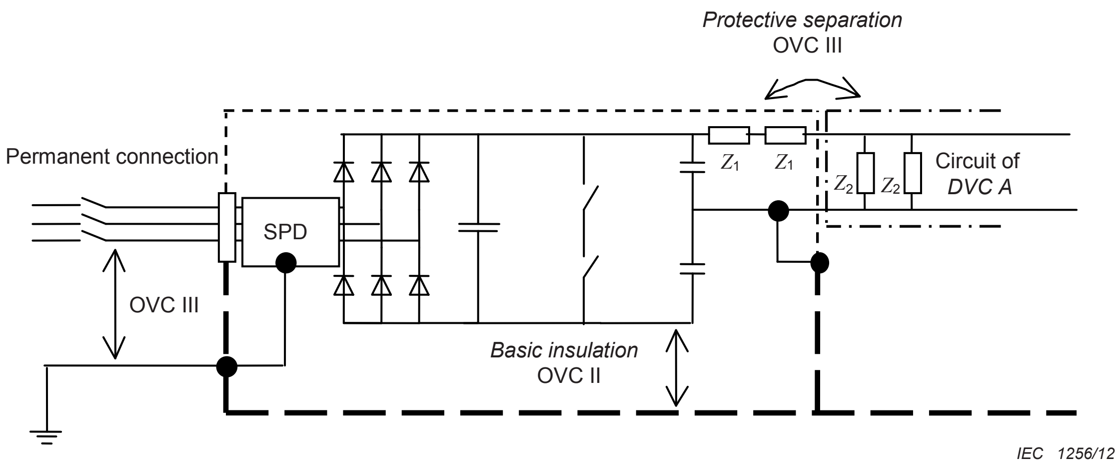


Figure I.8 –Example of *protective separation* evaluation for circuits connected to the *mains supply* where internal *SPD*s are used

NOTE The requirements for *protective separation* in Figure I.6 to Figure I.8 are not reduced by the use of the *SPD* (see 4.4.7.2.2 and 4.4.7.2.3).

I.2.2 Circuits not connected directly to the *mains supply* (see 4.4.7.2.3)

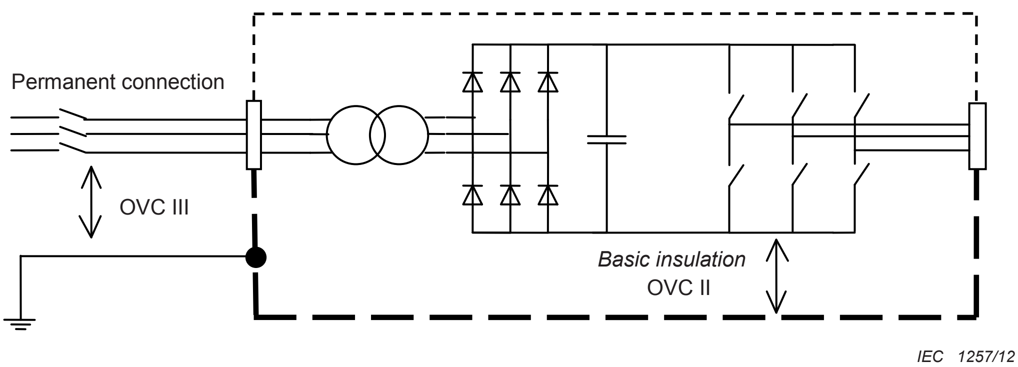


Figure I.9 – *Basic insulation* evaluation for circuits not connected directly to the *mains supply*

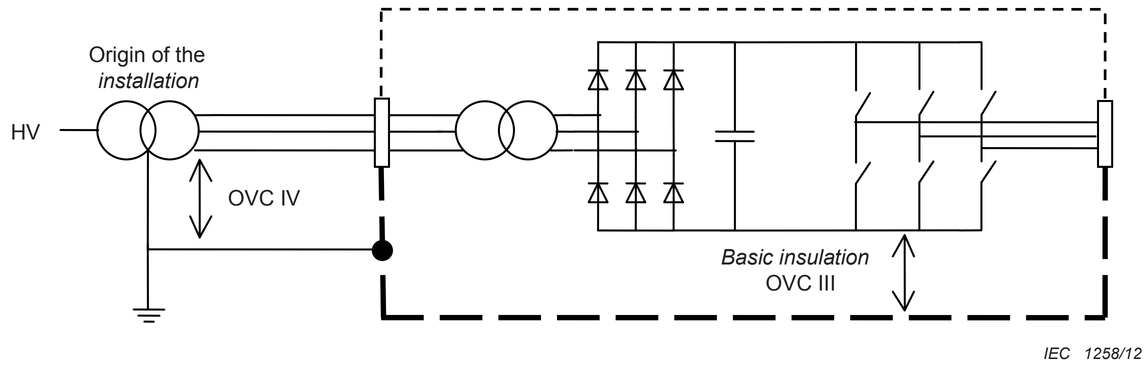
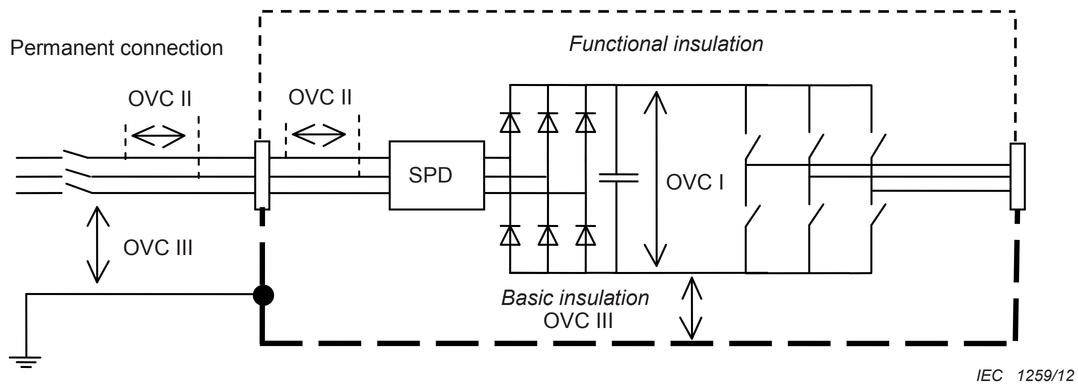


Figure I.10 – *Basic insulation* evaluation for circuits not connected directly to the supply mains

I.2.3 *Insulation* between circuits (see 4.4.7.2.4)

Insulation between two circuits shall be designed according to the circuit having the more severe requirement (see also Figure I.12).

I.3 Functional *insulation* (see 4.4.7.3)



NOTE 1 The *SPD* is not connected to earth, and so has no effect on the overvoltage catgory to earth.

NOTE 2 The requirements for *functional insulation* may be further reduced by the circuit characteristics (see 4.4.7.3).

Figure I.11 – Functional *insulation* evaluation within circuits affected by external transients

I.4 Further examples

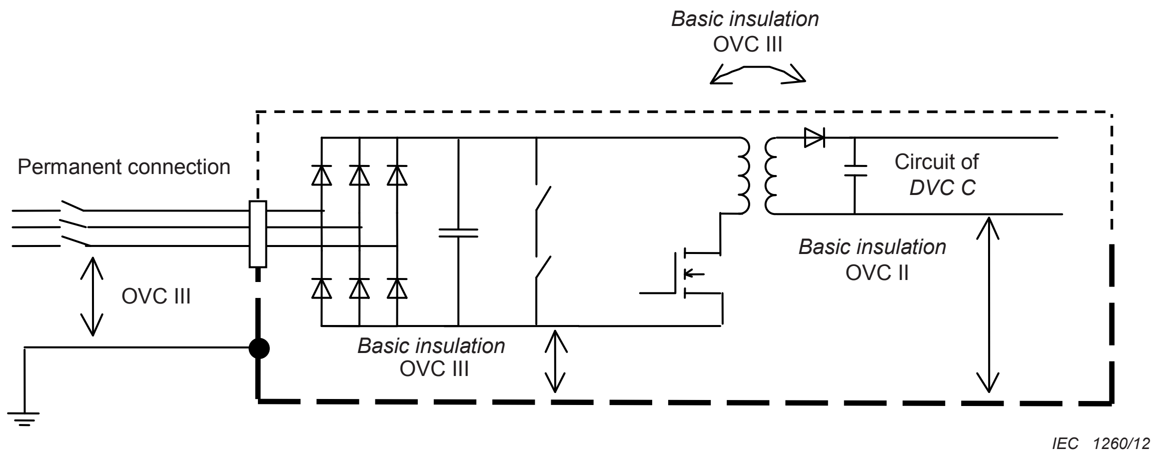


Figure I.12 – *Basic insulation* evaluation for circuits both connected and not connected directly to the *mains supply*

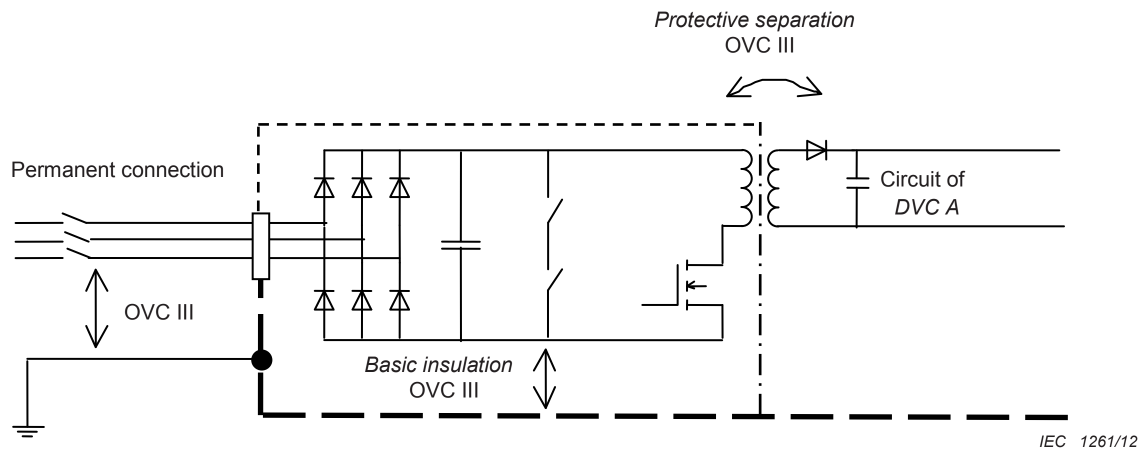
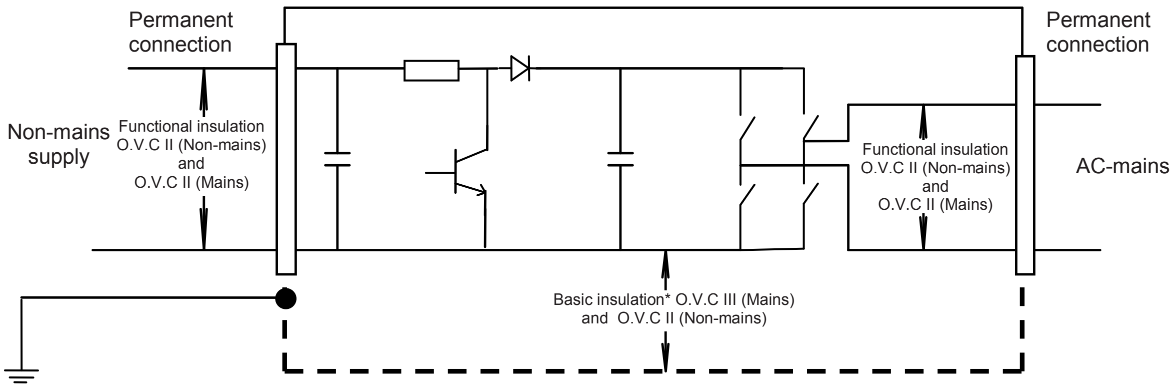


Figure I.13 – *Insulation* evaluation for accessible circuit of *DVC A*

I.5 Circuits with multiple supply (see 4.4.7.2.1)



Basic insulation*: O.V.C III based on the mains system voltage and O.V.C II from Non-mains. The most severe of these requirement applies. No reduction of the impulse voltage or Over Voltage Category for mains or non-mains supply.
Functional insulation: O.V.C II based on the mains system voltage and O.V.C II from the non-mains supply. The most severe of these requirement applies.

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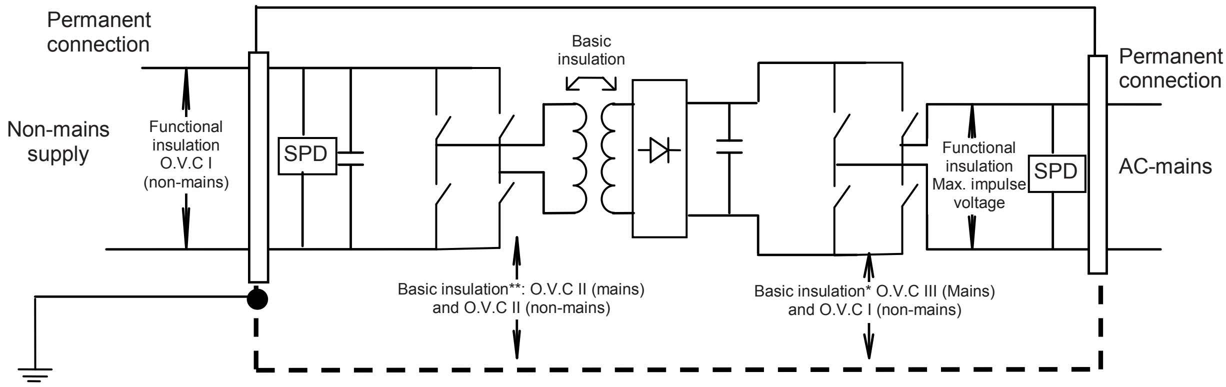
Figure I.14 – *PEC* with *mains* and non-*mains supply* without galvanic separation



Func. Insulation: Functional insulation is based on max. impulse voltage limited by circuit characteristic incl. SPD.

Basic insulation*: O.V.C III based on the mains system voltage and O.V.C II from Non-mains. The most severe of these requirement applies taking into account the reduction of the impulse voltage crossing the transformer.
The SPD does not give any reduction for basic insulation because it is located between phases.

IEC 1263/12

Figure I.15 – Transformer (basic) isolated *PEC* inverter with *SPD* and transformer to reduce impulse voltage for functional and *basic insulation*.

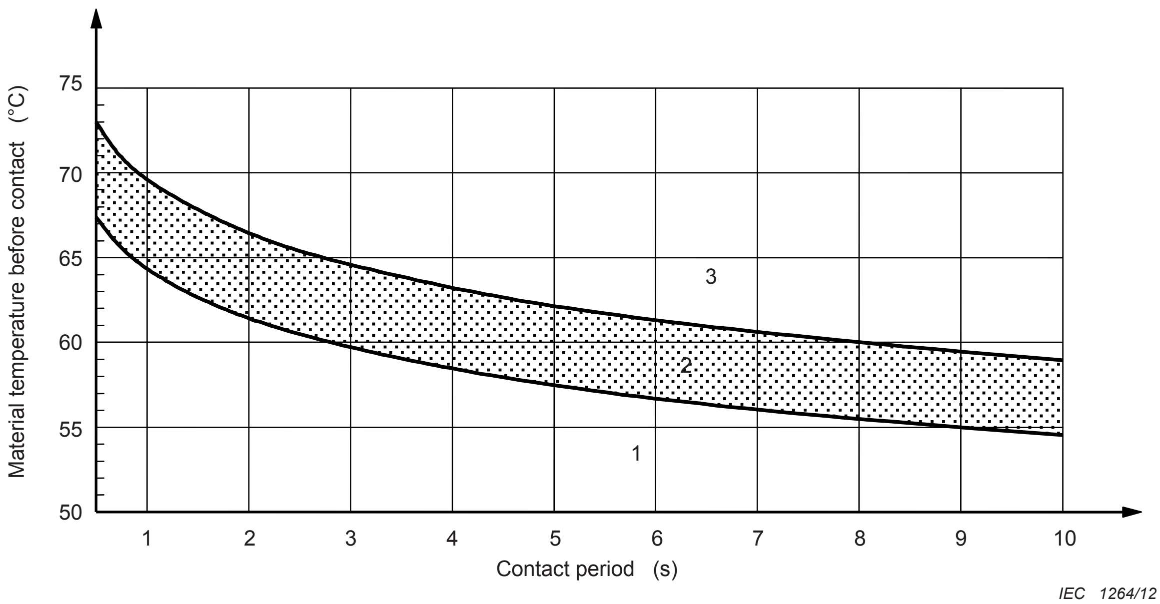
Annex J
(informative)

Burn thresholds for touchable surfaces

J.1 General

This annex contains information about burn thresholds for touchable surfaces for different materials. Figures J.1 to J.5 presented in this annex are copies of figures in IEC Guide 117:2010.

J.2 Burn thresholds



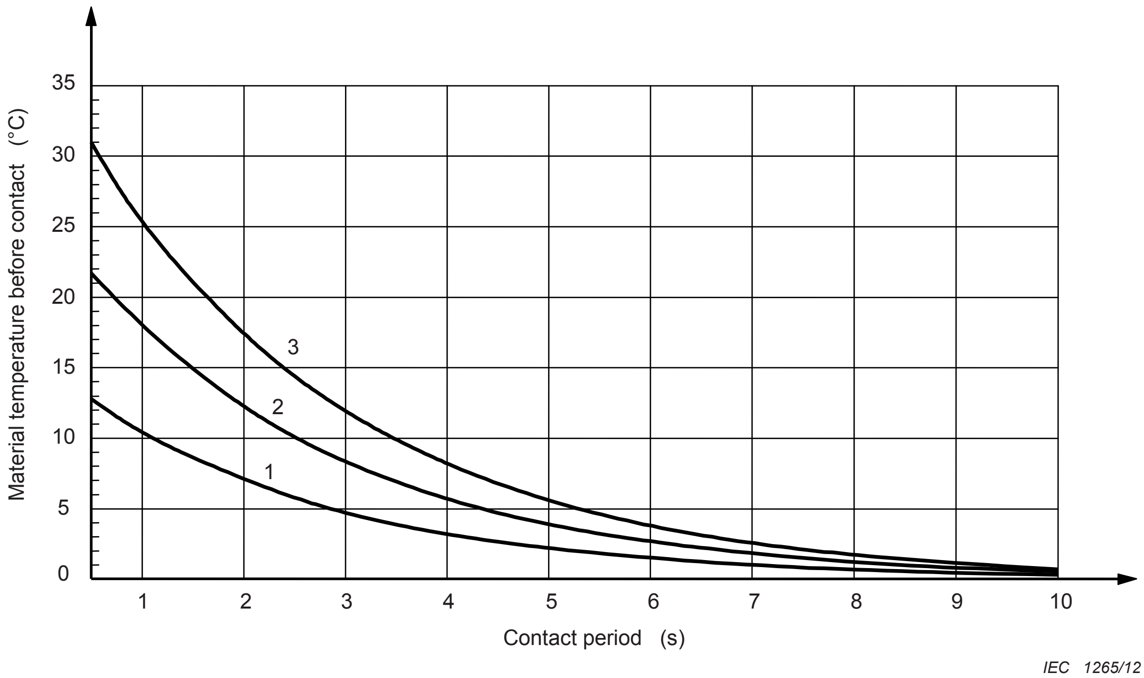
Key

1 No burn

2 Burn threshold

3 Burn

Figure J.1 – Burn threshold spread when the skin is in contact with a hot smooth surface made of bare (uncoated) metal



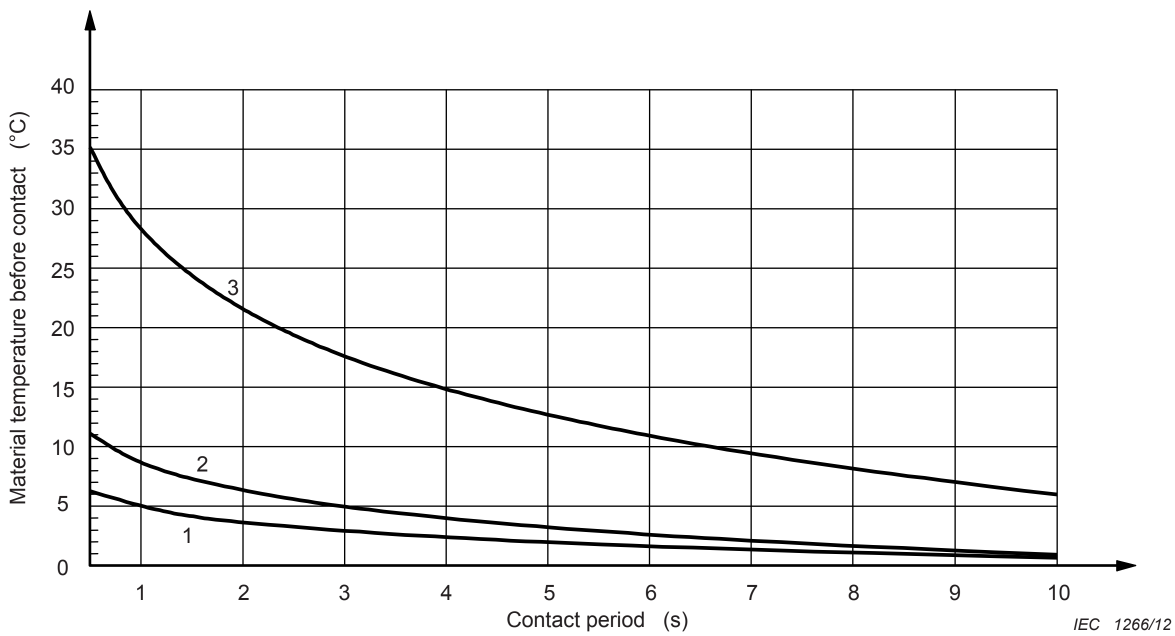
Key

1 50 μm

2 100 μm

3 150 μm

Figure J.2 – Rise in the burn threshold spread from Figure J.1 for metals which are coated by shellac varnish of a thickness of 50 μm, 100 μm and 150 μm



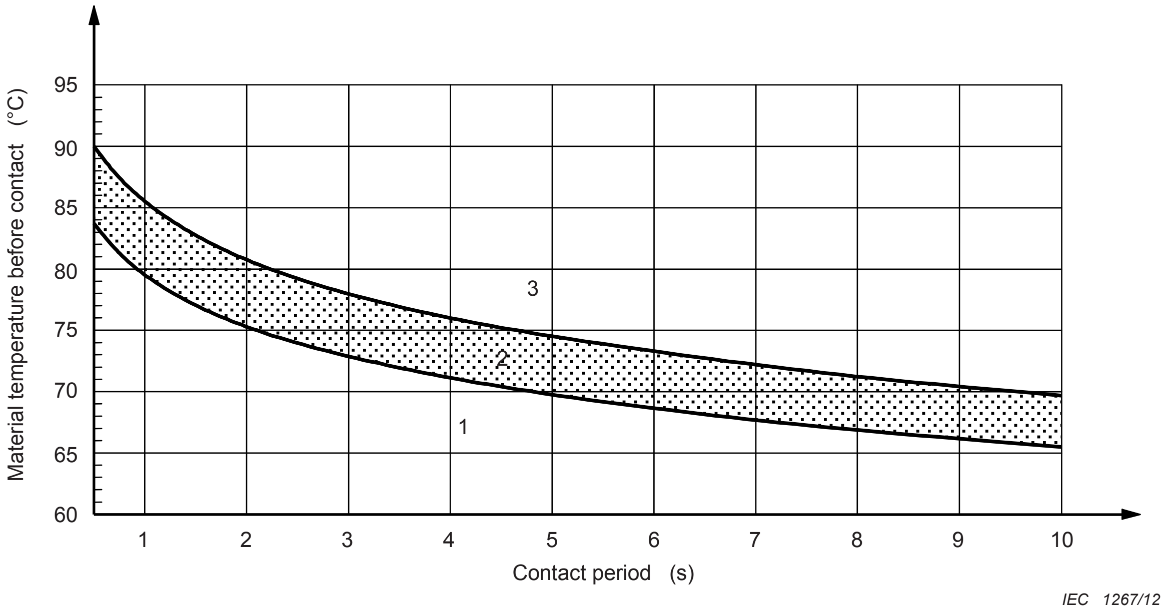
Key

1 Porcelain enamel (160μm) / powder (60μm)

2 Powder (90μm)

3 Polyamide 11 or 12 (thickness 400μm)

Figure J.3 – Rise in the burn threshold spread from Figure J.1 for metals coated with the specific materials



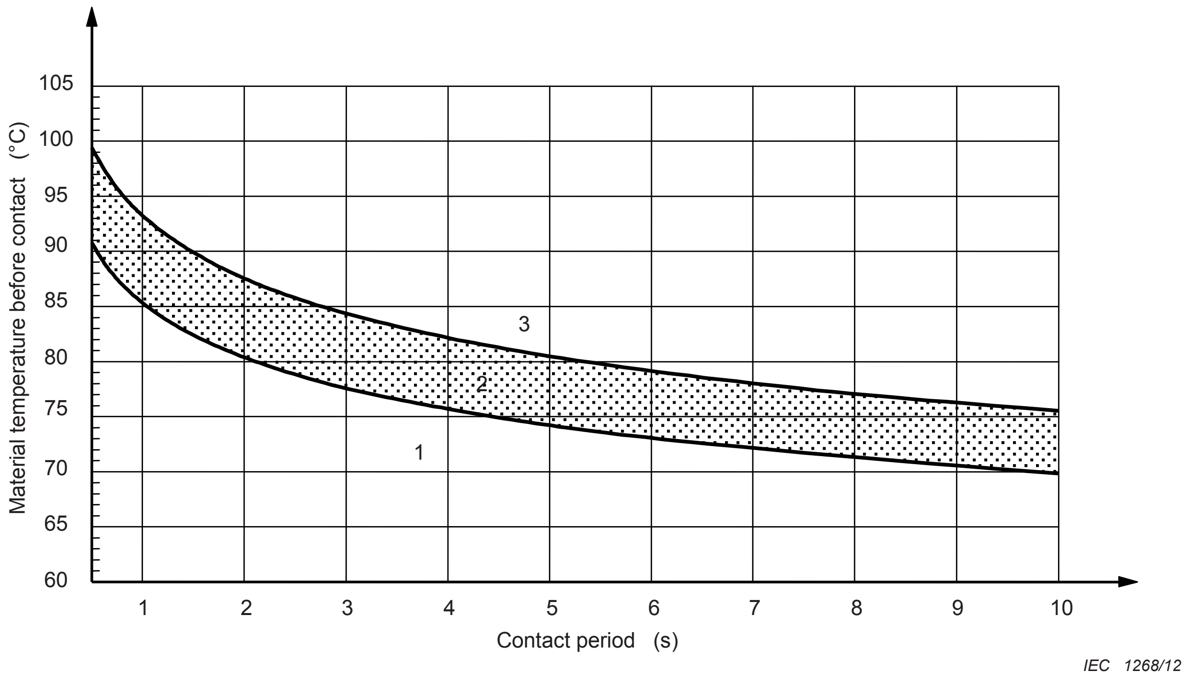
Key

1 No burn

2 Burn threshold

3 Burn

Figure J.4 – Burn threshold spread when the skin is in contact with a hot smooth surface made of ceramics, glass and stone materials



Key

1 No burn

2 Burn threshold

3 Burn

Figure J.5 – Burn threshold spread when the skin is in contact with a hot smooth surface made of plastics

Annex K
(informative)

Table of electrochemical potentials

Magnesium, magnesium alloys	Zinc, zinc alloys	80 tin/20 Zn on steel, ZN on iron or steel	Aluminium	Cd on steel	Al/Mg alloy	Mild steel	Duralumin	Lead	Cr on steel, solft solder	CR on Ni on steel, tin on steel 12 % Cr stainless steel	High Cr stainless steel	Copper, copper alloys	Silver solder, Austenitic stainless steel	Ni on steel	Silver	Rh on Ag on Cu, silver/gold alloy	Carbon	Gold, platinum	
0	0,5	0,55	0,7	0,8	0,85	0,9	1,0	1,05	1,1	1,15	1,25	1,35	1,4	1,45	1,6	1,65	1,7	1,75	Magnesium, magnesium alloys
	0	0,05	0,2	0,3	0,35	0,4	0,5	0,55	0,6	0,65	0,75	0,85	0,9	0,95	1,1	1,15	1,2	1,25	Zinc, zinc alloys
		0	0,15	0,25	0,3	0,35	0,45	0,5	0,5	0,6	0,7	0,8	0,85	0,9	1,05	1,1	1,15	1,2	80 tin/20 Zn on steel, ZN on iron or steel
			0	0,1	0,15	0,2	0,3	0,35	0,4	0,45	0,55	0,65	0,7	0,75	0,9	0,95	1,0	1,05	Aluminium
				0	0,05	0,1	0,2	0,25	0,3	0,35	0,45	0,55	0,6	0,65	0,8	0,85	0,9	0,95	Cd on steel
					0	0,05	0,15	0,2	0,2	0,3	0,4	0,5	0,55	0,6	0,75	0,8	0,85	0,9	Al/Mg alloy
						0	0,1	0,15	0,2	0,25	0,35	0,45	0,5	0,55	0,7	0,75	0,8	0,85	Mild steel
							0	0,05	0,1	0,15	0,25	0,35	0,4	0,45	0,6	0,65	0,7	0,75	Duralumin
								0	0,5	0,1	0,2	0,3	0,35	0,4	0,55	0,6	0,66	0,7	Lead
									0	0,05	0,15	0,25	0,3	0,35	0,5	0,55	0,6	0,65	Cr on steel, solft solder
										0	0,1	0,2	0,25	0,3	0,45	0,5	0,55	0,6	CR on Ni on steel, tin on steel 12 % Cr stainless steel
											0	0,1	0,15	0,2	0,35	0,4	0,45	0,5	High Cr stainless steel
												0	0,05	0,1	0,25	0,3	0,35	0,4	Copper, copper alloys
													0	0,15	0,2	0,25	0,3	0,35	Silver solder, Austenitic stainless steel
														0	0,15	0,2	0,25	0,3	Ni on steel
															0	0,5	0,1	0,15	Silver
																0	0,05	0,1	Rh on Ag on Cu, silver/gold alloy
																	0	0,5	Carbon
																		0	Gold, platinum

Ag	Silver
Al	Aluminium
Cd	Cadmium
Cr	Chromium
Cu	Copper
Mg	Magnesium
Ni	Nickel
Rh	Rhodium
Zn	Zinc

IEC 1269/12

Corrosion due to electrochemical action between dissimilar metals that are in contact is minimized if the combined electrochemical potential is below about 0,6 V. In the table the combined electrochemical potentials are listed for a number of pairs of metals in common use; combinations above the dividing line should be avoided.

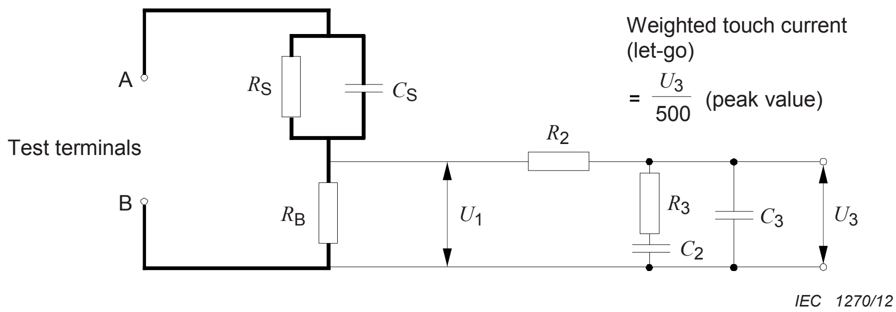
Figure K.1 – Electrochemical potentials (V)

Annex L
(informative)

Measuring instrument for *touch current* measurements

L.1 Measuring instrument

The measuring test circuit of Figure L.1 is from Figure 4 of IEC 60990:1999.



Key

RS	1 500 Ω
RB	500 Ω
R1	10 kΩ
CS	0,22 μF
C1	0,022 μF

Voltmeter or oscilloscope (r.m.s. or peak reading) input resistance: >1 MΩ
Input capacitance: <200pF
Frequency range: 15 Hz up to 1 MHz (appropriate for the highest frequency of interest)

Figure L.1 – Measuring instrument

Electrical measuring instruments shall have adequate bandwidth to provide accurate readings, taking into account all components (d.c., ac *mains supply* frequency, high frequency and harmonic content) of the parameter being measured. If the r.m.s. value is measured, care shall be taken that measuring instruments give true r.m.s. readings of non-sinusoidal waveforms as well as sinusoidal waveforms.

Annex M
(informative)

Test probes for determining access

The following diagrams are reproduced from IEC 60529 for convenience only.

Dimensions in millimetres

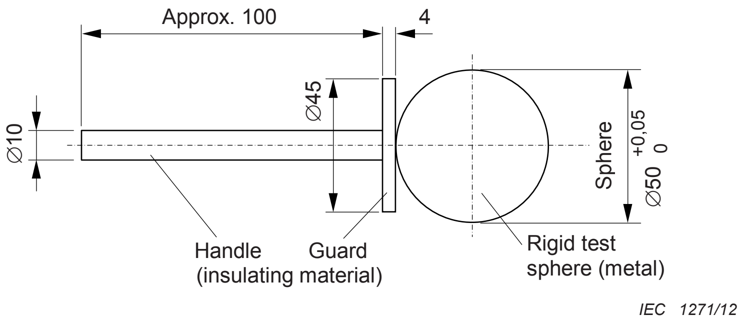


Figure M.1 – Sphere 50 mm probe (IPXXA)

Dimensions in millimetres

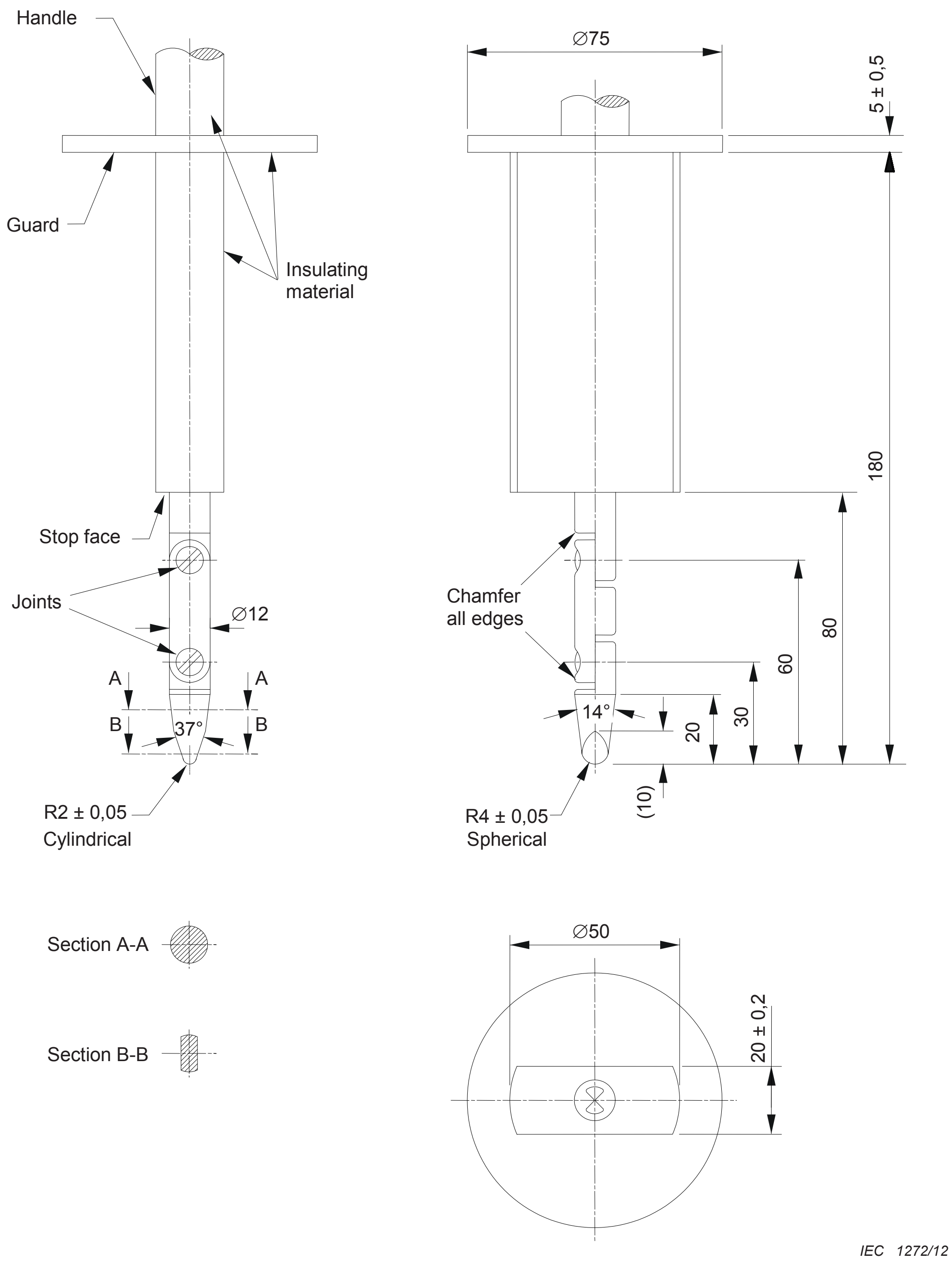


Figure M.2 – Jointed test finger (IPXXB)

Dimensions in millimetres

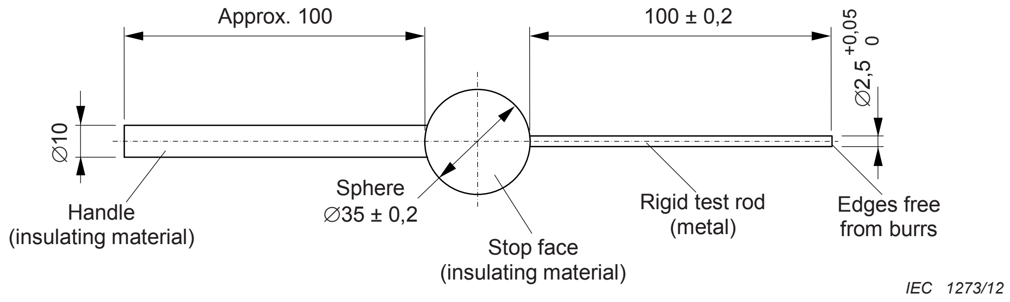


Figure M.3 – Test rod 2,5 mm (IP3X)

Bibliography

IEC 60073:2002, *Basic and safety principles for man-machine interface, marking and identification – Coding principles for indicators and actuators*

IEC 60085, *Electrical insulation – Thermal evaluation and designation*

IEC 60216 (all parts), *Electrical insulating materials – Thermal endurance properties*

IEC 60309-1, *Plugs, socket-outlets and couplers for industrial purposes – Part 1: General requirements*

IEC 60364-5-53: 2001, *Electrical installations of buildings – Part 5-53: Selection and erection of electrical equipment – Isolation, switching and control*

IEC 60449, *Voltage bands for electrical installations of buildings*

IEC/TR 60479-5:2007, *Effects of current on human beings and livestock – Part 5: Touch voltage threshold values for physiological effects*

IEC 60664-5: 2007, *Insulation coordination for equipment within low-voltage systems – Part 5: Comprehensive method for determining clearances and creepage distances equal to or less than 2 mm*

IEC 60695-11-5, *Fire hazard testing – Part 11-5: Test flames – Needle-flame test method – Apparatus, confirmatory test arrangement and guidance*

IEC 60721 (all parts), *Classification of environmental conditions*

IEC 60947-7-1, *Low-voltage switchgear and controlgear – Part 7-1: Ancillary equipment – Terminal blocks for copper conductors*

IEC 60947-7-2, *Low-voltage switchgear and controlgear – Part 7-2: Ancillary equipment – Protective conductor terminal blocks for copper conductors*

IEC 60950-1, *Information technology equipment – Safety – Part 1: General requirements*

IEC 61008 (all parts), *Residual current operated circuit-breakers without integral overcurrent protection for household and similar uses (RCCBs)*

IEC 61009 (all parts), *Residual current operated circuit-breakers with integral overcurrent protection for household and similar uses (RCBOs)*

IEC 61082-1, *Preparation of documents used in electrotechnology – Part 1: Rules*

IEC 61140:2001, *Protection against electric shock – Common aspects for installation and equipment*

IEC/TS 61201, *Use of conventional touch voltage limits – Application guide*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 61558-1, *Safety of power transformers, power supplies, reactors and similar products – Part 1: General requirements and tests*

IEC 61558-2-16, *Safety of transformers, reactors, power supply units and similar products for supply voltages up to 1 100 V – Part 2-16: Particular requirements and tests for switch mode power supply units and transformers for switch mode power supply units*

IEC 61643-12, *Low-voltage surge protective devices – Part 12: Surge protective devices connected to low-voltage power distribution systems – Selection and application principles*

IEC 62079:2001, *Preparation of instructions – Structuring, content and presentation*

IEC 62423: 2009, *Type F and type B residual current operated circuit-breakers with and without integral overcurrent protection for household and similar uses*

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